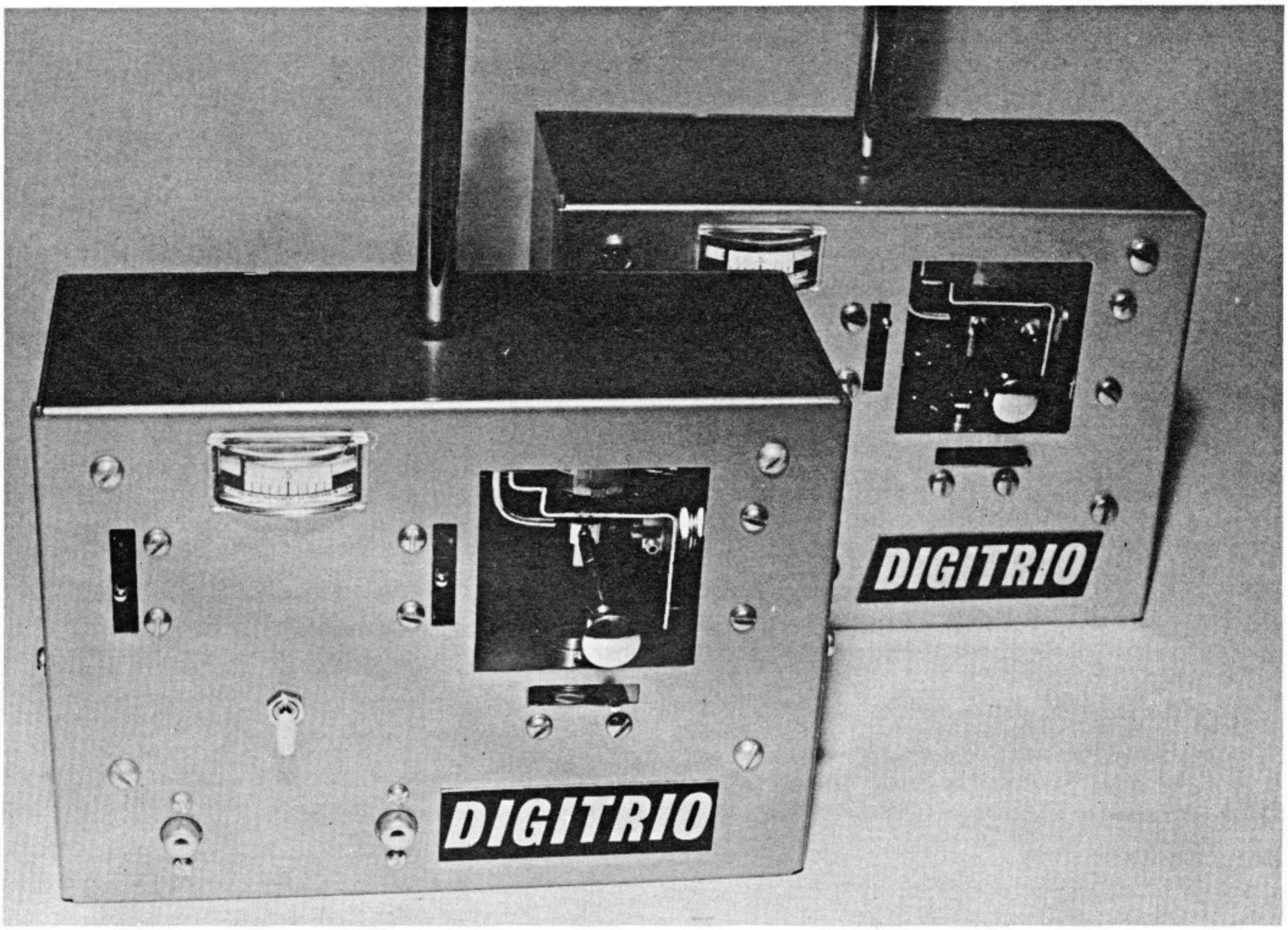
RCM DIGITRIO



By Ed Thompson

RADIO CONTROL MODELER MAGAZINE

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*** NOTE**

Due to popular request R/C Modeler Magazine has reprinted the "Digitrio" exactly as it appeared when first published as a series in 1966. Because this is an exact reprint of the original RCM Digitrio, many prices, stock numbers, firm names and addresses, coupons, etc., are obsolete or have changed since the first printing. We want to emphasize that this reprint has been made available strictly as a service to RCM readers and not as an updated or currently edited book.

Editor's Preface

The RCM Digitrio Proportional System, designed and developed by Ed Thompson, Technical Editor, was originally presented as a series of seven articles in Radio Control Modeler Magazine. We feel privileged to present this complete basic series to you with the knowledge that it represents one of the finest individual design and engineering accomplishments in the field of radio control – providing RCM readers with the most thorough and complete construction series ever published in any model aviation magazine.

No attempt has been made to condense, or otherwise shorten, the series, for Ed Thompson will take you from the basic theory straight through to the final installation of this digital proportional system. If you can use a soldering iron and ordinary model shop tools, you can build the Digitrio. No elaborate tools or electronic test equipment is necessary, due to the author's method of presentation. Although access to an oscilloscope would be convenient, even it is not mandatory for alignment.

Individual components for this system are available from most major electronic parts distributors. Complete kits for the transmitter, receiver-decoder, and servos are available from World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236. In addition, other RCM advertisers have made available such items as printed circuit boards, transmitter cases, stick assemblies, transmitter and airborne battery packs, simplified mounting boards, compatible servos, etc., for the convenience of scratch builders. The editors of RCM have built five of these systems from the article, and from the kits, in order to insure that all phases of this system were thoroughly bench and field tested. In addition, many individual modeler-technicians have cooperated in the testing of the system prior to its initial publication. To the latter individuals, we are deeply indebted.

To date, more than two thousand Digitrio systems have been built, and at the time of this writing, have established several first places in national competition as well as a new world's speed record for an R/C hydroplane.

If you follow these instructions to the letter, you will have a proportional system that will provide you with maximum reliability and performance for many years to come. If, for any reason, you should encounter any difficulty that cannot be corrected locally, simply drop a note to The Editor, R/C Modeler Magazine, P. O. Box 487, Sierra Madre, California.

We think you'll enjoy the RCM Digitrio Proportional System. Good flying!

Don Dewey, Editor

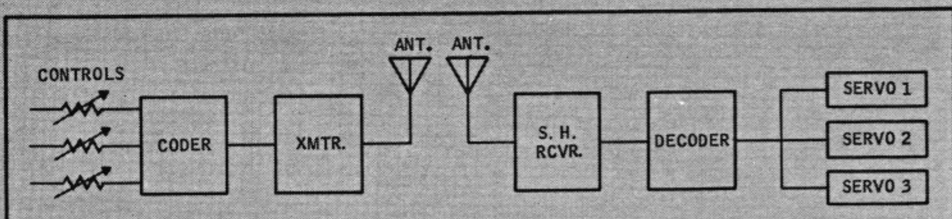


Figure 1

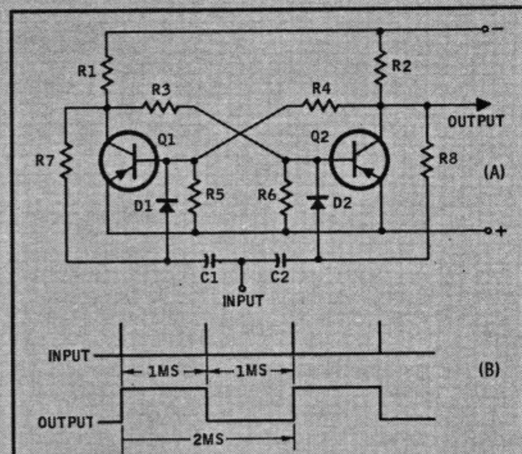


Figure 2

How to obtain Digital Proportional Control using basic computer circuits along with a brief description of the basic circuits that will be used in the RCM Digitrio is the subject of Part I and will enable you to better understand how your system will work.

Preface

There is little doubt in anyone's mind that the proportional age has descended upon us. I suspect most of us are a little confused by all the ballyhoo we read and hear about the different systems, no longer having a familiar yardstick to use when evaluating these various systems. In the past, we picked equipment on the basis of dependability, mainly because the equipment was almost identical in makeup – even to the point of looking alike except for the color of the cases! Proportional systems, on the other hand, may look alike, but the internal makeup is limited only by the manufacturers' imagination and ingenuity. Some of it is vastly complex, and if programmed properly, could solve mathematical problems and perform minor computing tasks!

The system presented here will not offer serious competition to Univac nor will it revolutionalize the proportional industry. It will, however, provide a proven three channel, so-called "digital" system. I say "so-called" digital system, because it is not truly digital, nor are the other systems currently on the market. Doug Spreng covered this in a previous article so I won't expound on it.

It appears that a lot of the equipment on the market gets homesick and has a nervous breakdown occasionally. The result is quite dramatic at times – especially when the aircraft tries to do a loop, barrel roll, Immelmann and half ganor at the same time. The usual result is that the hi-strung system is sent home to Papa for corrective action. We then twiddle our thumbs waiting for its return and mutter purple phrases about the manufacturer. We used to be able to spot impending trouble when a reed needed cleaning or tones needed adjustments etc. Now we are faced with sudden malfunctions which leave us baffled, disgruntled, frustrated and unsure (oh yes, reeds will be around for a long time yet). This is mainly due to the lack of knowledge about this new breed of cat.

The manufacturers are apparently not too concerned about this and are doing a good job of keeping their brain children a secret. I don't think this system will unlock any magic door of knowledge on the subject but it will give you an insight to some of the basics used. I sincerely hope that it will stir the imagination of some to experiment and improve the present state of the art.

How To Obtain Digital Proportional Using Basic Computer Circuits

The heart of the system presented here and in subsequent articles will consist of simple computer circuits. These are common circuits that are neither mysterious nor hard to comprehend. Figure 1 shows how we will accomplish this by means of a simple block diagram.

By adjustment of the controls we program the system. The coder senses the position of the controls and modulates the transmitter with this information. The receiver processes the information and passes it on to the decoder which, in turn, separates it into individual channels. This information is compared in the individual servos with information supplied by the servo itself relating to its present position. If the information received differs with that of the servo it senses in what direction to move in order to correct itself. When the servo moves far enough to agree with the incoming information it stops at its new position. The servo now has a new reference position and keeps comparing for further instructions. Old Hat, so far, and not too sensational.

The main departure from norm is that we are going to do it with computer circuits and pulses measured in milli-seconds or MS (1/1000 of a second) and micro-seconds (1000 micro-seconds equal 1 milli-second). We are also going to eliminate tones and use the carrier to convey this intelligence (shades of the RK-61 era!). We will pulse the carrier at precise variable rates and intervals. The receiving end will shape these pulses, sort them out, and precisely analyze each one for any change in program at the transmitter. Let's go on to the circuits we will use to accomplish this feat.

Brief Description Of Basic Circuits That Will Be Used

For the following discussions the term ground will be synonymous with emitter potential.

Figure 2A shows a bi-stable or flip-flop circuit. Although it is used only one time in this system it is used extensively in, and is the heart of, some of the decoders on the market. Inspection of the circuit will reveal a sort of suicide circuit. R1 and R2 are the collector loads for their respective transistors. R3 and R6 provide forward bias for Q2. R4 and R5 provide forward bias for Q1. Disregarding the other components for the time being let's look at the operation.

The conduction of either side depends on the other side being cut off, and vice versa. Due to this relationship, one side will be cut off and the other side will be conducting. To make it work let's assume that Q1 has a little higher gain than Q2. When we first apply power it conducts a little heavier. Its collector voltage going to ground reduces the forward bias on Q2 thereby helping its collector voltage go more

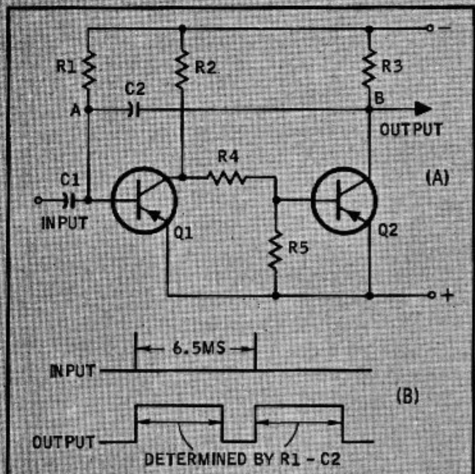


Figure 3

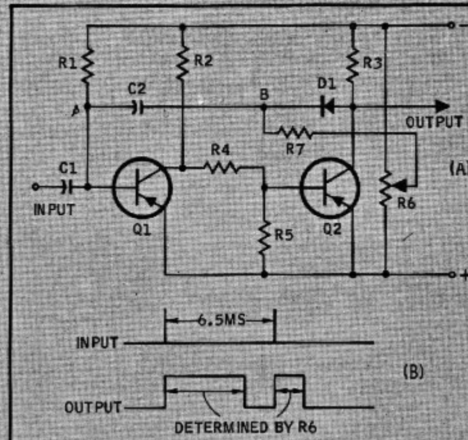


Figure 4

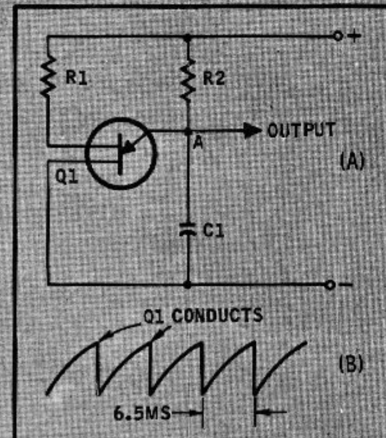


Figure 5

negative. Q2's collector voltage going negative provides more forward bias for Q1 assisting it even further in its race to conduction. This of course assists Q2 to cut off even more. This mutual assistance bond between the two always ends up with one holding the other into conduction.

This then, means that one collector will be negative and one at ground with no in-between conditions allowed. Actually, this takes place instantly, and the state of the two transistors is determined by which one gets a head start. We provide this head start with C1, C2, R7, R8, D1, and D2. If we apply a short positive pulse at the input terminal it will be transferred to Q1's base via C1 and D1.

Simultaneously it will appear at Q2's base via C2 and D2. We left Q2 cut off so the positive pulse will have no effect on it. However, since Q1 was conducting, the positive pulse will cut it off for the duration of the pulse. This causes Q1's collector to go negative briefly and provides forward bias for Q2 which takes advantage of the situation and, armed with a head start, reverses the condition of the circuit. Every time a positive pulse appears at the input the circuit will alternate its state. R7 and R8 are used to assist the action by biasing the diode capacitor junctions. If Q1 is cut off, R7 will apply the negative collector voltage to the D1-C1 junction minimizing the effect of the positive trigger pulse to Q1, conversely R8 will apply Q2's collector ground potential to the D2-C2 junction enhancing, or at least not detracting from the effect of the positive pulse to Q2. This, in effect is trigger gating and allows large trigger-pulse amplitude variations while retaining high trigger sensitivity. There are other ways to trigger the circuit but this is the way we will use it in the system. Actually all I have said so far is that each positive pulse applied to the circuit will change its state. This means that two pulses are required for a complete cycle. Now let's put it to work.

If we send short pulses spaced at 1MS intervals (that's 1/1000 of a second), we will change its state at that same rate. A bit faster than the kicking duck, eh? The output will be square pulses with 1MS widths or 2MS for a complete cycle (See Figure 2B).

We now have to go through another explanation, this time a monostable multivibrator or simply a one shot. (Figure 3A shows this circuit.) R2 and R3 are the collector loads for their respective transistors. R1 provides forward bias for Q1, R4 and R5 provide forward bias for Q2. Q1 is biased more heavily than Q2 and will be conducting in its steady state. Conduction of Q2 depends on the collector voltage of Q1 being negative (which it is not since it is now conducting) so Q2 will be cut off. This places a charge across C2 that is positive at Point A (because the forward biased base emitter junction of Q1 is a very low resistance to ground) and negative by the amount of supply voltage at Point B. If a short positive pulse is applied to the input it will briefly cut off Q1 causing its collector to go negative. This forward biases Q2 which instantly conducts. Q2's collector goes to ground and instantly causes a polarity reversal across C2. Point A now goes positive equal to the negative supply voltage with respect to Point B. This cuts off Q1 which now holds Q2 in conduction. C2 starts discharging through R1 and will keep Q1 cut off until it discharges its positive charge and Point A goes negative enough to cause Q1 to conduct again. This of course causes Q2 to cut off and the circuit is back in its stable state. (See Figure 3B.) At this time we can apply another positive pulse and start all over again. We can also apply a negative pulse to the base of Q2 and obtain the same results by forcing Q2 into conduction. We will in fact do this in the system. As you can see the time it takes to complete a cycle depends on how long it takes C2, discharging through R1, to return Point A to a slightly negative voltage to forward bias Q1. There are two easy ways to control this. We can either vary C2's capacity (larger capacity/longer cycle) or R2's resistance (larger resistance/longer cycle). How do you think we will do it? You guessed it, a third way. (See Figure 4A.) As you can see we have added three components. Now we can vary the voltage at Point B. When Q2 conducts now, Point A will go positive equal to the amount of negative voltage preset at Point B by the setting of R6. This means that for a given time constant of R1-C2 the cycle now depends on the voltage at Point B. The more voltage applied the longer it takes C2 to discharge and vice versa. Diode D1 isolates C2 from Q2. In the circuit's steady state Q2's collector is negative and D1 is reverse biased. When Q2 conducts, it grounds the preset voltage at Point B through D1 which is now forward biased. R7 is a current limiting resistor so we do not damage D1 or load Q2. By adjusting R6 we can vary the cycle time of the circuit. So now we have a **variable** one shot. (See Figure 4B for wave forms.)

One more time, fellas! An easy one this time and then we will put the circuits together. Figure 5A shows a unijunction transistor in a relaxation oscillator configuration. Simply and briefly R2 charges C1 until the voltage at Point A is positive enough to cause Q1

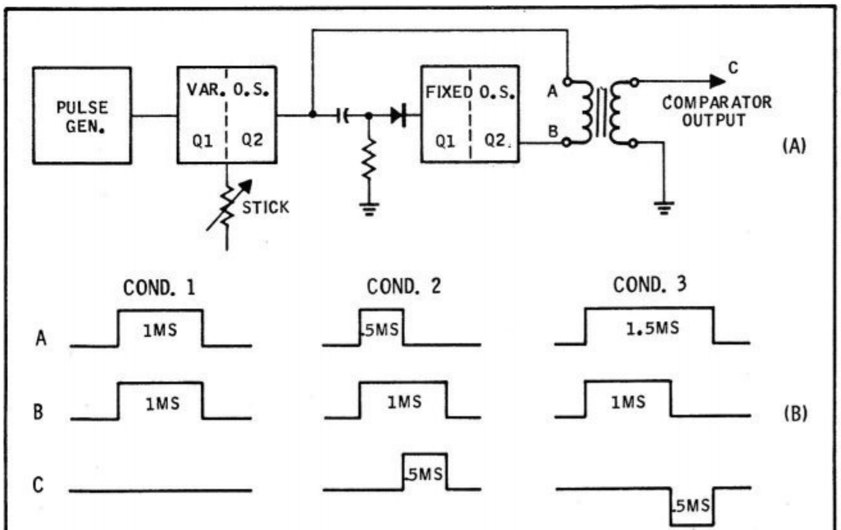


Figure 6

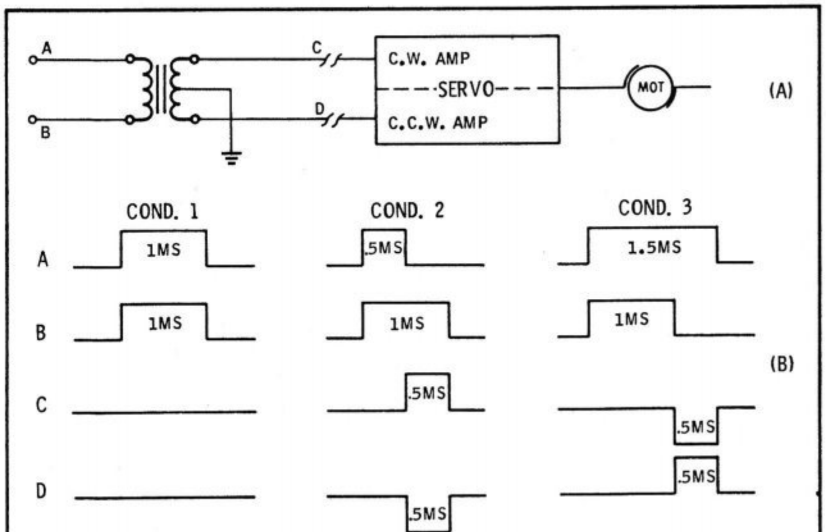


Figure 7

to conduct. When it does the forward biased junction effectively shorts C1's charge quickly cutting off Q1. It then starts over. R1 is similar to a collector load resistor and provides current limiting and temperature compensation. (Figure 5B shows the output wave form.) We will use the downward transitions as a trigger. If we replace R2 with a pot we can vary the repetition rate of the circuit. This circuit appears inverted in the transmitter schematic but inspection will show it is the same as described.

Connecting Basic Circuits To Give Desired Results

Let's assemble a simple circuit now, and see how we detect a change in pulse width. Figure 6A shows a variable one shot coupled to a fixed one shot of 1MS duration. Assume that the variable resistor of the variable one shot is connected to a control stick. We can now vary the pulse width of the variable one shot from .5MS to 1.5MS by movement of the stick to its extremes with 1MS being neutral. Let's run through the operation with the control stick in the neutral position. The pulse generator triggers the variable one shot every 6.5MS and is used to initiate and repeat the action at this rate. Although we will use the downward transitions of the pulse generator coupled to Q2, it is shown here coupled to Q1 to simplify the drawing. The leading edge of the pulse created by the variable one shot will instantly trigger the fixed one shot. The output of the variable one shot is also applied to Terminal A of the transformer. The pulse of the fixed one shot is applied to Point B of the transformer.

Looking at the waveforms (Figure 6B) for Condition 1 we can see that Point A and B of the transformer will have a positive pulse of 1MS duration applied simultaneously. This will not cause an output because the pulses are identical and cancel each other's effect. It's evident at this point that the transformer is used to compare the pulses and it will be referred to as a "comparator." Condition 2 shows the variable one shot with a .5MS pulse duration. Since the fixed one shot always produces a 1MS pulse, Point B will remain positive .5MS after Point A returns to negative. For the first .5MS the pulses cancel each other. When Point A goes negative we have a resultant .5MS pulse due to the remaining pulse length of the fixed one shot holding Point B positive. There is a 180 degree shift of polarity across the transformer so the output of the comparator is a positive .5MS pulse. Condition 3 shows the variable one shot with a 1.5MS pulse width. This will hold Point A positive for .5MS after the 1MS fixed one shot returns to negative. The 180 degree shift of polarity across the transformer will now cause the comparator output to be a .5MS negative pulse.

Let's go to Figure 7A, now, and see how to run a servo with this type of circuit. As you can see the comparator now has a center tapped secondary. An inspection of the waveforms (Figure 7B) will show that we can now get a positive output from either Point C or Point D depending on which way we move the stick. We also get negative outputs but the servo will only respond to positive pulses and will ignore these negative pulses.

Condition 1 shows neutral position and no output at either Point C or D. Condition 2 shows positive output at Point C and negative at Point D (which is ignored by the servo). The servo amplifies this positive pulse at Point C and runs in a clockwise direction. Condition 3 shows a negative pulse at Point C and a positive pulse at Point D. The servo will now run in a counterclockwise direction. This action is repeated every 6.5MS by the pulse generator so we keep pulsing the servo at this rate and can change its direction by movement of the stick.

We're almost home now, and if you're still with me the rest is a snap! If you're not, I suggest you reread those portions you're hazy about or get the local Einstein to help you. A little effort will be rewarded and once you get the hang of it you'll be saying things like, "how simple can you get" and "I knew it all the time."

Well, so far we have a quasi "bang bang" system. Now let's make it proportional. Figure 8 shows that we have replaced the fixed one shot with a variable one shot which we'll call the reference generator, and mechanically coupled the variable resistor to the

For your convenience, the following is a listing of various sources of supply for Digitrio kits and accessories as previously advertised in the regular monthly issues of R/C Modeler Magazine. For additional information, please correspond directly with the manufacturers concerned:

Complete Digitrio Kits

World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236.

These are the designer approved kits, each available separately, e.g., transmitter, receiver, decoder, and servos. Batteries, stick assembly, etc., not included. Tested and approved by RCM.

Compatible Servos

Spar Electronics, 15302 Oak Canyon Road, Poway, California 92064.

Designed for use with the Digitrio system, these servos have not been tested by RCM, but were used with a Digitrio system that recently set a world's hydroplane record.

Orbit Electronics, Inc., 11601 Anabel Avenue, Garden Grove, California.

Orbit has produced a digital servo that is compatible with the RCM Digitrio. These have not been tested by RCM, to date.

Hardware and Stick Assemblies

Justin Inc., 418 Agostino Road, San Gabriel, California.

A completely drilled and ready-to-use transmitter case with all stick assembly and pot mounting brackets for the Digitrio. Tested and approved by RCM.

Stanton R/C, Inc., 4734 North Milwaukee Ave., Chicago, Illinois 60630.

A Digitrio stick assembly kit and pot bracket hardware. Tested and approved by RCM.

Printed Circuit Boards

West Coast Slides, Box 788, San Pedro, California.

Printed circuit boards for the transmitter, receiver, decoder, and servos. These units have not been tested by RCM, to date.

Stanton R/C, Inc., 4734 North Milwaukee Ave., Chicago, Illinois 60630.

Printed circuit boards for the RCM Digitrio transmitter were tested and approved by RCM. It is assumed that the other printed circuit boards are also available.

Transmitter Stick Assemblies

World Engines, Inc., 8206 Blue Ash Road, Cincinnati, Ohio 45236.

The popular Bonner stick assembly, used on the Bonner Digimite, PCS, Kraft, Controlaire, and F&M proportional systems, is available from World Engines for use with the Digitrio. Tested and approved by RCM.

Micro-Avionics, Inc., 346 E. Foothill Blvd., Arcadia, California.

The Micro-Avionics stick assembly, used on the Micro-Avionics and Orbit proportional systems is available for Digitrio builders. Some transmitter case modification is necessary to fit this unit. Tested and approved by RCM.

Power Supplies

P & D Manufacturing Company, P. O. Box 34, Chino, California.

Complete power packs, or power pack kits, are available from this manufacturer. Designed exclusively for the Digitrio system, they have been tested and approved by RCM.

Mounting Boards

Fly-Tronics Engineering, 3010 Brook Drive, Muncie, Indiana 47304.

The Fly-Tronics Circuit Master is a printed circuit board on which the Digitrio servos mount, as well as a 15-pin Cannon plug for the receiver-decoder and power supply, thus eliminating many of the wires and most of the plugs in the system. Tested and approved by RCM.

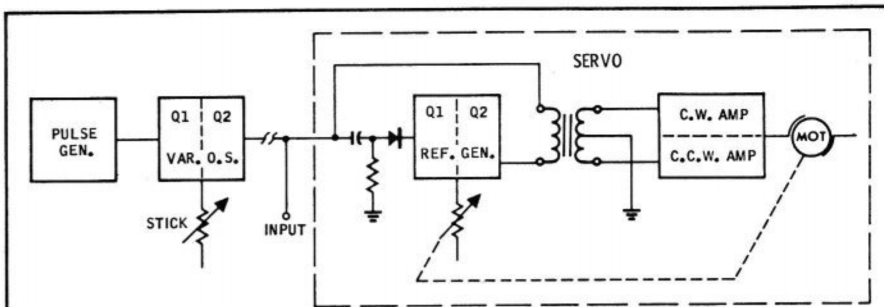


Figure 8

motor. All of this, including the comparator, is now contained in the servo case. When the motor runs it also turns the variable resistor. We now control the pulse duration of the reference generator and lengthen or shorten the pulse depending on which direction the motor turns. If the incoming pulse duration is longer than the reference generator, assume that the comparator will cause the servo to run in a counter clockwise direction. If the variable resistor turns in a direction so as to lengthen the reference generator pulse it will eventually match the incoming pulse length and the comparator output will go to zero stopping the motor. As long as we hold the control stick in this position the servo will remain where it is. Any slight movement of the stick however will cause comparator output and the servo will correct itself. It works the same way only opposite if the incoming pulse duration is shorter than the reference generator pulse. Here is the main departure from analog servo operation. Since any slight movement of the stick will cause comparator output of the same voltage (only the pulse duration varies) we get full power for the smallest incremental movements of the servo.

Figure 9A shows how we do this via radio control. The coder pulses are variable and for Condition 1 (Figure 9B) modulates the transmitter with a pair of pulses spaced 1MS apart. Point B shows the carrier being "spiked" off by these pulses. The receiver receives and processes these pulses and a replica of Point A appears at Point C. The flip flop we discussed earlier converts these pulses to a pulse with a 1MS duration. We can apply this pulse to the input of Figure 8 and by varying the spacing of the pulses transmitted, by stick movement, we can vary the position of the servo. Figure 9B waveforms show how the decoder follows stick movement.

There you have a basic single channel digital proportional system. This has been a simple explanation without frills and the confusion factor has been held to a minimum. As we progress we will replace the transformer comparator with transistors, add two more channels and provide a means for the extremely short comparator pulses to run the servos smoothly.

(END PART I)

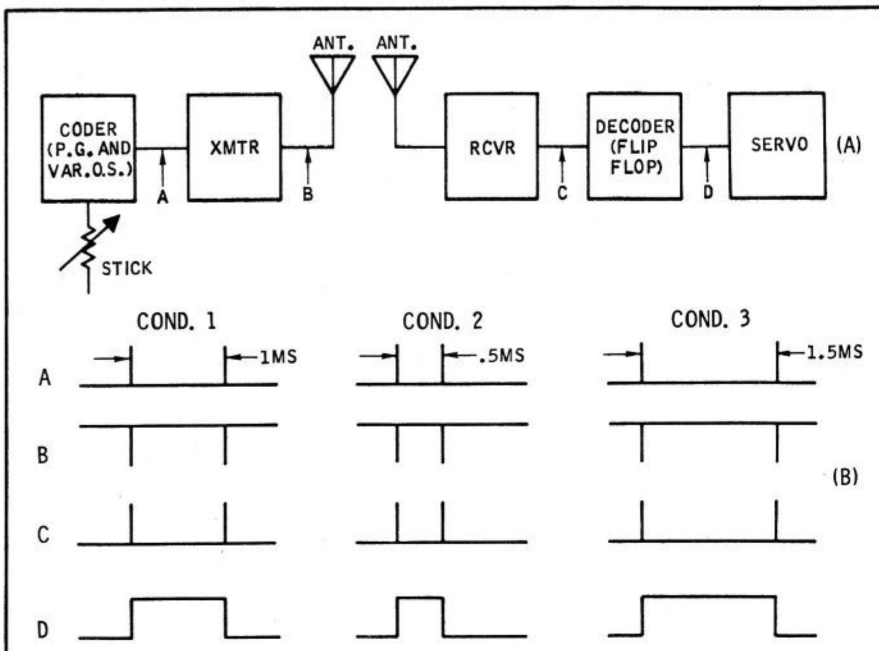


Figure 9

Preface

If the first article in this series stirred your interest and imagination, this and succeeding installments, will answer any questions you might have concerning the RCM Digitrio. Since Don has assigned me the position of Contributing Technical Editor and placed no restriction on the content or length of this series, I think you'll find the articles quite complete – even to the point of boredom for those with a "better-than-average" technical background. This attempt at completeness, however, will allow the average RC'er to "keep up" with the various stages of construction, and what otherwise might be an advanced project for the technician alone. Also, unlike a "quickie" article, this series can be used as a reference by experimenters who would rather "roll their own."

The theory that prefaces each segment of this series will be written somewhere above Ohm's Law and below complicated discussions requiring specialized knowledge or math for understanding. You will not have to be an engineer to understand the language used – I am writing for your understanding and not to impress anyone with technical terminology. The RCM Digitrio was not born from an Einstein-type inspiration, nor was it copied from any other system. Rather, it came from several years of staring at a scope and asking a myriad questions of people with advanced technical backgrounds. Although this system is designed to be duplicated without an oscilloscope, I would suggest that you buddy up with a friend who can assist you if you should run into difficulty.

Throughout the series, reference to ground will be synonymous with emitter potential of the stage under discussion. Let's get started with the transmitter-coder.

Theory of Transmitter

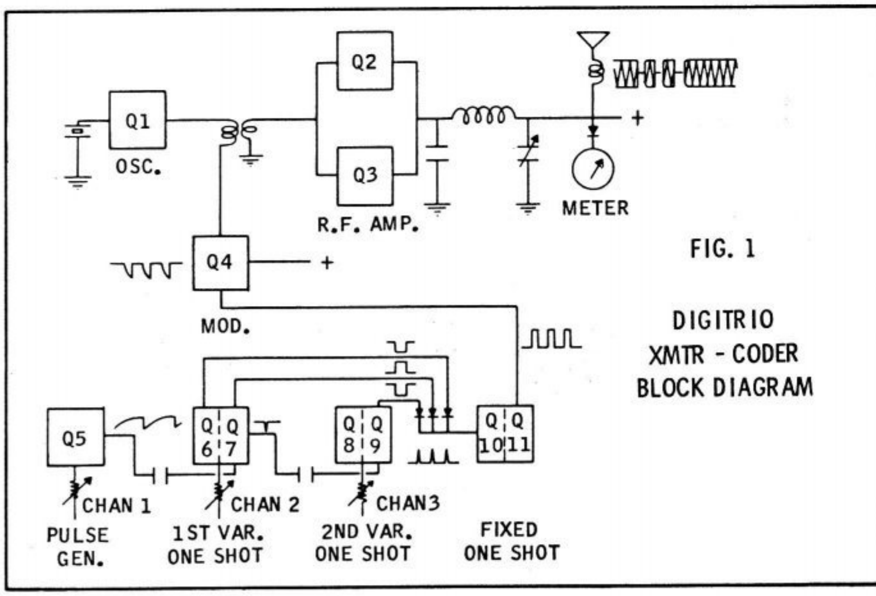


FIG. 1

DIGITRIO XMTR - CODER BLOCK DIAGRAM

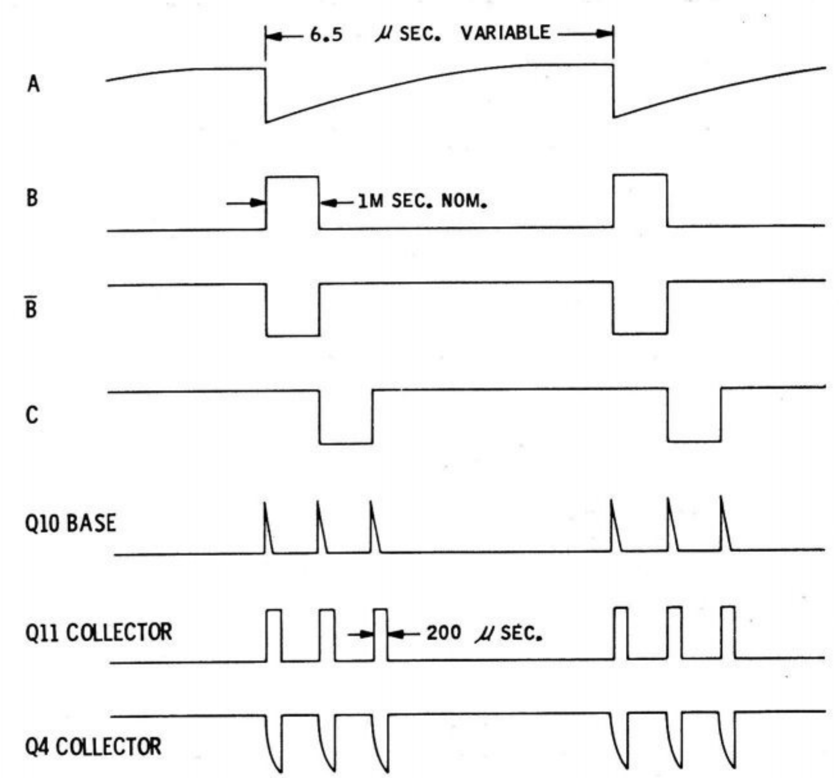


FIG. 2

DIGITRIO CODER WAVEFORM

Figures 1, 2, 3 and 4 and the schematic will be used for the following theory discussion. Study these for familiarization before proceeding. All action starts with the pulse generator Q5. The waveform for Point A, Figure 2 shows how C14 charges positive until the firing point of Q5 is reached. When Q5 fires, the rapid downward transition couples a negative-going pulse to Q7's base via C16. R13 and R30 provide a means of varying the time lapse between negative transitions. If the resistance of either R13 or R30 is increased it will increase the time required for C14 to charge to the firing point. The opposite is true if the resistance is decreased. R29 is used to decrease the effect of R30's movement. R13 is used as a coarse setting of Channel 1 and R30 is used for the motor stick control. By selection of R29 we can adjust the servo movement extremes. So far then, we have a negative pulse going to Q7's base with control of the repitition rate.

When this negative pulse is applied to Q7's base the first variable one shot (Q6 & Q7) triggers (See Points B and B of Figure 2 waveforms). The cycle time of this one shot is determined by R31 and/or R34. R34 is the stick control and R31 the trim. R32 decreases the effect of R31's movement. The instant this one shot triggers, Q7 conducts, coupling a positive pulse across C20. When the one shot cycle is completed Q6 conducts (returning to its normal state) coupling a positive pulse across C21.

Q8 and Q9 form another variable one shot identical to Q6 and Q7. It is triggered by a negative pulse coupled across C17 when Q7's collector goes negative at the completion of its cycle. When this second one shot has completed its cycle Q8 conducting, couples a positive pulse across C19. C19, C20 and C21 are tied to ground with R21, R22 and R23. The short time constant of these resistor-capacitor combinations result in short positive pulses applied to Q10's base (See Figure 2). D4, D5 and D6 form an "OR" gate and prevent the negative transitions of the one shots

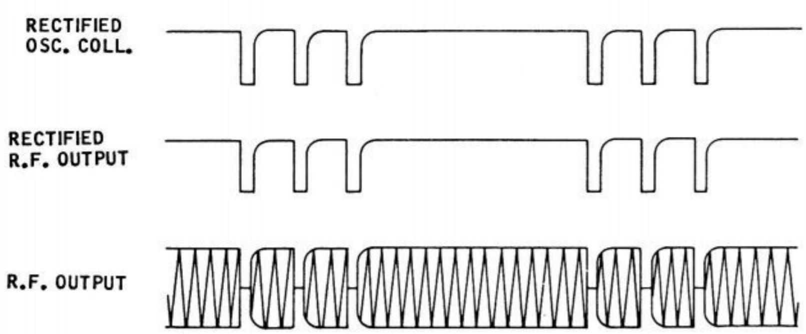


FIG. 3

DIGITRIO XMTR WAVEFORMS

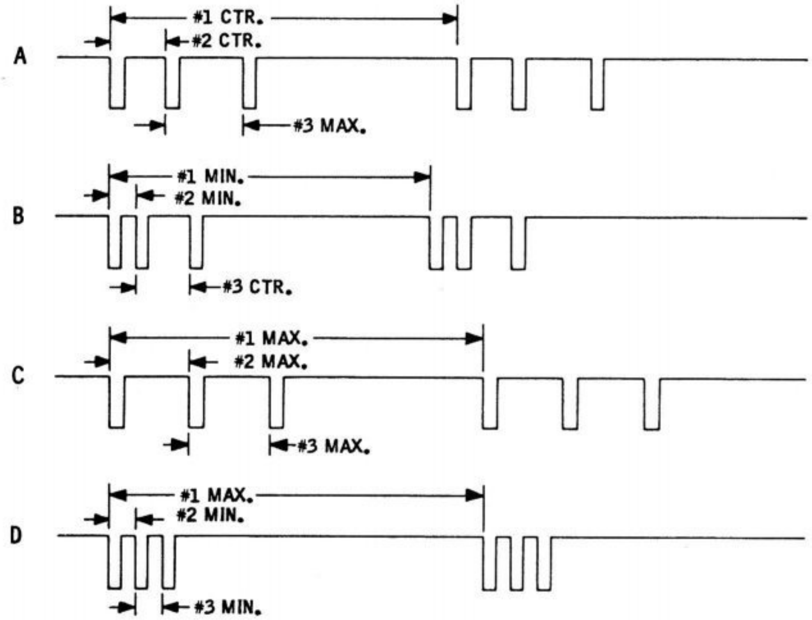


FIG. 4

DIGITRIO PULSE TRAIN WAVEFORMS

from appearing at Q10's base as well. as isolating the different sources from each other. Let's review what we have so far.

The pulse generator initiates the action. When it triggers the first variable one shot, we produce Pulse 1 at Q10's base. We can vary the time between the #1 pulses with R13 (coarse) or R30 (motor control stick). When the first variable one shot completes its cycle we produce Pulse 2 at Q10's base. We can vary the time between Pulses 1 and 2 with R34 (control stick) or R31 (trim).

At the same time Pulse 2 is produced, we trigger the second variable one shot. When it completes its cycle we produce Pulse 3 at Q10's base. We can vary the time between Pulses 2 and 3 with R38 (control stick) or R35 (trim). The time between #1 pulses will be Channel 1. The time between Pulses 1 and 2 will be Channel 2. The time between Pulses 2 and 3 will be Channel 3. Since all channels are initiated at the completion of its preceding channel there is no interaction.

The pause between "sets" of three pulses is called the "sync" pause. The receiving decoder uses this pause to reset, or sync, itself as we'll see later. So far we have three independently controllable positive pulses at the base of Q10. These positive pulses are used to trigger the fixed one shot described below.

Q10 and Q11 form a fixed one shot that will produce a positive pulse at Q11's collector (See Figure 2) of approximately 200us duration each time it is triggered. These positive pulses are directly coupled to Q4's base and will cause this stage to cutoff for the duration of each pulse (See Figure 2). We will call Q4 the modulator as it is used to control the transmitter output. That's it for the decoder, now for the transmitter.

Q1 is the oscillator and gets regenerative feedback across L1 to sustain oscillation. The frequency of oscillation is determined by the crystal. R1 and R2 provide forward bias for this stage. L2's primary and C2 form a tuned circuit for the collector and is tuned to the operating frequency. L2's secondary couples the RF energy to the RF amplifier. The oscillator operates on the fundamental frequency desired and the crystal is a commonly available third overtone type.

Q2 and Q3 form the RF amplifier. Although sufficient power would be available with a one-transistor circuit, two are used in parallel to share the load and heat dissipation. R4-C4 and R5-C5 are used to insure that one transistor doesn't "hog" all the driving power and provide the DC bias voltage return to ground. The RF amplifier operates in Class C and derives forward bias voltage from the RF voltage rectified at the base emitter diode. C6, C7, C8 and L5 form the RF amplifier tuned circuit and is tuned to the operating frequency by C7-C8.

C9, C10, R6, R7 and D1 sample and rectify the RF voltage at the antenna which is applied to M1. R7 allows adjustment to suit the meter used. Positive voltage is applied to the amplifier through L6 which isolates the RF from the rest of the circuit. C3, C11, C12, C13, L3 and L4 are all used to provide RF feedback immunity.

Q4 modulates the transmitter by turning off the oscillator each time a positive pulse is produced at Q11's collector (See Figure 2). By using this method, oscillator leak-through is eliminated when operating the transmitter in close proximity to the receiver when testing etc. This method also produces extremely clean transmitter pulses from the standpoint of rise time and modulation depth.

The emitter of Q4 is tied to the positive side of the battery supply. Its collector goes directly to the oscillator. Q11's collector is normally negative with respect to Q4's emitter, forward-biasing Q4. This applies positive voltage to the oscillator's collector and bias resistors allowing it to operate. R8 and R9 are the bias resistors for Q4. Whenever Q11 conducts, its collector goes to ground potential and this removes forward bias from Q4. The result is that Q4 cuts off, removing the positive voltage going to the oscillator and the oscillator stops. This occurs each time one of the 200us positive pulses, which we generated earlier in the coder, appears at Q11's collector. The RF at the antenna therefore is a carrier that is spiked off in a train of three 200us pulses with controllable recurrent rate and independent control of pulse separation. Figure 3 shows waveforms for the transmitter. The gentle curve at the top of each output pulse trailing edge helps prevent ringing in the receiver IF stages. When we get to the receiver you will note how clean the signal is. Figure 4 shows variations of the pulse trains as control pot settings are changed. Pulses are shown at center or extremes for simplicity but pulse separation is continuously adjustable throughout the control pot ranges.

Z1 is a zener diode wired in the circuit in a reverse bias configuration. It has the property to conduct when its reverse breakdown voltage is applied. It will maintain this voltage as the applied voltage is increased (current increases of course) up to its dissipation limits. R28 (2 ea. 180 Ohm ¼w in parallel) sets the current in a middle range to provide a stable voltage (5.1v) for the coder regardless of normal battery voltage fluctuations. This prevents trim drift due to varying voltage. Figure 1 can be used as a visual aid to tie all the foregoing theory together.

The battery pack is eight 600 M.A. Pencell nicads wired in series. This gives about four-five hours operating time. I doubt if a 9v dry battery will fit in the case shown and do not recommend their use. C23 and C24 are used to filter the circuit DC-wise. J1 and J2 are used as charging jacks for both the transmitter and receiver. They are wired to the off side of the switch. The antenna is center-loaded and contrary to many proponents of the unloaded or base-loaded types I have yet to encounter dead spots while using it. If you are of the "rather fight than switch" group, a base loading coil can be added and a "stick" used, at the expense of lowered "radiated" power.

Parts List and Procurement

By far one of your biggest problems in constructing the Digitrio will be procuring the parts. To make it as easy as possible for you I have included the manufacturer and manufacturer's part number. An unfortunate aspect of our hobby is that most electronic parts dealers handle only parts by certain manufacturers and we electronic builders bounce back and forth between distributors trying to come up with our total requirements. The two largest catalog dealers are very fast and efficient, as long as they have the part on hand and you give them **their** catalog number for the part. The sad part comes when they don't have a part and instead of sending it when they do get it in stock, they send you a "sorry we're temporarily out of the part you requested – reorder in 30 days" type reply. Also I have yet to receive a reply to inquiries about the availability of parts for which I didn't have their catalog number!

Of course, I think we all understand that any purchases **we** make will hardly make a dent in their profits, and in some cases, their handling costs will even exceed their profits – **costing** them money! So it's a sad lot for us "scratch builders." On the brighter side, we are fortunate to have a couple of hobby distributors who will go out of their way to help us when we need parts. Their assortment of parts, however, is limited to selected items used in their own equipment or carried by popular demand. One of these distributors is kitting this system and by buying in large lots they may save you money over buying individual parts – plus a lot of leg work.

For you scratch builders my parts list shows the parts I used in the original "Digitrio" which I obtained from ordinary sources. To give you the best possible chance of duplication I'll comment on the "odd ball," critical ones and give some substitutes.

1. C15, C18 and C22 are "Cal Rad"

RCM DIGITRIO TRANSMITTER PARTS LIST

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER	MANUFACTURER NUMBER (Controlaire)
Ant.	C. L. Ant.	World Engines	(Controlaire)
C1	100 PF	Erie	831X5R101K
C2	15 PF	"	831U2M150K
C3	.1	Centralab	UK10-104
C4	.005	"	CK502
C5	.005	"	"
C6	50 PF	Erie	831U2M500K
C7	50 PF	"	"
C8	7-100 PF	Arco	423
C9	27 PF	Erie	831U2M270K
C10	.001	"	CK60AW102M
C11	.05	Centralab	UK10-503
C12	.05	"	"
C13	.05	Centralab	UK10-503
C14	1.0 Tantalum	Mallory	TAS105KO35POA
C15	.1	Cal Rad	.1 Mylar
C16	.01	Centralab	CK-103
C17	.001	Erie	CK60AW102M
C18	.1	Cal Rad	.1 Mylar
C19	.001	Erie	CK60AW102M
C20	.001	"	"
C21	.001	"	"
C22	.01	Cal Rad	.01 Mylar
C23	100 Electrolytic	Mallory	TT15X100
C24	15 MFD @ 15V	World Engines	— — — —
D1	Ger. Diode	Ohmite	IN56A, IN 34 etc.
D2	Sil. Diode	"	IN457
D3	"	"	"
D4	"	"	"
D5	"	"	"
D6	"	"	"
J1	Phono Jack	Switchcraft	3501F
J2	"	"	"
L1	47 uh choke	Miller	74F475A1
L2	OSC Coil Hand Wound on C.T.C. Coil Form No. 2173-3-3		
L3	47 uh choke	Miller	74F475A1
L4	"	"	"
L5	RF amp coil	B & W	No. 3007
L6	47 uh choke	Miller	74F475A1
M1	1 M.A. meter	Ace	22B3
Q1	2N706	Motorola	2N706
Q2	2N706	Motorola	2N706
Q3	"	"	"
Q4	2N3638	Fairchild	2N3638
Q5	2N2160	G.E.	2N2160
Q6	2N3638	Fairchild	2N3638
Q7	"	"	"
Q8	"	"	"
Q9	"	"	"
Q10	"	"	"
Q11	"	"	"
R1	1K ¼W	Ohmite	LIDSM
R2	4.7K ¼W	"	"
R3	47 ¼W	"	"
R4	330 ¼W	"	"
R5	330 ¼W	"	"
R6	1K ¼W	"	"
R7	50K var.	Mallory	MTC54L1
R8	4.7K ¼W	Ohmite	LIDSM
R9	4.7K "	"	"
R10	Deleted	— — —	— — —
R11	1K ¼W	Ohmite	LIDSM
R12	27K "	"	"
R13	10K var.	Mallory	MTC14L1

(PARTS LIST CONTINUED ON PAGE 26)

DIGITRIO TRANSMITTER PARTS LIST (Cont.)

R14	1K ¼W	Ohmite	LIDSM
R15	10K "	"	"
R16	1K "	"	"
R17	27K "	"	"
R18	1K "	"	"
R19	10K "	"	"
R20	1K "	"	"
R21	10K "	"	"
R22	10K "	"	"
R23	10K "	"	"
R24	27K "	"	"
R25	1K "	"	"
R26	1K "	"	"
R27	10K "	"	"
R28	90 ½W — 2 ea. 180's ¼W in parallel	"	"
R29	10K ¼W	"	"
R30	10K var.	"	CU1031
R31	10K var.	"	"
R32	22K ¼W	"	LIDSM
R33	4.7K "	"	"
R34	10K var.	"	CU1031
R35	10K var.	"	"
R36	22K ¼W	"	LIDSM
R37	4.7K "	"	"
R38	10K var.	"	CU1031
S1	DPDT Switch	World Engines	W. E. DPDT
XTAL	----	" "	----
Z1	5.1V Zener Diode	IR	1N751A
--	Ant. Grommet	World Engines	----
--	1N34 for F.S. MTR.	Ohmite	1N34 etc.
--	P.C. Board	World Engines	----
--	Hook-Up Wire	" "	----
--	Case	LMB	#145
--	Hook-Up Wire	World Engines	----
--	Heat Shrink Tubing	" "	----
Misc.	Nuts, Bolts, Washers, etc.		

parts. These should be +-10% mylar, paper or tantalum. The first two are cheaper. An alternate is "Goodall" although I don't have a part number and couldn't find them myself through normal channels. Tantalums are more expensive but should be readily available from a number of different sources. I have a "Cal Rad" catalog but they apparently only sell to dealers and don't show an address. So try your local dealer, or World Engines. Don't substitute run-of-the-mill miniature capacitors with wide capacitor and temperature tolerances or low leakage resistance.

2. D2 through D6 — You're on your own here but any **good** silicon diode should work. I wouldn't recommend the so-many-for-a-dollar-in-a-package type.
3. L5 — Try "Airdux" #516T as a substitute. I would recommend that you use the coil stock rather than hand winding. It will look a lot neater and chances of exact duplication are much greater!
4. I used a 50 ua meter in my original which I purchased from the Lafayette store in town. They later closed down and I wrote to Lafayette about availability along with a complete description. I have yet to receive a reply. The Ace meter looks better anyway. The main thing is that you can use what you have from 50 ua to 1M.A. — that's why R7 is in the circuit.
5. I don't recommend substitution for any of the transistors used except the manufacturer of the 2N706's. Several manufacturers make this item. If you have trouble finding the 2N3638's, try World Engines.
6. R7 and R13 — I ordered these from the Mallory catalog. If necessary, substitute "Centralabs." The 10K is Ace #29A14. Substitute the 50K with Ace #29A15. (25K)
7. R30, R31, R34, R35 and R38. Don't substitute these with cheaper pots. These are sealed and as linear as you'll find. They should last the life of the system without trouble.
8. Crystal — Specify frequency when ordering. Ask for fundamental, third overtone, parallel mode type.
9. Z1 — This should be available from several other manufacturers, T.I. and Motorola are two.
10. R10 — This was a 47 Ohm resistor originally used in the pulse generator circuit in series with B1 (top lead of Q5 on schematic), for temperature stabilization. Tests proved it to be unnecessary and it was deleted.
11. R12, R17 and R24 — Here I would recommend 5% resistors. Although shown on parts list as 10% by the Ohmite number (LIDSM). This will insure more accuracy in your one shot cycle times. If you use Ohmites, the number is (LIDED). In any case, the resistance value and wattage must precede the type number when ordering. If you don't have these, and will be delayed in obtaining them, don't worry about it — it's not that important.
12. C14 — Although a normal electrolytic can be used here the tantalum shown will make adjustment of this circuit much easier and more stable.

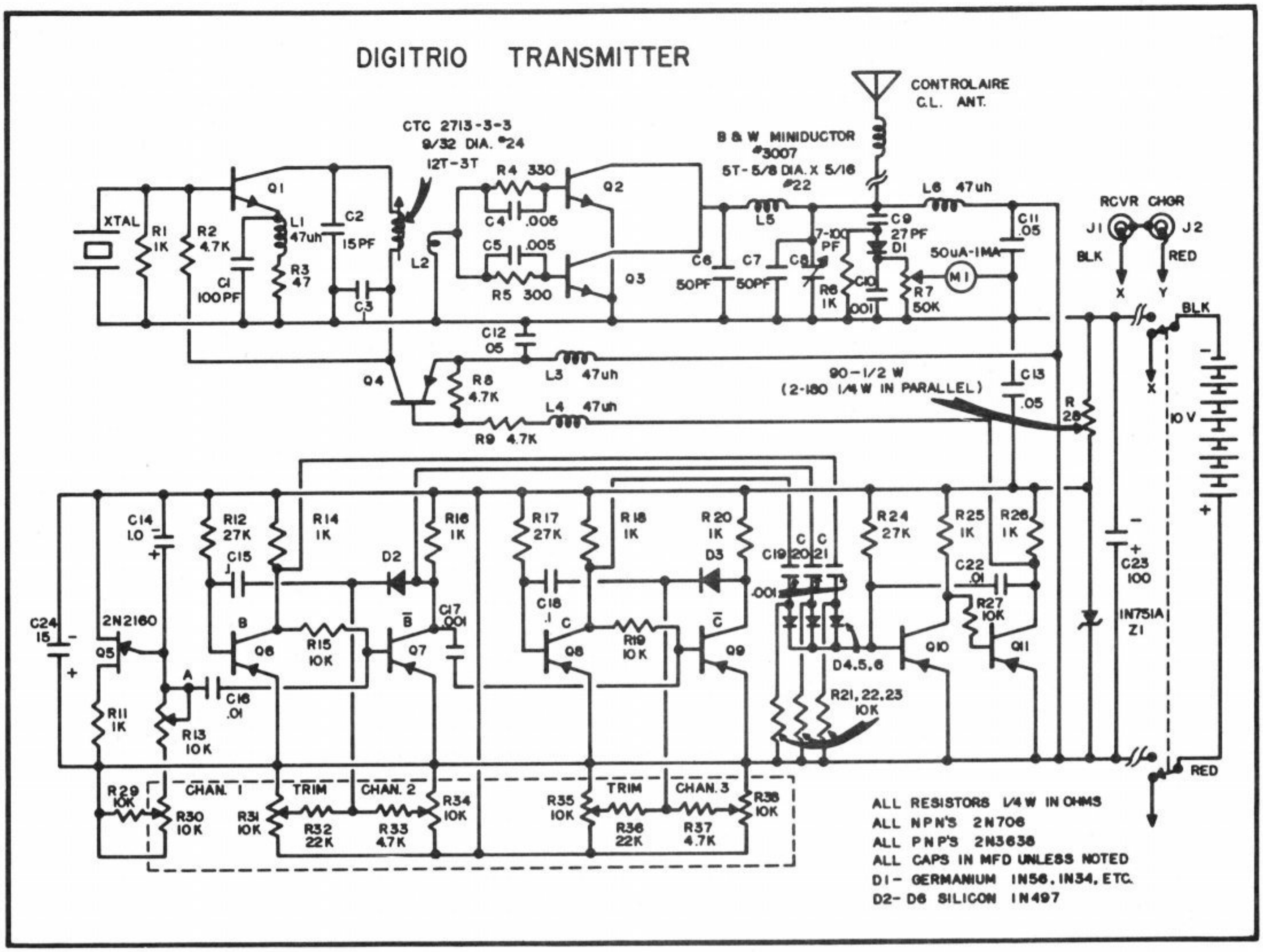
Since this system is being kitted, all parts are also available individually from WORLD ENGINES. I have personally built a transmitter using only parts supplied by them and approve of every one.

Making the P.C. Board

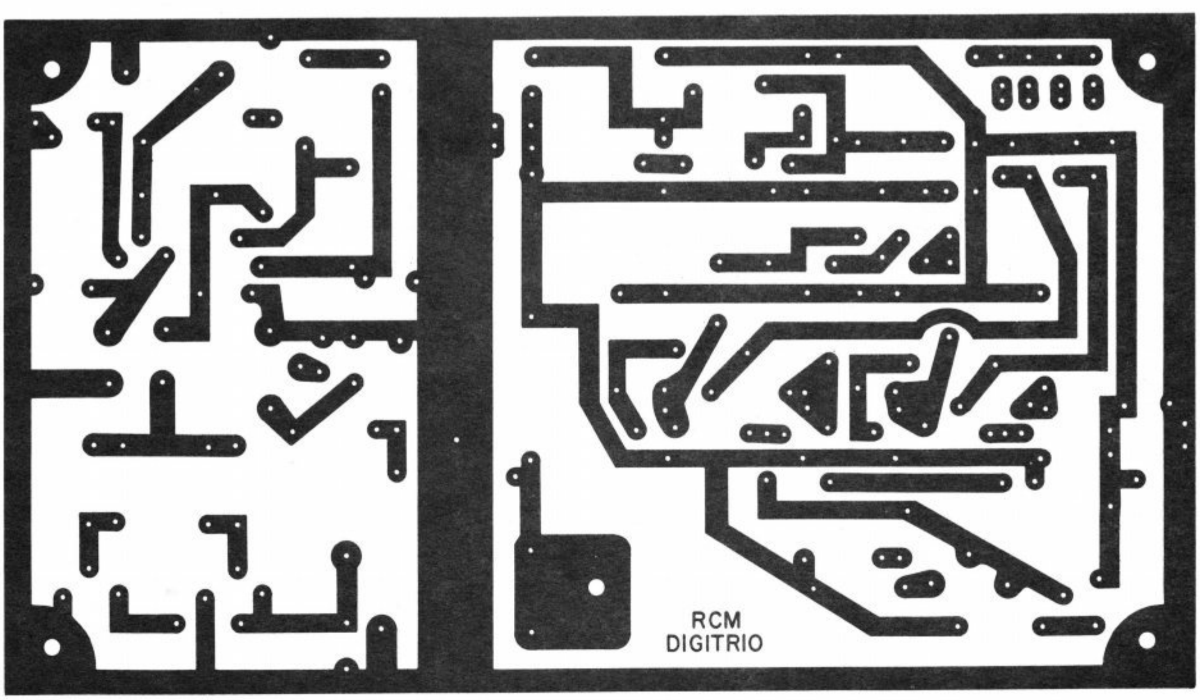
There are numerous methods for making a printed circuit board, although the photographic method is by far the most efficient and produces the highest quality results — albeit more expensive. If you decide to produce your boards photographically, obtain the following materials; available from your local electronics supply house: Kepro Photo-Sensitized Copper Clad glass epoxy board, 12" x 12" Catalog #S1-1212G ($10.20); Kepro Developer #D1-PT ($1.15); and Kepro Etching Solution #E-1PT ($.85). The foot square piece of photo-sensitized copper clad board will be enough for all of the printed circuit boards used in the RCM Digitrio. If the Kepro items are not available locally, write Kepro System, Inc., Tree Court Industrial Park, St. Louis, Missouri 63122. In addition to the above, you will need to round up a #2 photoflood bulb from your local photo dealer, a sheet of plate glass 12" x 12" or larger, and two pyrex trays.

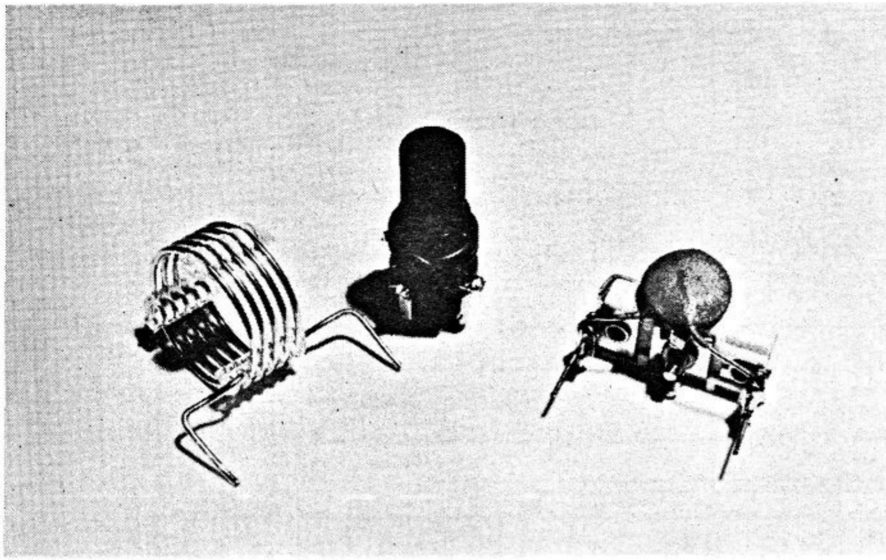
Cut out the full-size printed circuit board layout for the transmitter from your copy of RCM and take it to your local blueprint shop to have a negative made, same size. When you have the negative, you're ready to go. Set the two pyrex trays in the kitchen and pour the entire pint of developer in one and the etching solution in the other. Draw the shades or drapes in order to keep the room light down to a minimum — total darkness is not necessary, just dim light. Cut off a section of your twelve inch square photo-sensitized board just slightly larger than the size of the transmitter board. Wrap the balance of the board up in its light-tight protective wrapper and put away until you're ready to make the receiver-decoder and servo amplifier boards.

Place the section of copper clad board you have cut on a flat surface with the copper side up. Place your negative over the board so that the words "RCM Digitrio" read properly (glossy side of negative up). Wipe your piece of plate glass completely clean and free of dust, then place it over the copper clad board and negative — the glass holding the

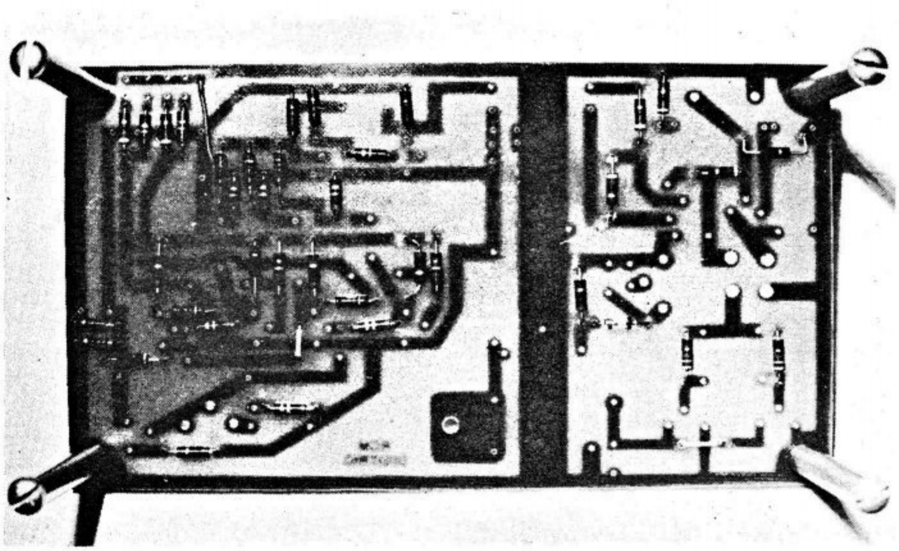


Full size transmitter P/C Board ready for photographer.

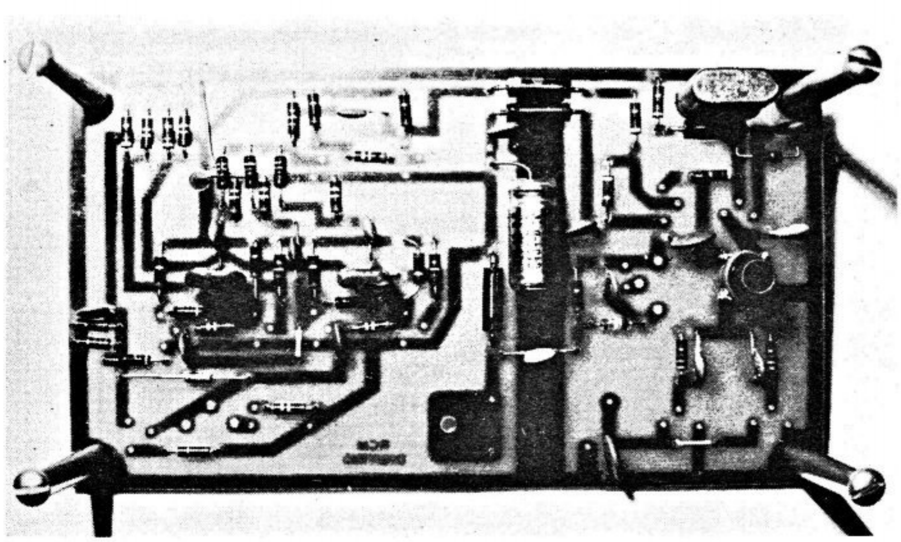




Left to Right: L5 cut from B&W or Airdux prewound stock, hand-wound L2, and C8 assembly (Arco 423 with 50 PF capacitor in place). Preliminary assemblies.



Transmitter PC board with all resistors and diodes in place. Leave 1/32" clearance between resistors and board in case you have to remove a component. Four mounting posts provide a "table" for working on PC board.



PC board with resistors, diodes, capacitors, crystal, 47uh chokes, and osc. coil (L2) in place.

sandwich in place. Now, position the #2 photoflood bulb in position exactly 10" from the plate glass.

When everything is ready, watch the clock, and turn on the #2 photoflood for seven minutes. At the end of this time, turn off the light, remove the copper clad board by its edges, and slide into the tray of developer. Rock the tray of developer slightly to provide agitation of the solution for one minute. Remove from the tray and set the developed board down on a paper towel for a couple of minutes to air dry. **Do Not** shake or blow on the board to dry it! When dry, you will be able to see a faint image on the board. Now, slide the board into the etching solution and turn on the lights in the room.

Etching the board depends upon the temperature of the etching solution, and the amount of agitation provided during the etching process. We place the pyrex tray over a burner on the stove and heat the solution every two or three minutes, agitating intermittently by gently rocking the pyrex tray from end to end. As the copper is etched away from the board, the solution will turn from an orange-brown color to a muddy brown-black. Complete etching should be completed in from 30-45 minutes in this fashion. Inspect the board and make sure there is no copper remaining between lands and that etching is complete. Remove the board from the solution and place in the kitchen sink. Turn on the cold water and let it run over the board for a full five minutes. During this time, you can clean up the rest of the materials. If you pour the etching solution down the drain, use plenty of running water or you'll be presented with a plumbing bill for new pipes!

Dry off the board and drill all holes with a #60 drill. Trim the board to exact size on your jig saw and then sand the edges. Your transmitter board is now completed.

Wiring the Printed Circuit Board

Before we assemble the components on the board, some preliminary work should be accomplished:

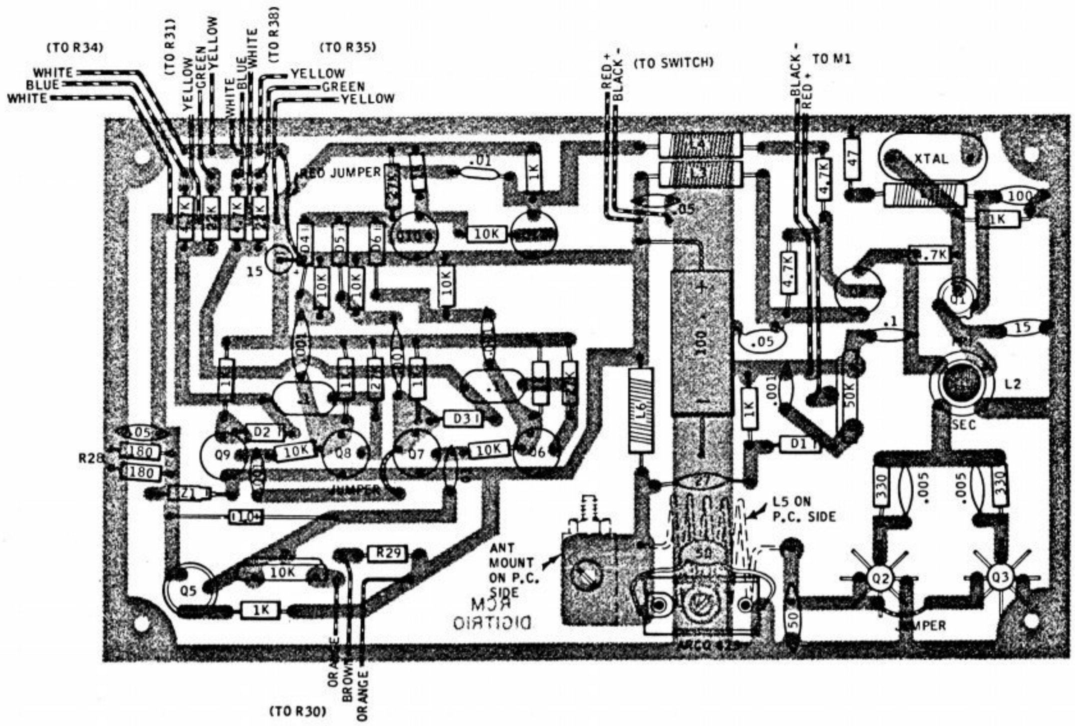
( ) Drill the four mounting holes, in each corner of the board, with a #17 or #18 drill.

( ) Drill the antenna mounting hole with a #31 drill.

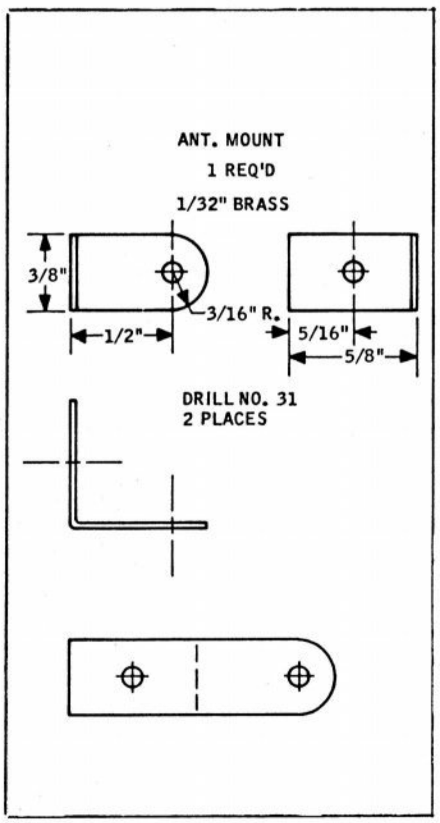
( ) Looking at the overlay, take your parts which will require holes larger than the #60's already drilled, and drill the board so they will fit.

( ) Close wind L2's primary at the bottom of the coil form, as indicated on the schematic. The three-turn secondary utilizes standard insulated Bonner hook-up wire and is close wound on top, and in the middle, of the primary. Coat the completed coil with Ambroid glue.

( ) If you wind L5 by hand, use a



Full-size component overlay shown above. Be sure to observe proper polarity of diodes. Also note location of primary and secondary on L2.



form slightly under ⅝" to allow for expansion when removed. If you use the prewound AirDux coil stock indicated, cut it long enough to allow for 1" leads when finished.

( ) Wrap and solder stiff wire around the lugs on C8 so it can be mounted without drilling excessively large holes. About #24 will be adequate.

( ) Solder C7 directly across C8, making sure it doesn't short across the plates.

( ) Screw your PC mounting posts to the component side of the board and it will form a platform to aid you in assembling the components (see metal work drawings for fabrication of these posts).

Before actually soldering the components in place, here are a few tips on proper soldering techniques. Use a low wattage iron (35 watts or so) with a small pointed tip. Apply the iron to the component lead about ⅛" above the copper lands. Touch your solder (a good, small-diameter resin type such as Ersin Multicore) to the opposite side of the lead. This will "tin" the lead. Slide the iron tip down the lead until it contacts the copper land, put another touch of solder on the opposite side of the lead and copper land simultaneously. The solder will flow around the lead and form a mound. Retract the iron by sliding it up the lead. Clean your iron every five or six "joints" by wiping it quickly with a clean rag or on a damp piece of foam rubber. After every 20-30 joints, clean your iron thoroughly and re-tin. This may sound like a lot of trouble but after a while it will become a matter of habit and will pay many dividends in the form of better looking and better constructed boards.

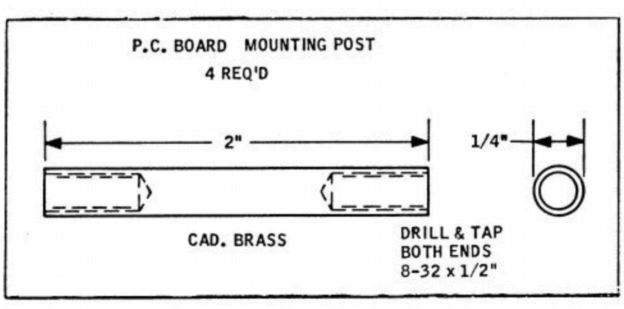
( ) Install the three jumpers as shown on the overlay. One is below Q2, another between Q7 and Q8. Use remnants of the resistor leads for these. The jumper above the 15MFD capacitor (C24) should be a piece of red insulated hook-up wire. Don't solder the bottom end as we'll insert the positive lead of C24 in this same hole later on.

( ) Mount all resistors except the small variable resistors R7 and R13.

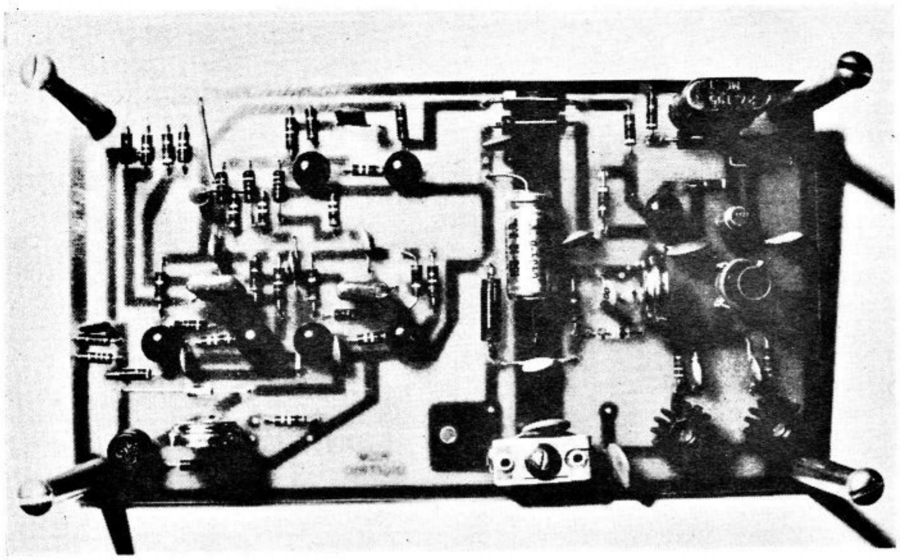
( ) Mount all diodes including Z1. Do this carefully, observing polarity markings on the overlay. When you bend the diode leads, do so from the tip so a radius is formed at the body. If bent too sharply, the glass envelope may crack.

( ) Mount the four 47 uh chokes — L1, L3, L4 and L6.

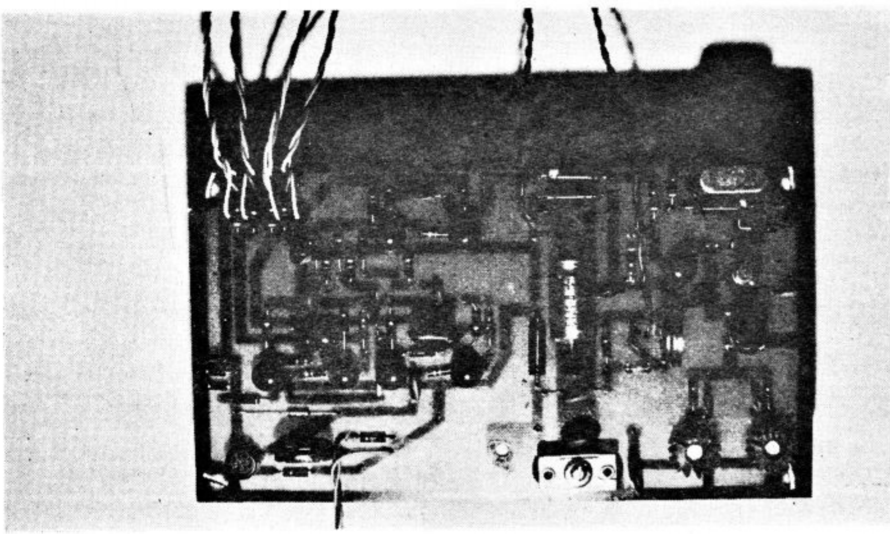
( ) Mount the 1, 15, and 100 MFD electrolytics, observing polarity.



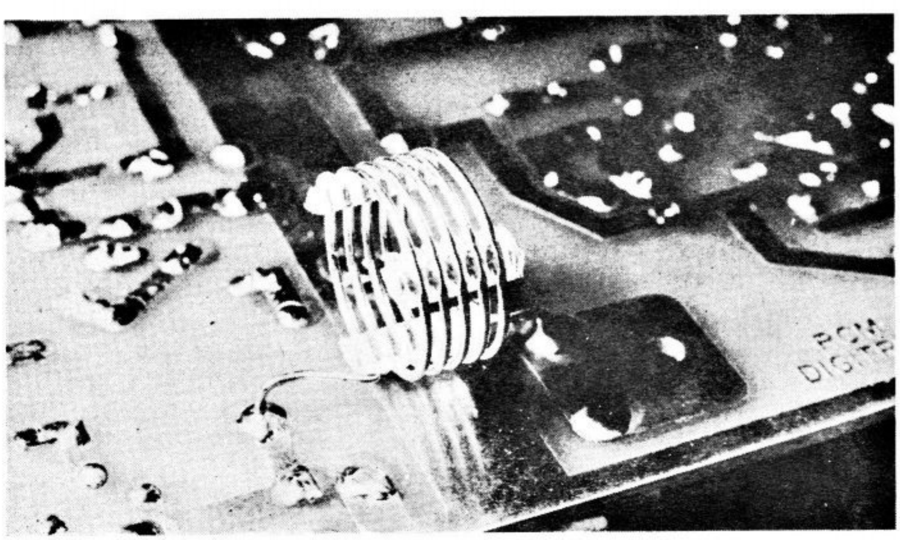
Although the sheet metal work is the subject of next month's installment, the four PC board mounting posts will provide a convenient set of legs — making your PC board a table on which to work. Antenna mount shown upper left.



All transistors and Mallory pots (R7 and R13) in place along with Arco 423. Note heat sinks on Q2 and Q3.



All wiring in place ready for connection to transmitter assembly. Wires in upper left to stick pots; center top to switch; center right to meter; and lower left to R30.



Close-up of L5 installed on PC side of board. This is 5 turns of standard prewound B&W or Airdux stock – saves winding. Be sure to leave clearance between L5 and board. Hole at right is for antenna mount.

(C14, C23, and C24).

( ) Mount remaining fixed capacitors.

( ) Mount crystal and L2 flush against board to provide back cover clearance.

( ) Mount all transistors, starting with the 2N3638's.

( ) Mount C7-C8 assembly, L5, and small variable resistors R7 and R13.

( ) Install heat fins on Q2 and Q3 and mount any remaining parts.

( ) Make and install the antenna mount with 4-40 nut, bolt, and lockwasher (see metal working drawings for fabrication).

( ) Cut 12" lengths of #26 standard hook-wire (I use Controlaire) in the colors shown on the overlay, the orange-brown-orange trio should be 17" long. Insert these in pairs or groups of three as indicated. Twist them and tie a knot at the end. This will keep them separated and out of your way.

Before we proceed further, let's make a preliminary check of the board:

( ) Measure the resistance between the red and black wire going to the transmitter switch. Your meter should indicate approximately 1000 ohms.

( ) Temporarily lift one end of L3 and L6. The meter should not change appreciably. When connecting the meter, observe polarity.

( ) Swap leads (reverse polarity) and a slight decrease in resistance may occur. This indicates that Z1 is connected properly. Don't accept this as final proof, but double check the installation of all diodes (especially Z1) for correct polarity. I would recommend that you apply voltage in steps by tapping down on your transmitter battery pack with the meter on the milliamp range and in series with the negative lead. Don't re-connect L3 and L6 yet. Starting with 5 volts (4 nicads), increase the voltage a cell at a time. The current as indicated on the meter should progressively rise but at no time exceed approximately 50 ma. Re-connect L3 and L6 and start all over. The current should now not exceed approximately 120 ma. If it is much less, your oscillator is not operating. To check this, run your slug clockwise until it is at the bottom of the coil form. Slowly backing it out, adjust it for peak meter reading. Don't operate it very long under these test conditions.

( ) To check operation of Z1, connect your meter across Z1 – the red lead to positive battery, the black lead to the junction of the two 180 ohm resistors (R28) and Z1. Starting at 5 volts, again tap up a cell at a time When you reach the sixth cell, the voltage should stabilize at approximately 5.1 volts. As you continue tapping, this voltage should not rise appreciably. You will note that the Zener diode will feel warm to the touch after a few moments of this test. This is normal and no cause for alarm. If you get carried away and apply more than the recommended voltage (8 nicads in series), or reduce the value of R28, be prepared to buy another Zener!

That's it for the preliminary checkout. If you encounter any difficulty, re-check the board and try to locate any improperly installed, or possibly defective, component. If you can't correct the trouble, call on your "technician type" buddy. Set the PC board aside now, and get your hacksaw, drill, vise, and taps ready for the next part which is the fabrication of the case, stick, and pot assemblies also final assembly and preliminary checkout.

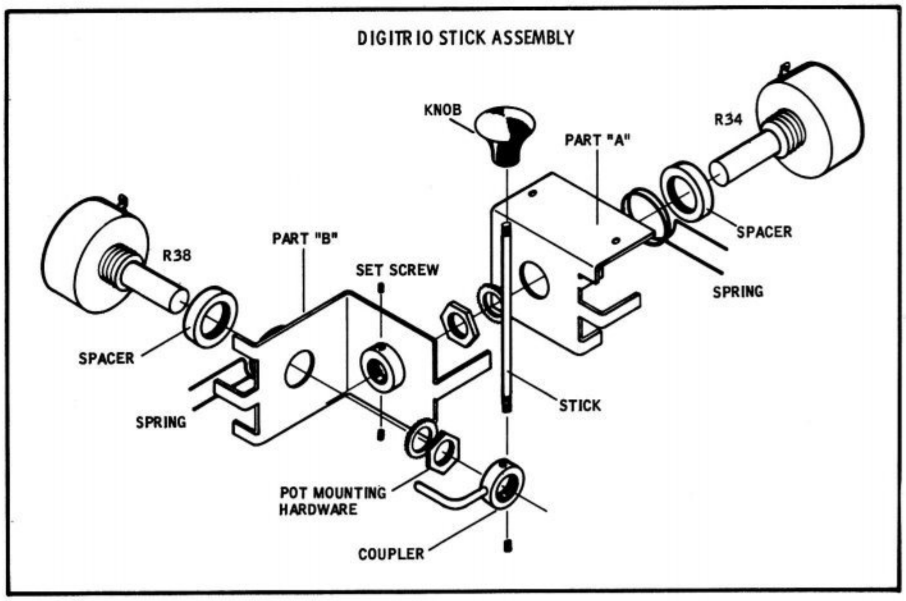
Part III: Transmitter Final Assembly

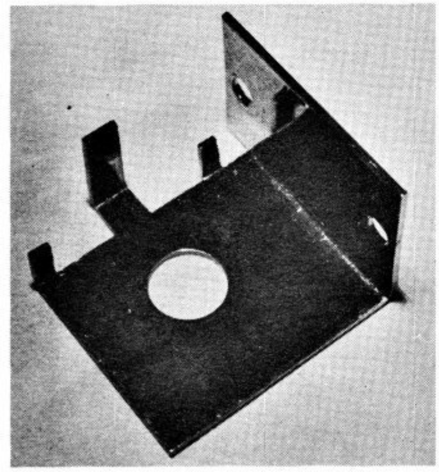
The Transmitter Case

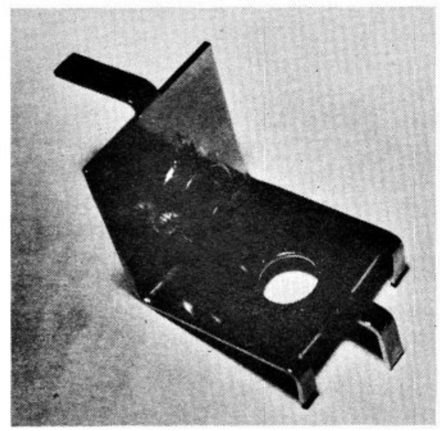
UNLESS you are a frustrated fender bender or ex-Navy machinist's mate, the miscellaneous sheet metal work involved with the transmitter case and stick assemblies will be the most tedious part of the entire RCM Digitrio system. We have tried, through experimentation with various prototypes, to simplify this phase of the construction to a point where it will require only a minimum of time and the normal shop tools. **Do** follow these instructions carefully, however, exercising care in your workmanship, so that each part of the mechanical work will be accurate, and at the same time, produce a presentable finished product.

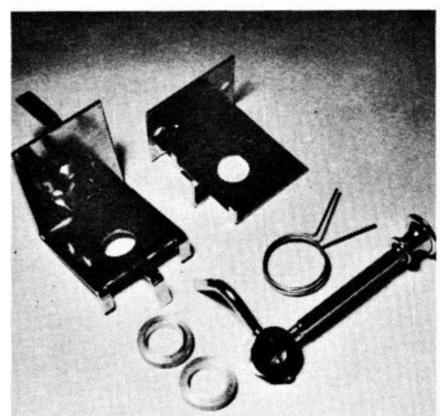
The transmitters for the three RCM Digitrio prototypes were all fabricated from standard LMB #145 aluminum boxes, available at most electronic parts houses. Simply cut out the full size front panel layout illustrated here and paste it to the front of the LMB box with rubber cement. Use an electric drill and drill a series of holes around the inside perimeter of the main stick cut out, trim slots, and meter cutout. Punch out the excess metal, then trim to the actual dimensions of the cutouts with a file. Drill all remaining holes as specified. If you use a panel meter other than the one specified (Ace R/C), change this dimension accordingly prior to commencing fabrication. If you cannot locate the LMB box, the case can be fabricated from aluminum in a vise, using hardwood blocks to prevent surface damage. Alternately, all sheet metal work can be done at any local sheet metal shop for a nominal charge. We would suggest **not** drilling the antenna hole in the top of the transmitter can until final assembly in order that this hole will align properly with the antenna mount on the PC board.

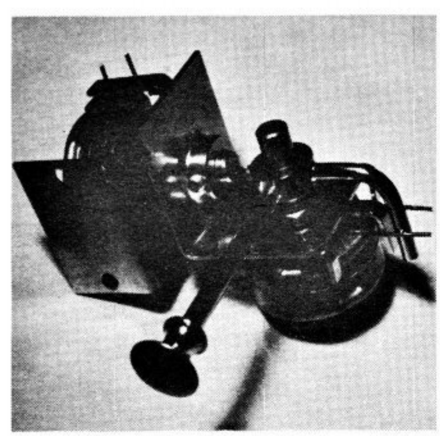
After finishing the sheet metal work, use a fine file to true up all cutouts in the front panel. De-burr all drilled holes, then polish the can with steel wool, followed by a wet sanding with 400-600




Part A, stick assembly.


Part B, stick assembly.


Stick parts prior to final assembly.


Completed stick assembly.

wet-or-dry paper. The transmitter case can now be anodized or painted. RCM's three prototypes were anodized antique gold and orange-gold at a local plating shop. The minimum charge for anodizing is usually $15, with the price for anodizing a single case, five dollars. So, if you have a couple of friends building the Digitrio, take a minimum of three cases at once to the platers in order that they may be done for approximately five dollars a piece. If you are not choosey about the color, you may have it plated along with another customer's run and beat the minimum also. If you prefer, the case may be given a coat or two of primer followed by several thin coats of spray paint such as automotive enamel in aerosol cans, available at most hardware and paint stores.

Control Sticks

Carefully study all of the drawings for the control stick assembly and obtain a good mental picture of all the parts and the functions they will perform. Adhere as closely as possible to the dimensions shown or you won't end up with the stick centered in the case cutout. Use a coping saw with a fine metal blade, or a jig saw to cut out the parts. A hacksaw will prove to be pretty cumbersome for this work. Clean all cut edges with a fine-toothed file, and before making any bends in the vise, check the drawings once again. Be sure to use hardwood blocks in your bench vise in order to prevent surface damage to the individual parts. One easy method for transferring the templates to the sheet brass stock is by the use of Dykem Blue. The latter, available in 8 ounce cans in most hardware stores, is brushed on the surface of the sheet stock and allowed to dry to its natural dark blue color. The sheet metal templates can then be scribed on the surface, allowing the brass to show through the blue painted surface, giving you accurate lines on which to cut.

If you are long on ambition, but short on tools, you can make some substitutions for the parts shown. For example, the trim and control sticks can be replaced with ordinary 6-32 bolts cut to the indicated lengths. The couplers, which incidentally, are the only items requiring a few minutes of lathe work, can be removed from ¼" shaft couplers used by most "hams." The silver-soldered coupler on Part B can also be taken from a ¼" shaft coupler and bolted in place, although some excess "play" will result. Aluminum can be substituted for the brass parts, although the centering springs will eventually "dig in" and periodic adjustment will be necessary. The mounting posts can alternately be made from standard 3/16" brass tubing, available at most hobby shops, and threaded as indicated with washers to increase the shoulder area. If you utilize the latter substitution, make sure the overall length including the washers is the same as shown on the drawings.

The curving arm on the one coupler can be a 6-32 bolt (with plain unthreaded shoulder), heated with a torch and bent as shown. Thread and solder it to the coupler as shown.

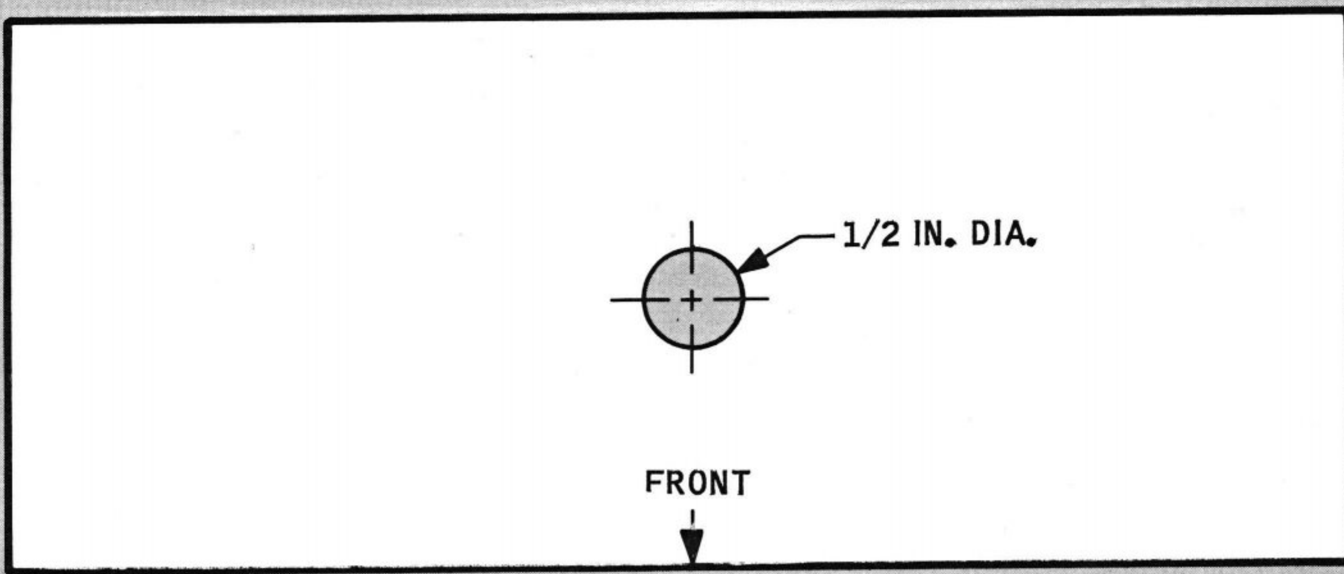
The pot spacers can be standard ⅜" pot mounting nuts rounded off with a file.

All of the above substitutions have been tried on one prototype, and although they are not as nice looking as the specified items, and though some play may be encountered in the control stick, they will enable the modeler with limited shop tools to reproduce this system with more-than-acceptable results.

So much for alternate ways of fabricating the control stick parts. When you get to the centering springs, this will be simply a matter of "bend and try" until you get the desired tension and action. Each one you bend will get progressively better until, finally, you end up with what you want in centering action.

The "knob" on the control stick shown

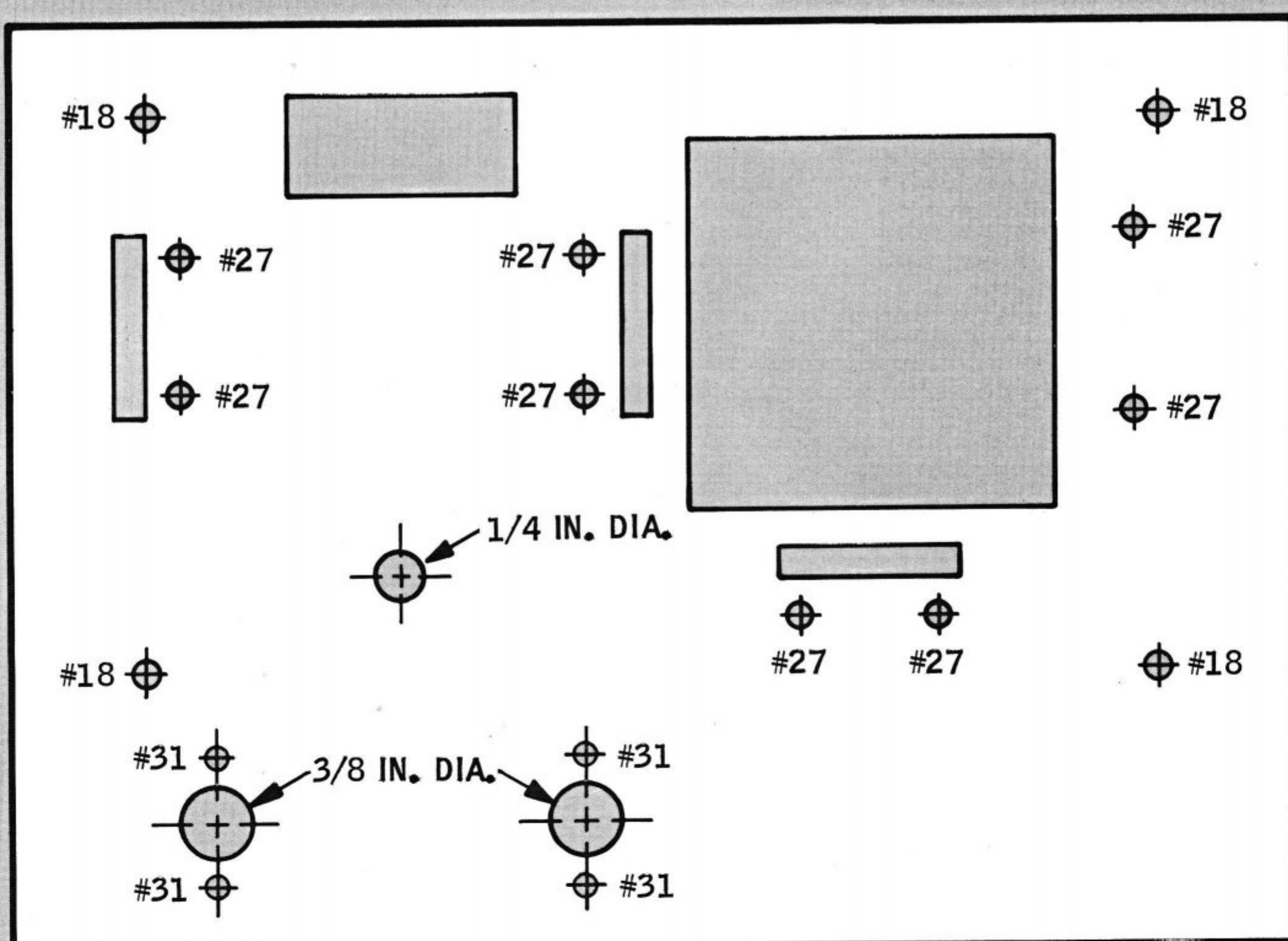
RCM DIGITRIO: FULL SIZE TRANSMITTER TEMPLATES

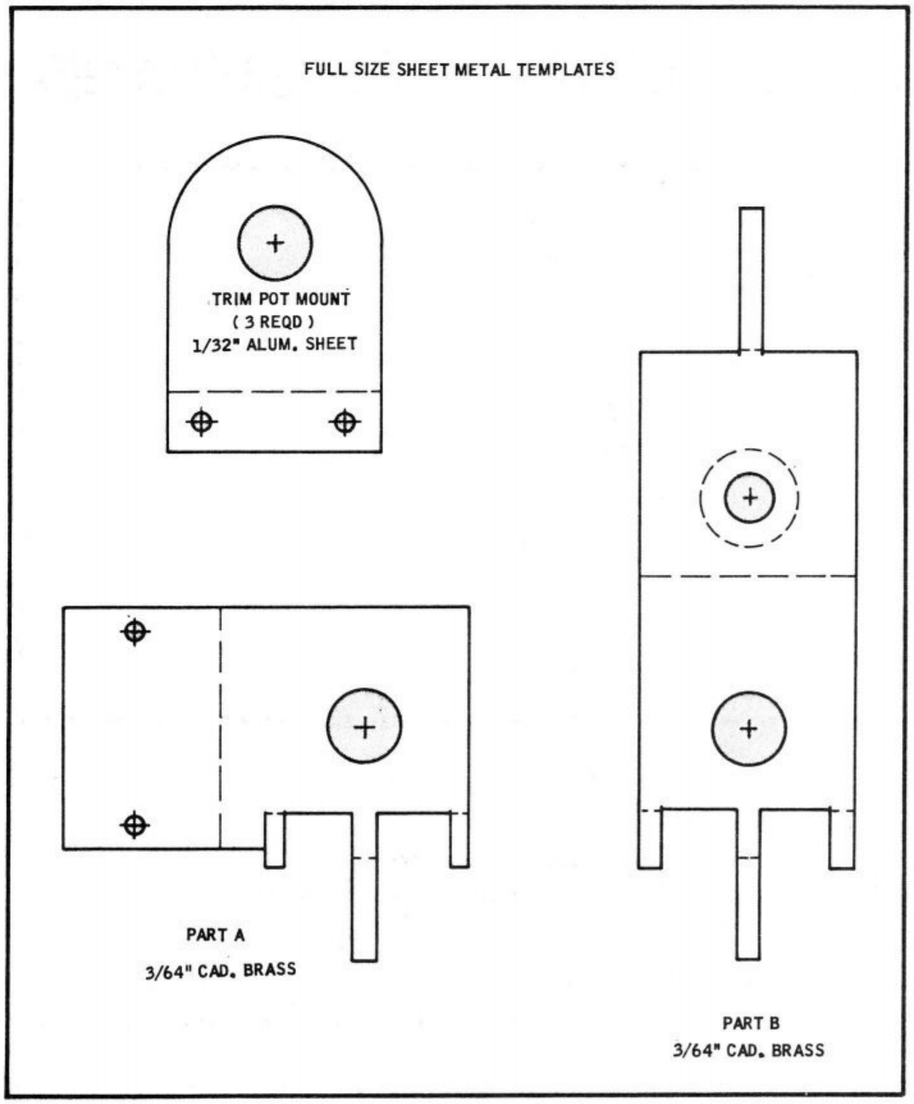


TOP VIEW

NUMBER BESIDE HOLE INDICATES DRILL SIZE OR DIAMETER.
PASTE ON LMB 145 CASE & REMOVE EXCESS MATERIAL.

FRONT VIEW





in the photographs was a chrome plated cabinet knob from the hardware store. On the RCM prototypes, we had all metal control stick parts satin chromed at the same time as the anodizing was done, with the exception of the trim levers and main control stick, which were bright-chromed, giving an excellent final appearance. Insofar as the control stick knob is concerned, almost anything that feels right to your hand can be threaded and installed in place.

By the way, when silver soldering the coupler on Part B, watch closely the temperature of the sheet brass – the melting point of the brass stock is quite close to that of the silver solder. Also, be sure to dunk the completed assembly in cold water while it is still hot in order to retain the original temper.

Now, saw the two pot shafts off at $\frac{5}{16}$" and assemble the stick as shown in order to try it out. Adjust the springs for the desired tension and centering. Place one drop of it on each pot shaft bearing and work it in. Bend all of the pot terminals back to keep them out of the way during final assembly.

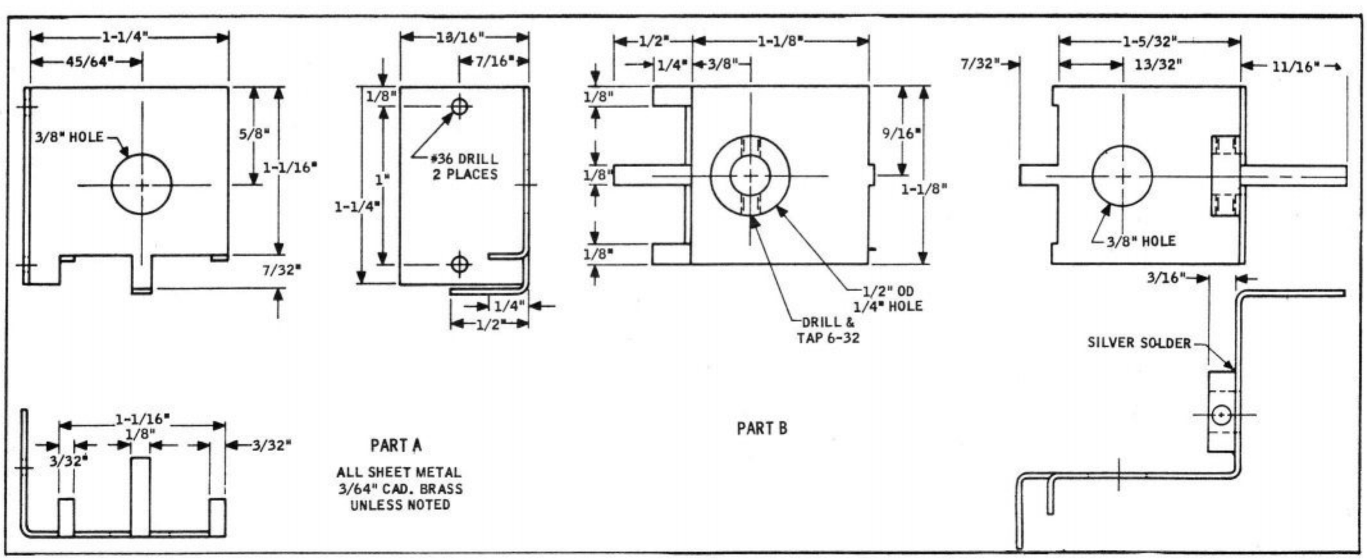
Assembling Transmitter

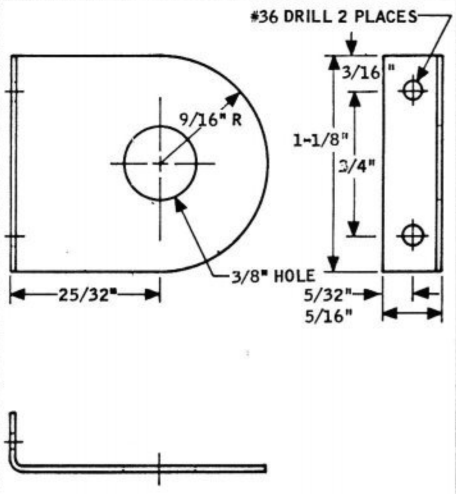
Prior to final assembly, saw the pot shafts to $\frac{5}{16}$" and mount all the trim pots in their mounts (3 ea.). The lip of the mount should bend forward away from the pot. Now, file a notch for the locking lug. The terminals should be centered at the top (rounded portion) and bent back. Turn the shafts to the center of their travel, then slip a coupler over each shaft. Temporarily install and tighten the trim sticks so they point straight down past the mounting lip (centered in the cutout).

Loosen the shaft couplers on the stick assembly and use the following procedure for exact electrical center of the stick pots. Place your ohm meter on a scale which will read 5000 ohms around midscale. Connect one lead to the center terminal, then by swapping the other lead between the outside terminals while moving the shaft, obtain the same reading on both sides. There are other methods of doing this with batteries in a bridge circuit, but this will be accurate enough. Tighten the couplers securely and double check the pot settings. Repeat if necessary.

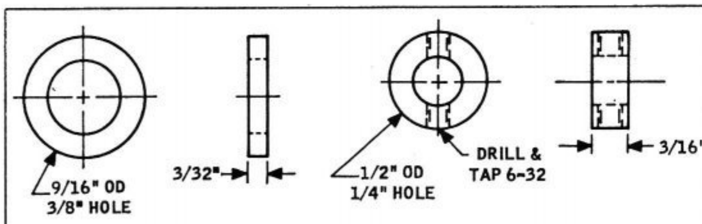
Mount the trim pots and stick assembly to the case with #6 sheet metal screws. Mount the switch and meter to suit the type you will use. Install the four PC board mounting posts to the front of the case with 8-32 x ½" bolts. Use internal lock washers under all bolt heads. Mount the two charging jacks with 4-40 nuts, bolts, and lock washers and bend the center lugs over. Cadmium-plated pan head bolts for all exposed boltheads will enhance the overall appearance of the transmitter.

This would be a good time to decide



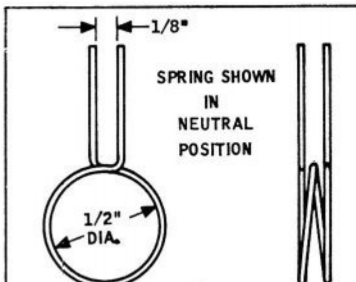


TRIM POT MOUNTING BRACKET
3 REQD 1/32" SHEET ALUM



SPACER
2 REQD CAD. BRASS

TRIM POT COLLAR
3 REQD CAD. BRASS



SPRING
2 REQD 1/32" M. WIRE

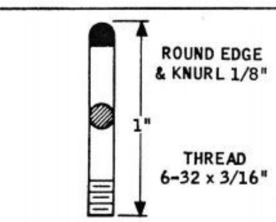
how to mount your battery pack. You can make a strap and bolt it to the bottom or front or however you wish. I used eight 600 mah Gould SCL Pencell Nicads wired in series and taped together with black electrical tape. Allow about 8" leads and color code them red for positive and black for negative. Make sure your mounting strap doesn't cut through the tape or protective covering of the batteries or you'll short some of them out. If you use the LMB box you won't have much choice where to place the batteries. The pack described will set neatly behind J1 and J2.

Cut a thin piece of felt and contact cement it to the bottom of the transmitter to prevent damage to the case when you set it on your best furniture. You can drill four holes in the corners and use small push-in rubber feet for this purpose if you can find them.

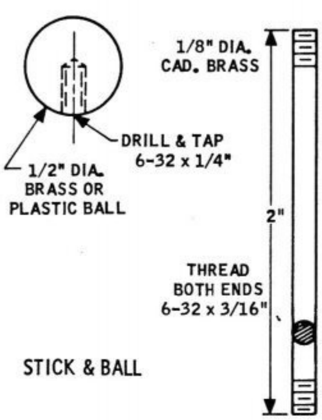
Now, place the transmitter case with all parts mounted, on its top and rear facing you. Place the completed PC board, component side down with L5 and antenna mount closest to you. Run all leads straight out the top of the PC board toward the transmitter (these leads should come from under the board). All the pot leads should be on the right-hand side. The switch and meter leads should be left of center.

The objective of all this is to wire the leads to their components, and when we're finished, lift the PC board up by its rear edge and secure it to the mounting posts. This will also allow you to work on the transmitter later on without having a rat's nest of wires to contend with.

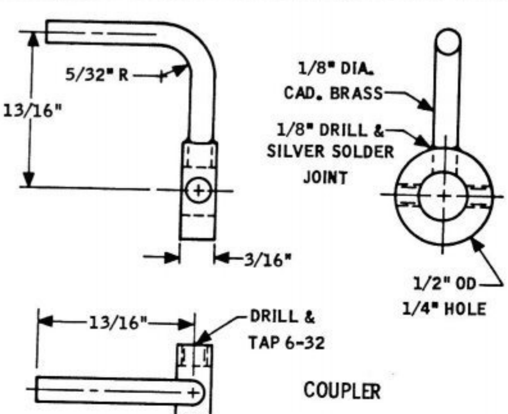
Adjust the board until it is about two inches from the case and maintain this distance throughout final assembly. When connecting pots, the odd colored wire always goes to the center terminal. The other two wires go to either outside terminal. Leave enough slack in these to reverse later. The white-blue-white wires on the far right side go to R34 which is the stationary stick pot. The yellow-green-yellow wires on the far right side go to R31 which is the vertical trim pot across the cutout from R34. Route this wire down, and left across the case at the lower case bend (as viewed now). The other white-blue-white wires go to the moveable stick pot and the other yellow-green-yellow wires to the trim pot, as viewed now, at the top of the cutout. Route this wire under R34 and keep it close to the case. Tie it off to the upper right mounting post (as viewed now). The orange-brown-orange wires go to the remaining trim pot (motor control) at the left side of the case (as viewed now). When connecting the leads to the stick and trim pots, allow enough slack so you can tie the wiring to the lower right PC mounting post (as it sets now) with the exception of the wires to moveable stick pot R38 – they must be free to move, so allow about 1" additional slack. After connecting R38's wires, route them behind R38's locking lug and tie them off to prevent breakage at the terminals (see photo). Tie the motor control pot wires to this same post (lower right) and run the wires across the bottom bend of the case (as it sets now) and secure them along with the vertical trim pot wires to the case with tape in a couple of places to keep them out of the way. Allow enough slack to tie it off to the lower left PC mounting post (as viewed now). Allow enough slack in the switch and meter wires to tie them off to the lower left-hand PC mounting post also (as it sets now). Use a short piece of Controlaire heat shrink



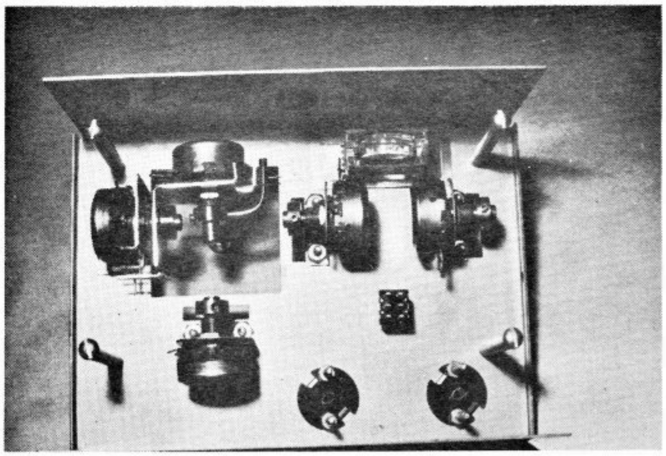
TRIM POT STICK
3 REQD 1/8" DIA CAD. BRASS

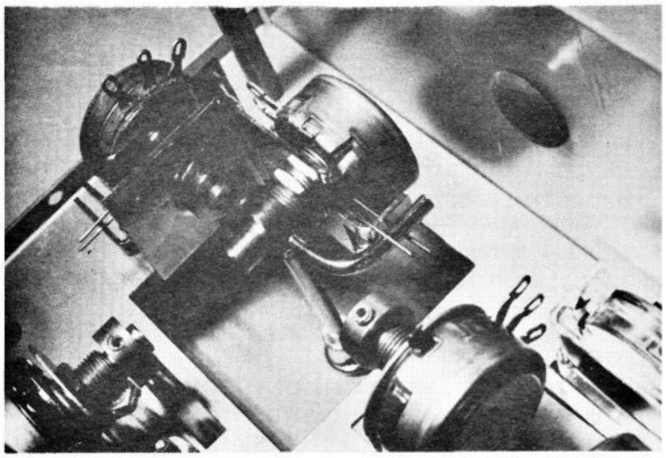


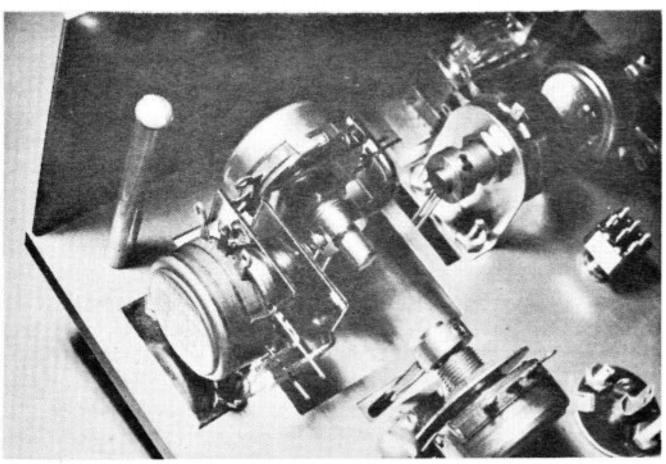
STICK & BALL

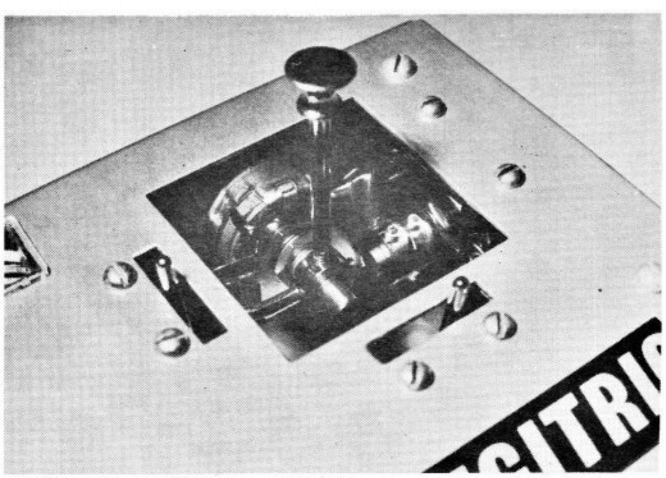


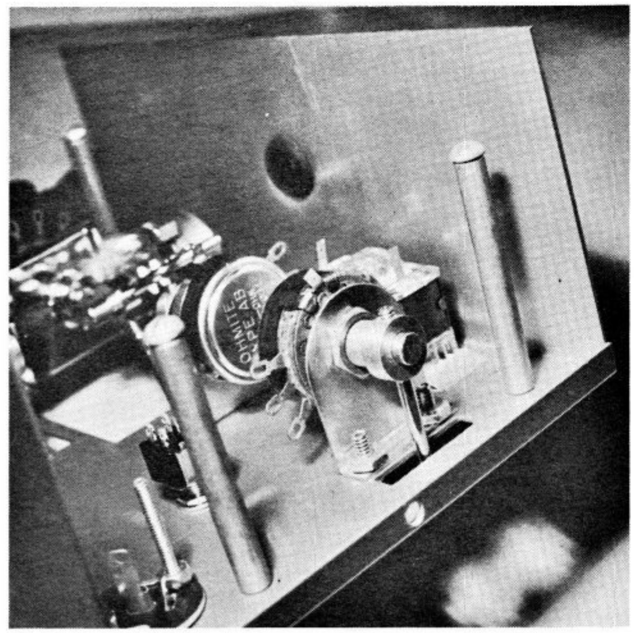
COUPLER
CAD. BRASS

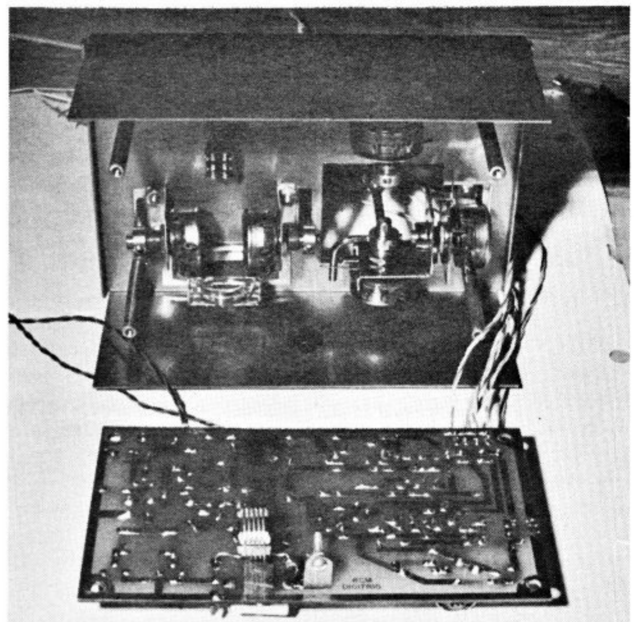












Left, top to bottom: Transmitter case with all hardware mounted. Second and third photos show detailed close-ups of stick and trim pot assemblies. Fourth photo, opposite, shows the completed stick from the front. Above, top; Throttle stick assembly and P.C. board mounting posts. Above: Proper position of transmitter and P.C. board during final assembly and checkout.

tubing 1" from terminals on all wires (large for 3 wires – small for 2 wires) for that extra touch. (See photo.) . You can use plastic insulation stripped from hook-up wire for all "tie offs" or lacing cord or small strips of electrical tape.

Connect the red meter wire to the positive meter terminal and the black meter wire to the negative meter terminal. Connect red and black battery wires to the "on" side of the switch with red at the bottom as viewed now. Check the switch with an ohm meter to find the "on" side. It should be on the left side as viewed now if you use the World Engines switch. Wire J1 and J2 as shown in the schematic. Connect a red wire from the positive side of the "off" side of the switch to the center terminal of J2. (Right hand jack.) Run a black wire from the side terminal of J2 to the side terminal of J1 (left-hand jack). Run a black wire from the center terminal of J1 to the negative "off" side of the switch. Use some positive method of identifying the jacks as follows:

J1 "Receiver" (Left Side)

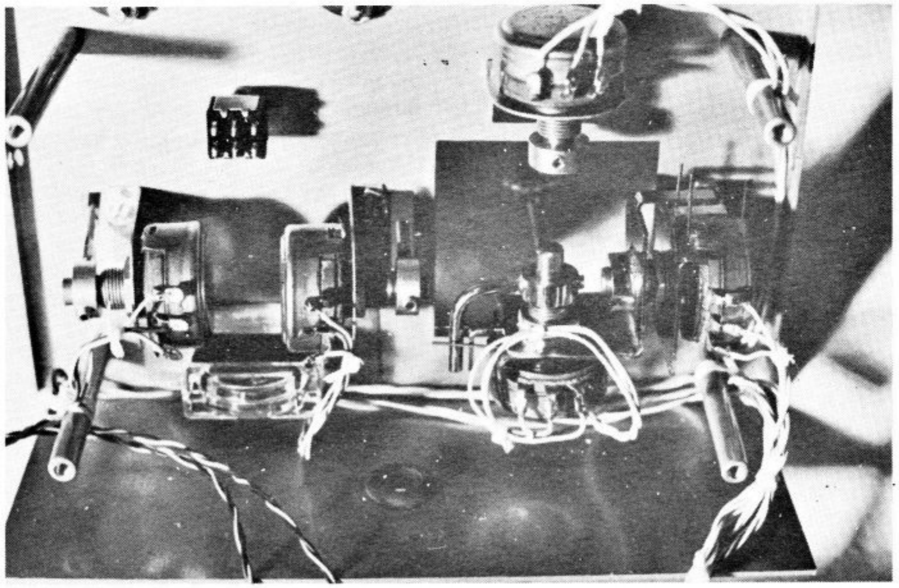
J2 "Charger" (Right Side)

This is important, and if reversed while charging, batteries will be subjected to deterioration. With this arrangement the transmitter and receiver batteries can be charged simultaneously. In any event, the switch must be in the "off" position. You will probably have to increase your present charger's output, however. You can charge the transmitter independently if you insert a shorted plug in the receiver jack. In the latter case, be sure the charging rate is adjusted for use in this fashion.

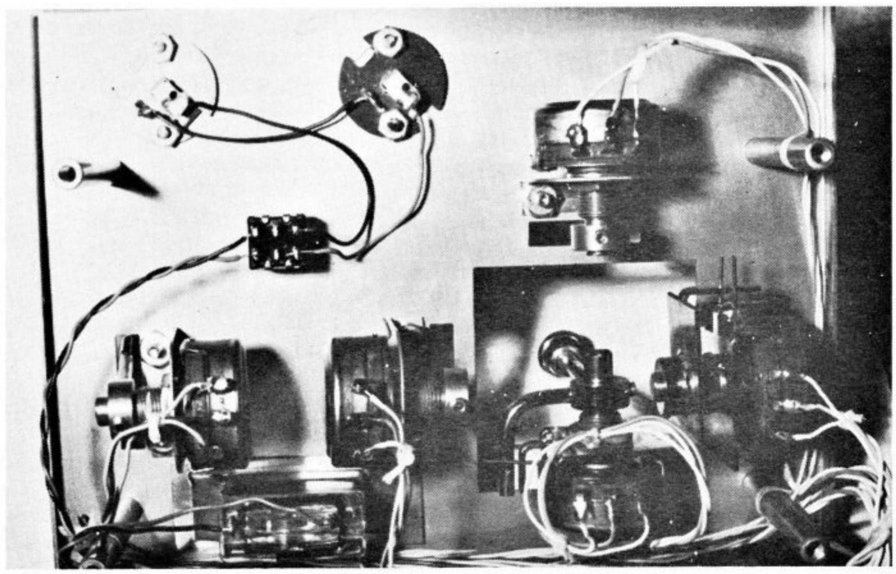
This is important. Whenever, and however, you charge your batteries, always, double check the polarity, plug arrangement and charging current. Connect two 8" lengths of red and black wire to the center terminals of the switch and install the rubber antenna grommet. **Do not connect the battery yet.** Secure the PC board into place. All wiring, except J1, J2, and leads from the switch to the battery should loop over the top of the board (when right side up). Make final adjustments of wiring now to insure that no interference is encountered when moving the stick or when sliding the case together.

Preliminary Checkout

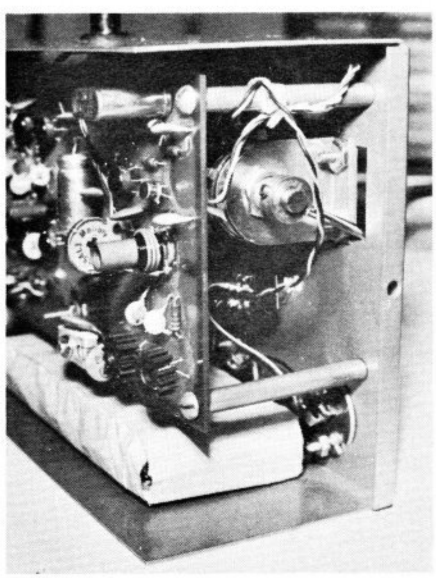
Before installing the batteries and tuning the transmitter, let's double check the wiring. With the switch in the "off" position measure the resistance between the 8" red and black leads going to the center terminal of the switch. If you read anything other than infinite resistance you have either wired the switch backwards or have wired J1 and J2 improperly. Don't proceed until you have corrected your trouble. If you do read infinite resistance "throw" the switch to "on." You should now read



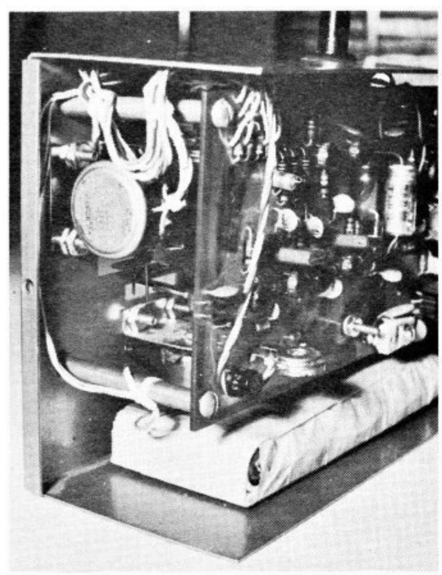
First stages of wiring. Note tie-off strain relief and cabling of wires.



Next stage of wiring with jacks and switch wired in circuit.

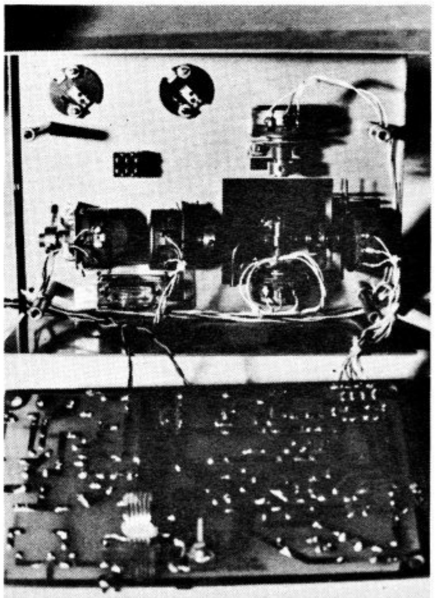


End view of completed transmitter.



Opposite end of completed transmitter.

When completed, the P.C. board simply lifts up and is secured to the four mounting posts.



approximately 1000 ohms resistance. Again I recommend tapping down on your battery pack as we did previously during the PC board preliminary checks.

Throw your switch "off" and connect the battery pack, with your meter on the milliamp scale in series with the negative (black) leads. You should not get an indication on the meter at any tapping voltage. Throw the switch to the "on" position. You should read somewhere between 50 and 120 M.A. Again, if this is much lower, your oscillator is not operating and the slug in L2 must be adjusted.

If everything has gone well so far, we are ready to tune the transmitter. Insert the antenna and place the transmitter on a non-metallic table, and fully extend the antenna. There should be ten sections to the "Controlaire" antenna exposed including the section with the loading coil – count them. Insure that there are no metallic objects or wiring in the proximity of the antenna. With the switch "on" and meter in series with the negative lead, run L2's slug clockwise until it is at the bottom of the form. If your oscillator was running when you started, the meter reading should have read approximately 120 M.A. If not, bottom the slug and back it out slowly until the meter reading peaks.

Due to varying components values in the oscillator circuit some pruning of L2 may be necessary. The oscillator circuit, unlike most, has no critical setting and will operate over a broad range of adjustments. It packs a "wallop" by itself and would make a good RF section for a single channel transmitter. When your oscillator tuning is complete, L2's slug should be about halfway into the windings. If it is sticking out the back of the form, when you're through tuning, remove a turn from L2's primary and try it again – remove enough turns (one at a time) until it peaks with the slug halfway as described. If the slug is completely inside the winding when you're through tuning, add a turn, or turns, to the primary until the slug is halfway as described.

Turn the switch "off" and remove the external meter. Make a field strength meter with it as follows: Wrap the leads of a germanium diode (1N34 is a good one) around the meter plugs and plug them into the meter. Extend the leads upward and connect them to the chandelier or tape them to the wall about 2-3 feet from the transmitter. Keep the leads separated by a few inches. Place the meter on its lowest voltage range.

Connect the batteries to the center terminals of the switch directly or with a plug and place them in their assigned mounting place. If you are using a 1 M.A. meter set R7 for maximum meter deflection. If you are using a more sensitive meter set it in the middle. Turn the switch on and grasp the transmitter firmly. With an insulated tool adjust the variable capacitor (C8) for maximum voltage on the field strength meter. If the F.S. meter reads backwards, reverse the diode or the leads.

Actually all this could have been done with the meter on the front of the case but this method proves out the "radiated" power and should be used for the initial tuneup.

Now get your favorite transmitter, or borrow one, and run a comparative test to further insure your Digitrio's radiated power. Unless you have one of the "King Kong" type presently splattering their way around the flying sites you should find that the RCM Digitrio has the edge. You will also note that the meter jumps around as you grasp the case then remove your hands. This is normal with the antenna system used – your body actually being part of the system. That's also why it is important to tune it up while grasping the case firmly.

Assemble the case and note the panel meter reading with the antenna fully extended while holding the case as you would while flying. This reading will be your reference to indicate proper output from this point on. If you are using a 1 M.A. meter and have set R7 for maximum meter deflection you should read in the upper 1/3 of the scale. Adjust R7 for your reference reading. Adjustment of R7 may affect tuning slightly so if you move it very far touch-up C8. Any major deviation of the meter from now on, either **up** or **down,** will indicate trouble somewhere in the transmitter. Since the antenna has been tuned with you grasping it, it will detune slightly when you set it down. For the following tests be sure you hold at least one hand on the case.

To demonstrate that the antenna is truly resonant place your hand about 6" from one of the bottom sections (below the loading coil) and slowly move it toward the antenna without actually touching it. You should note very little change on the F.S. meter. Do the same thing to one of the top sections (above the loading coil). The effect will be much more pronounced, indicating that your hand capacity is detuning the antenna.

Another test is to retract one of the lower sections of the antenna. This will not have much affect on the F.S. meter reading. Now retract one of the upper sections and you will see what happens if you neglect to extend the antenna fully – especially the section immediately above the loading coil.

Remember this last test, it might save your airplane. Why does the top section (above the loading coil) have more effect on the F.S. meter than the bottom section? An unloaded ¼ wave vertical at the frequencies we use would be about nine feet long. The antenna is loaded to this electrical length to make it resonant while being shorter. Since the bottom sections are only about two feet long we have electrically concentrated seven feet of antenna from the bottom of the loading coil to the tip of the antenna, or, roughly ¾ of the electrical length. This, plus the fact that the impedance rises from feed point to tip, makes the top section much more sensitive to length and body capacity. Prove this to yourself by running the checks we did previously over again. I'll let you take it from there.

From now on tuning can be accomplished with the panel meter – peak it up by adjusting C8. We'll cover final system tuneup in the last article of this series, at which time we'll adjust R29 and R13. For now, set R13 at center resistance. If you have a scope or access to one, you can check the coder against the waveform drawing. If you encounter any trouble tuning up the transmitter, consult your now ex-"technician-type" pal.

Errata

The following corrections should be made to Part II of the RCM Digitrio, which appeared in the September 1965 issue:

1. Figure 2: B should be the second waveform from the top on page 23 – not the third.
2. Schematic, Page 27: the wire from the bottom half of the on-off switch should be shown going to point Y.
3. Schematic, Page 27: The wire connecting J1 and J2 should be labeled *black*.

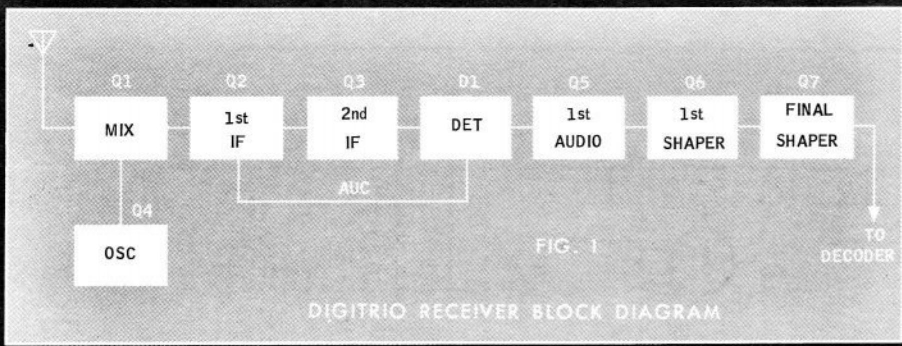
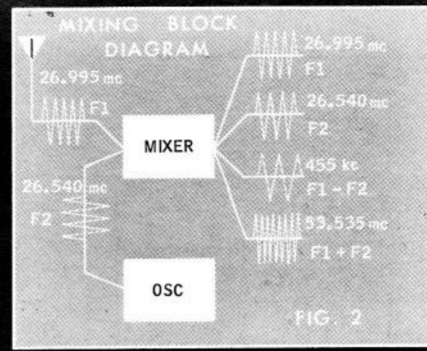


FIG. 1

DIGITRIO RECEIVER BLOCK DIAGRAM



MIXING BLOCK DIAGRAM

FIG. 2

Part IV: Constructing the Digitrio Receiver

PREFACE

JUDGING from the overwhelming amount of mail and phone calls we have received from virtually every corner of the United States, as well as overseas, we can safely assume that there are well in excess of a thousand RCM Digitrio's presently under construction. Many of our readers have asked for advance construction details, as well as information as to who is kitting the system. Unfortunately, this widespread enthusiasm is the very reason why we cannot meet these reader demands for advance material. In the way of explanation, since the reader response is so great, all of my own available time is being spent re-writing the articles around new packaging, making the articles themselves more complete, and adding artwork to assist you in construction. And, since reproduction of the system itself is of paramount consideration, Don and Chuck are each building new systems around these changes in order to check the validity of the articles prior to publication. This, plus constant proofreading of the manuscript and artwork, has placed the RCM staff on a very tight schedule. I hope that you technicians can appreciate this thoroughness and realize the benefits to the less experienced constructor.

The original system was built entirely with diverted "grocery money," and lacked the advantages of extended research and development that only money can buy. Electronically, very few changes were necessary since the original prototype performed to perfection. I sent it to Don Dewey for evaluation as a prelude to a possible construction series. Based upon Don's evaluation, and subsequent acceptance, I decided to repackage the system more attractively. Don not only accepted the articles, but agreed to help defray the repackaging expenses. So, back to the drawing board I went, this time with the assurance that what I could put on paper mechanically, Chuck Waas (Don's untiring workhorse), could build!

As you can see, the entire project was snowballing. However, with all the assurance and help received to this point, one thing still "bugged" me. Servos! Where was I going to find a suitable servo-mechanism that would not only meet the system requirements, but overcome the horrifying thought of having to scratch-build these units? Just about this time in the overall scheme of things, Jack Port of Controlaire expressed the desire to kit the system, and offered his new proportional servo for the Digitrio. That did it, and off we went! With all systems go, the repackaged unit was completed less than six weeks.

The weekend the repackaging process was finished, I phoned Don and told him to put on the coffee, as I was coming over. (Ed.'s note: The "coming over" consisted of driving approximately 700 miles from Glendale, Arizona, to Sierra Madre, California!) I installed the equipment in a newly completed, and modified Falcon 56, built by Rusty Fried, and headed for California. After a day's work getting everything ready, we sneaked into Don's favorite flying site (after the guard went home) and put in the first test flights on the repackaged system. These were completely successful, and we were by the first hurdle.

The next day, Chuck and I visited Don Mathes and Doug "Mumbles" Spreng at Micro-Avionics, Inc. After trying unsuccessfully to dislodge any secrets about their new system, we decided to go flying. And since I had the only airplane ready to fly, I had the feeling that my system was going to be "nit-picked" to pieces. One consolation was that I couldn't think of any two individuals more qualified to do it! On the way to the flying site, Doug kept mumbling something about – "If it will fly there, it will fly anywhere!" When we arrived, the full impact of his statement was evident. The flying site looked like a tennis court with the surrounding fence lowered to five feet! It was bounded by a skeet range and pistol range (I still think I was shot at!) towering radio antennae, and vehicles with C.B. rigs constantly running up the street. I think I heard some of them talking into their mikes about some "kids" flying toy airplanes.

Doug won the toss to fly – mainly because everyone else was chicken. After a masterful flight that left Don Mathes in a prone position most of the time (he remembered the time that Doug hit himself on a low pass), Doug,

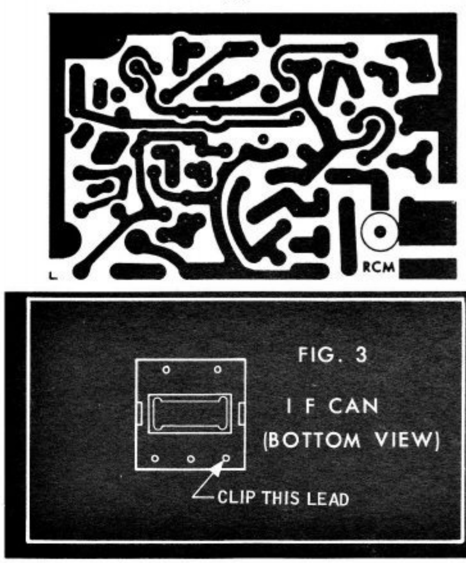


FIG. 3

I F CAN (BOTTOM VIEW)

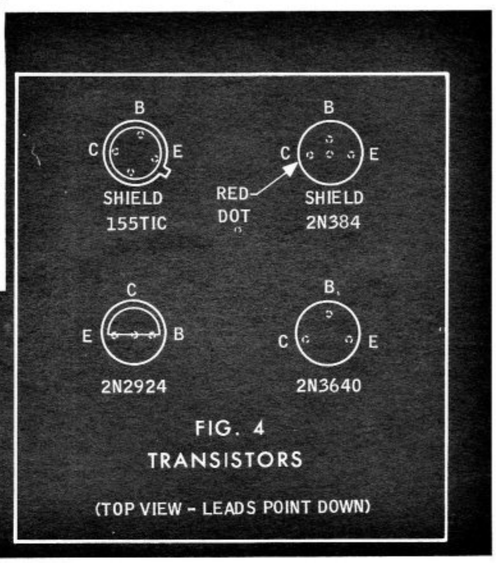
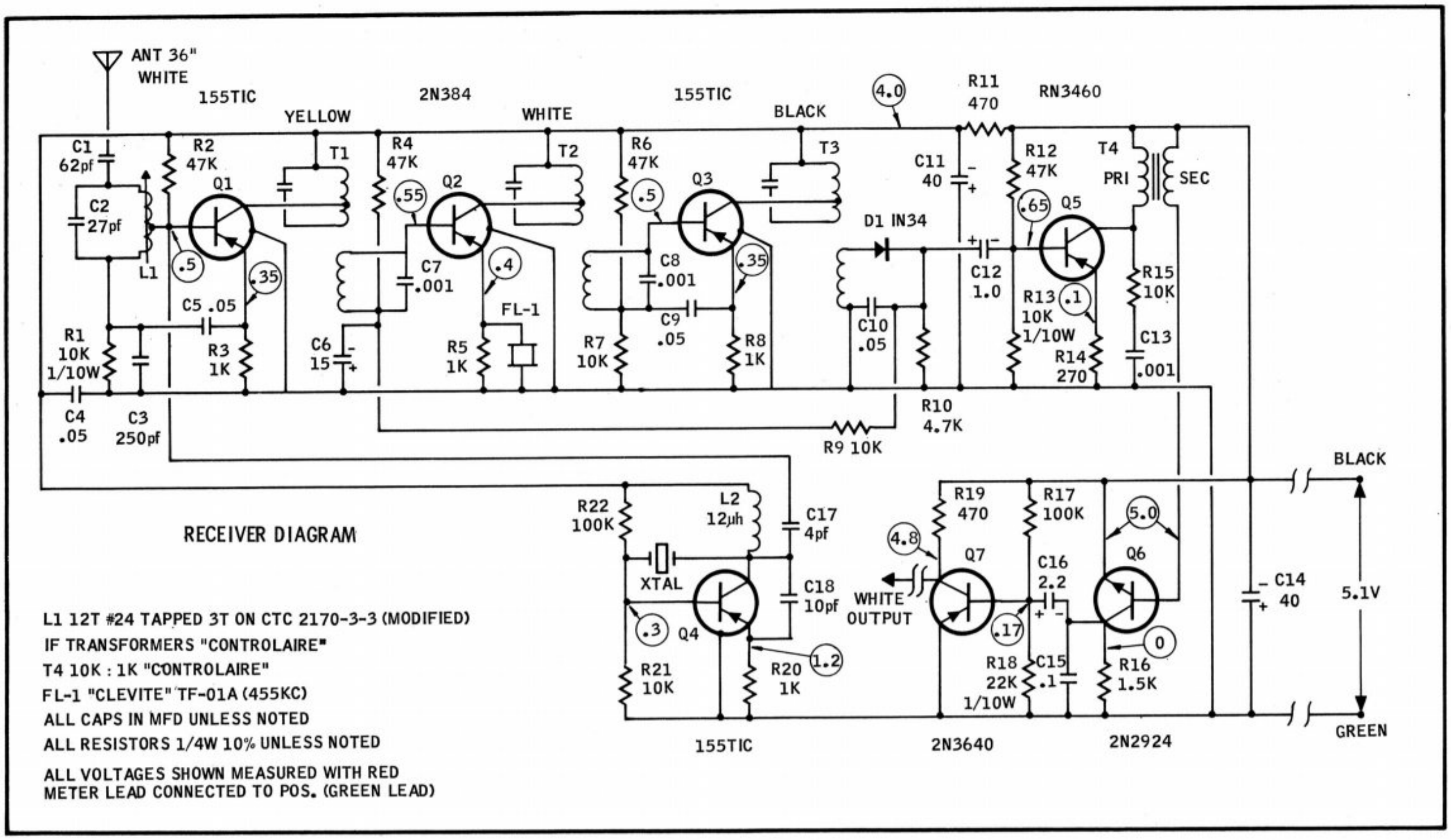


FIG. 4

TRANSISTORS

(TOP VIEW - LEADS POINT DOWN)

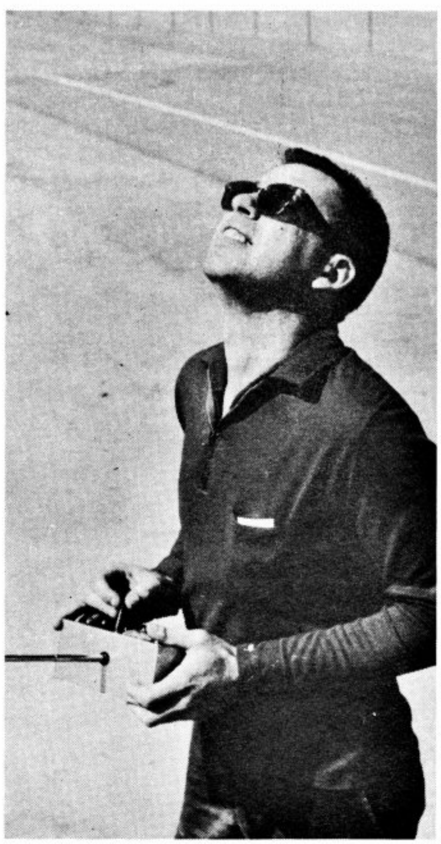


much to my surprise, began talking coherently! This was the tip-off! The Digitrio was destined to become successful. What's more, Doug continued to talk coherently for a full fifteen minutes, which I believe, is a record.

I left the plane with Don Dewey for two weeks, during which time Bill O'Brien flew it for approximately sixty flights without mishap. This included passing the transmitter around to all interested bystanders to try. Upon return of the system, I added another 125 flights without any form of problem or mishap.

And that's the Digitrio, as it stands today. I hope you will be patient until the conclusion of the series, and understand our reasons for having to decline to furnish advance information. We're doing our best, and feel that this additional effort on the part of many individuals will provide you with a proportional system that will render many years of reliable service.

For the advanced technicians, the scope pictures accompanying this article were sent in by Dave Holmes of Grafton, Virginia. Dave's Digitrio transmitter is operating on 6 meters, and he passed on the following information for the hams wanting to make this conversion:



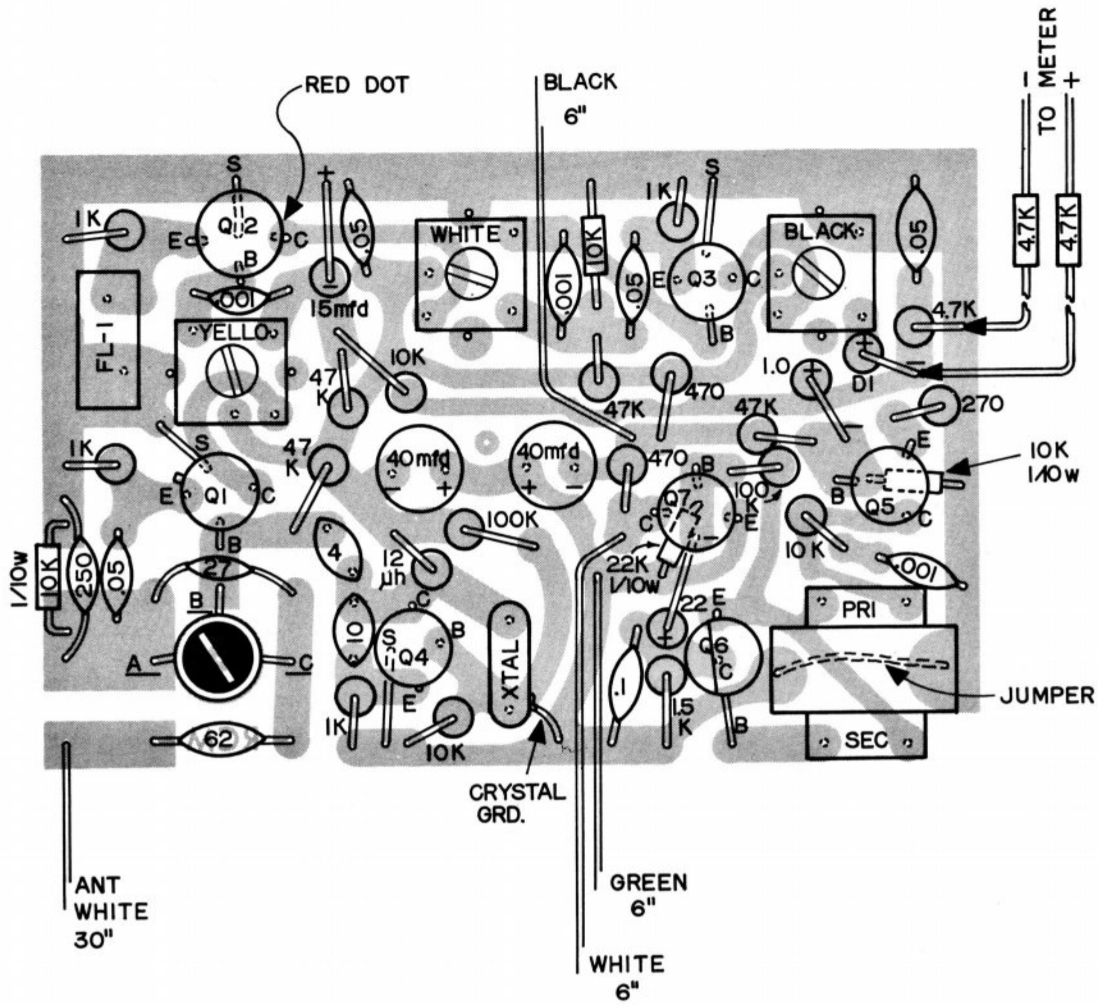
1. Pri L2 is six turns #20 on CTC 2175-4-3 ceramic form.
2. Sec L2 is 2T hook-up wire.
3. L5 is 3T #14.
4. C2 is 10 PF.
5. C6 is 39 PF.
6. C7 is 22 PF.
7. C8 is 7-45 PF.
8. L1 is 10 to 12 uh.

Dave says his transmitter puts out about ⅛ watt.

I will write a complete 50 MC conversion article for publication as soon as time permits but this information should give the more advanced technicians a starting point.

One major manufacturer is kitting the system, the only "designer approved" kit, another company is providing the system ready-to-fly, and several more are offering the printed circuit boards ready for wiring. However you decide to build it, we hope you will do just that — build it. And in so doing, increase your own enjoyment of this hobby by expanding your knowledge and abilities.

The RCM Digitrio was designed for **you.**



RCM DIGITRIO

THEORY OF RECEIVER

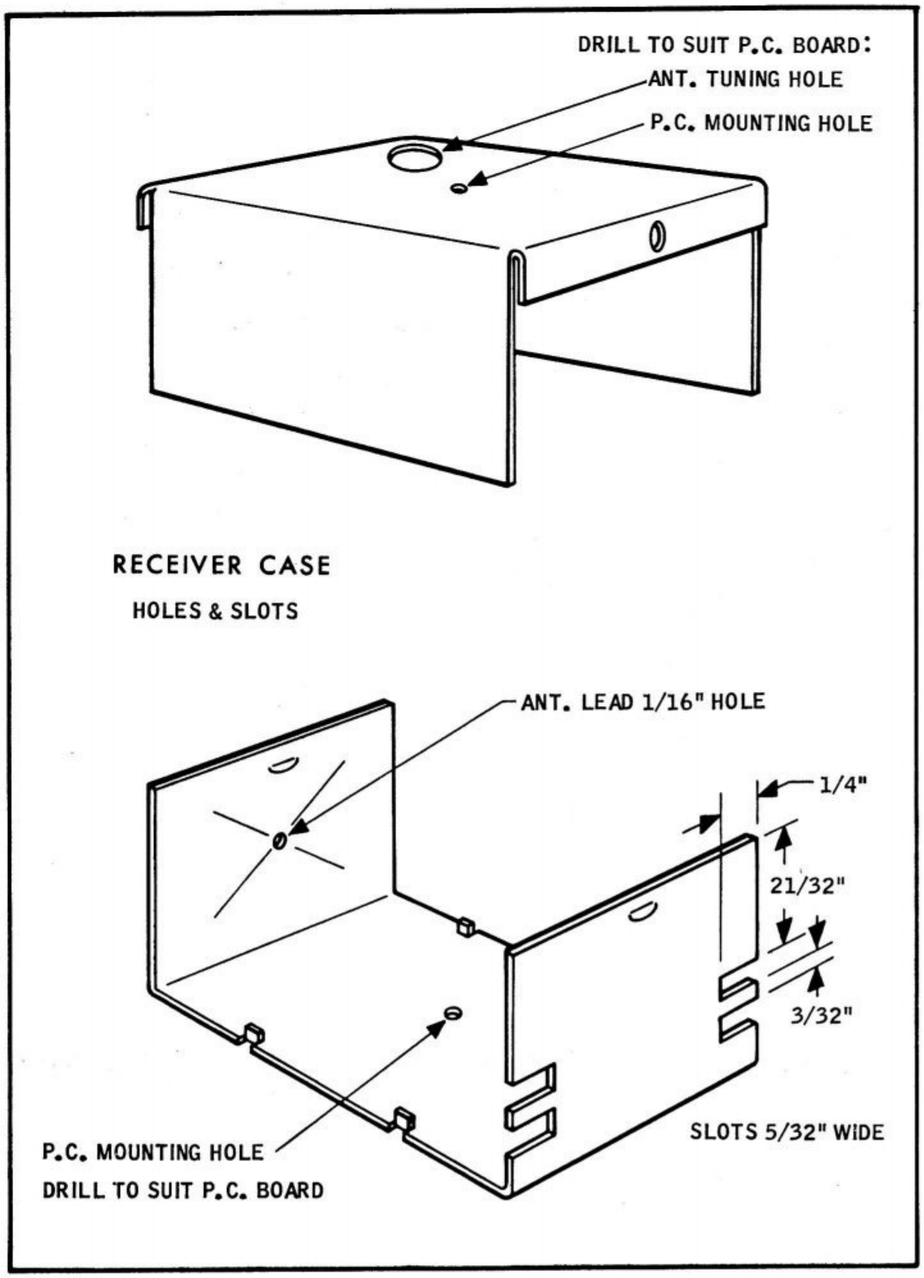
Since receivers fall into the "done to death" category I won't waste much of your time on the more elementary features of superhets. Instead of cluttering up the page with sporatic theory let's take a signal through and apply theory as we go.

Assume we are transmitting our pulse trains at 26.995 MCS, our signal is impressed on the antenna and fed to the tuned circuit (L1 and C2) through C1. This tuned circuit is tuned to 26.995 and will basically reject all others. Since our antenna is short at this frequency it presents a high impedance at the connecting point (top end of tuned circuit). This is proper since a parallel-tuned circuit at resonance presents maximum impedance. However we must transfer this signal to a relatively low impedance (base of Q1. L1 is tapped three turns from the "cold" end to effect an impedance transformation and "suck" our signal out of the tuned circuit without destroying its "selective" properties. C3 supplies the RF ground for the bottom end of the tuned circuit. C5 is connected from the "cold" end of the tuned circuit to the emitter of Q1 to complete the signal path and prevent degeneration of the signal by R3. R3 is used for temperature stabilization of the stage. R1 and R2 provide forward bias and establish the DC operating point of the stage. Let's stop there for now until we cover the oscillator.

Q4 is the oscillator and operates as a series mode crystal oscillator at 26.540 MCS. R21 and R22 provide forward bias for this stage. R20 provides temperature compensation and emitter isolation from ground. L2 is an RFC and provides collector voltage while maintaining a high impedance to RF at that point. C18 increases the collector-emitter capacitance to allow easier oscillation.

Assume we have just applied voltage to the circuit and Q4 starts conducting. This rapid conduction develops a voltage across L2. This instantaneous conduction will be a sharp rise in current rich in harmonics. At some point the multi-frequency characteristics of this sharp wave front will correspond to the series resonant frequency of the crystal. Since the crystal impedance is low at its series resonant frequency and there is a 180 degree phase shift across it, regeneration will occur. The crystal impedance rises sharply on each side of its series resonant frequency so oscillation will occur only at the series resonant frequency of the crystal. As mentioned earlier, C18 allows easier oscillation. It provides regenerative feedback to the emitter and its value is high enough to swamp the inherent collector-emitter capacitance and make oscillation relatively independent of transistor parameters. C17 couples the RF voltage to the base of Q1. The fact that we have two paths of regeneration, the circuit is fairly tolerant of transistor characteristics, and is lightly loaded, makes it a very reliable circuit. The next step is to mix the oscillator frequency with the incoming signal, and I'll try to make it as painless as possible!

To get successful mixing action we must operate Q1 in the non-linear portion of its dynamic transfer characteristic curve or drive it hard enough to exceed the linear portion of its curve. In this case, Q1 is biased in the low current portion of this curve. (Close to the non-linear knee). The oscillator drive then automatically exceeds the linear operating point, and mixing, as well as amplification, occurs. The out-



put of the mixer Q1 contains four frequencies, as follows:

1. Original signal input 26.995 MCS.
2. Oscillator input 26.540.
3. The difference between the two inputs 26.995 minus 26.540 = 455 KC.
4. The sum of the two inputs 26.995 plus 26.540 = 53.535 MCS. (See figure 2.)

T1 is tuned to 455 KC and will pass this frequency on to Q2 while rejecting the other three. This signal will be a replica of our incoming signal, differing only in frequency. The selection of 26.540 MC for our crystal should now be obvious. If your receiver oscillator is operating 455 KC below the incoming signal from the transmitter the same relationship applies, regardless of your transmitting frequency. Another way would be to use a crystal 455 KC higher than the incoming frequency (while you have your pencil handy figure it out).

T1's primary is tapped to provide proper impedance matching to Q1's collector and the primary-secondary turns ratio provides interstage impedance matching. R4, R9 and R10 provide forward bias for this first IF stage. R9 and R10 are used as the AVC voltage divider as well. C6 is used as signal ground for T1's secondary as well as an AVC filter. R5 provides temperature compensation and is bypassed at 455 KC by FL1.

FL1 is a ceramic filter that has series resonant properties at 455 KC. At this series resonant frequency it exhibits very low impedance and effectively bypasses R5. It has a pass band of four to seven percent. At frequencies outside its bandpass it presents a high impedance, and degeneration occurs. The use of FL1 increases selectivity sufficiently so as to pay for itself. C7 loads the secondary of T1 and helps minimize signal ringing. It also seems to have a resonating effect and actually increases stage gain. Our signal is amplified by this first IF stage and is coupled through T2 to the next (second IF) stage. Let's proceed with the signal and cover AVC later.

T2 is also tuned to 455 KC and the signal is further amplified by Q3. R6 and R7 provide forward bias for this stage while R8 is used for temperature compensation. C9 couples the "cold" end of T2 to the emitter to complete the signal path without degeneration. C8 is used the same as C7. T3 is again tuned to 455 KC and couples the signal to the detector diode (D1). D1 rectifies the IF signal and passes only the positive half. C10 removes the 455 KC signal component, by-passing it to ground.

So far we have processed our signal into a train of audio frequency pulses. Look again at R4, R9 and R10. These resistors establish the negative bias voltage for Q2. They also forward bias D1. The rectified positive IF signal from D1 will cause the junction of R9 and R10 to swing in a positive direction. This will in turn cause the negative bias on Q2 to decrease thereby controlling the gain of that stage. C6 is used to filter the signal excursions into a smooth DC control voltage. This AVC (automatic volume control) is necessary to prevent signal overloading of the IF stages and provide a relatively constant signal for the rest of the receiver. Since this AVC voltage varies with signal strength we can use it to peak up the receiver.

C12 couples the detected signal to Q5 (first audio). R12 and R13 provide forward bias and R14 is used for temperature stabilization. R14 is purposely not by-passed so that the stage **is** slightly degenerative. The signal is amplified and coupled to Q6 via T4. R15 and C13 are used to smooth the negative going signal transitions which otherwise would be sharp ringing pulses. Q6 has no forward bias and conducts when the signal level exceeds approximately .3 volts. This lack of bias prevents low level trash and/or electrical noise from triggering the rest of the circuits. When Q6 conducts, the voltage at the top of R16 goes negative, driving Q7 into conduction. C15 is a noise filter and is quite effective. C16 is used as a coupling capacitor between Q6 and Q7. R17 and R18 forward bias Q7. Q7 develops its signal across R19 which goes directly to the decoder. The last two stages are over-driven to shape/square the pulses. C4, C11, C14 and R11 are all used for filtering and decoupling.

I have deliberately omitted references to waveforms to minimize the confusion factor. I would suggest that you reread the foregoing again, only this time include the waveforms with the text. As you can see, all the wave forms are smooth with no "brute force" characteristics. This allows for non-critical tuneup and reliability. Also there are no ringing tendencies or any form of instability. A word of warning: **Don't** indiscriminately substitute parts values or try to improve the circuit unless you thoroughly understand all aspects of the circuits and are willing to take the consequences! Don't be led down the primrose path by those who tell you that range will be increased by reducing the value of R11. It's much more complicated than that! You might get more noise through the IF's but it could be mostly noise generated by the IF's themselves. As you follow the waveforms and block diagram (figure 1) you will note how the signal progresses through the receiver until we get to Q7's collector. This signal going to the decoder is a good replica of the signal at Q10's collector in the transmitter. These pulses will precisely follow stick movements at the transmitter. Let's get this thing built so we can continue.

MAKING THE RECEIVER CASE

The receiver case is a standard LMB #SL-MOO aluminum box. The drawing shows cutouts and holes necessary for packaging the receiver/decoder. If you intend to have the case anodized or painted use emery cloth and steel wool to polish it as described in the transmitter article.

PREPARING THE P.C. BOARD

Whether you make your board or buy it with a kit you should prepare it as follows:

( ) Make sure it fits the case. The receiver board fits into the half of the case with the lip bent up on each end. File the edges of the board until it fits properly. Make sure there is adequate clearance at the ends so the box will go together smoothly.

( ) Locate the mounting hole and drill it with the P.C. board and insulating sheet in place, conductor side down on the P.C. board. Use a drill size somewhat smaller than the mounting screw diameter so it can tap itself into the board.

( ) Find the center of the coil form hole and drill it as above with the same drill.

( ) Remove the board and enlarge the mounting hole in the case to match the diameter of the mounting screw. Enlarge the coil form hole with a #9 drill. Enlarge the coil form hole in the insulating sheet to permit tuning.

( ) Drill all holes in the P.C. board with a #60 drill if they are not already drilled.

( ) Take all components with leads/lugs larger than #60 and drill the board to fit them. The IF transformers will have to be modified as follows before fitting: stand the IF transformers on their tops so that the leads/lugs are pointing upwards. Position the transformers so that the leads are arranged as in figure 3. Clip the lower right lead off flush with the can on all three transformers.

( ) We are only going to use the top portion of the coil form and throw away the end with the lugs. Remove the tuning slug and cut the coil form 9/16″ from the top. Enlarge the coil form hole in the PC board to slightly less than required (#9 drill) and finish up with a round file for a press fit.

( ) Place a 6″ square piece of fine emery cloth on a flat surface and "sand" the copper side of the board to remove all "burrs."

( ) Clean the copper side with scouring powder until it is bright and shiny.

( ) Insert the coil form until it is flush with the opposite side of board and epoxy it into place.

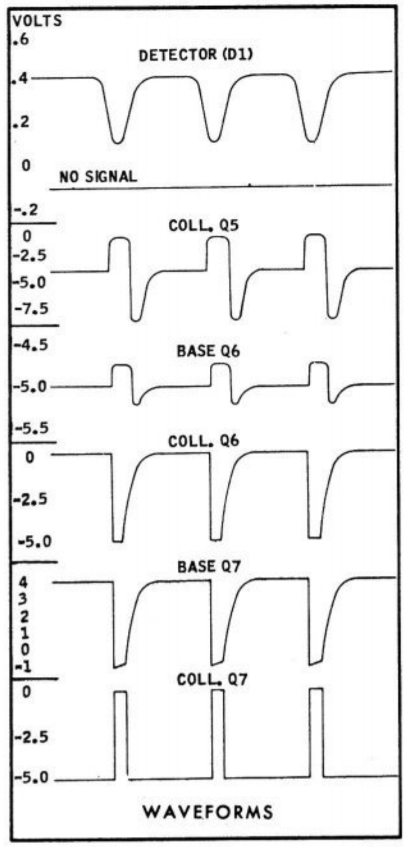
WIRING THE P.C. BOARD

Refer to construction overlay and photographs to wind turns on L1.

( ) Scrape the end of a piece of #24 enameled wire (approximately 12″ long), insert, and solder it in Hole "A". Bend the wire over flat against the P.C. board and wind three turns in a clockwise direction. Cut, scrape and insert the other end in Hole "B". Scrape one end of the remaining wire and insert it also in Hole "B" and solder. (You may have to enlarge Hole "B" slightly to accommodate both pieces of wire.) Continue winding, in a clockwise direction for nine more turns. Cut, scrape, and solder the end of the wire in Hole "C." When you are through you should have a close-wound/twelve-turn coil tapped at three turns. Inspect the coil closely for shorted turns. If you are not satisfied with the coil, either mechanically or electrically, simply rewind it. Wire is cheap, and quality at this stage of the game will pay off.

( ) Mount the three IF transformers, observing the color coding of the cores (see schematic and construction overlay.)

( ) The AF transformer will probably have a corrosion-resistant agent on the metal mounting lugs. This should be removed by filing and tinning the lugs thoroughly before mounting. The transformer frame acts as a jumper and must have a good electrical connection. An external jumper across the top of the transformer soldered directly to the P.C. board will insure a good connection. Make sure the primary and secondary are as shown on the construction overlay.



( ) Mount the crystal flush against the board. Note the wire labeled "crystal ground" on the construction overlay. When you solder this wire make sure you do not "unseal" the crystal.

( ) Solder FL-1 into place by bending the lugs over and avoid overheating.

( ) Mount the two 40 MFD. filter capacitors, observing polarity.

( ) Mount all resistors as shown on the overlay. Do not forget R1 (10K 1/10W) under the 250 PF cap (C3). Use only sufficient heat on the 1/10W resistors to insure a good connection, as they are prone to change value when overheated.

( ) Mount all disc capacitors making sure none of them "overhang" the edges of the board.

( ) Mount D1, observing polarity.

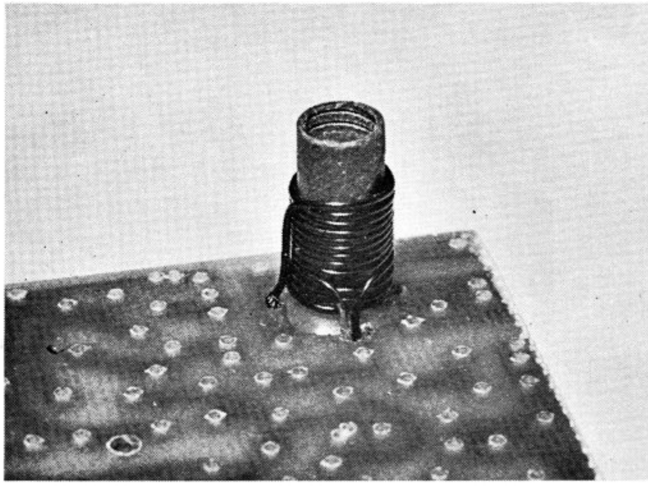
( ) Mount the remaining capacitors, observing polarity.

( ) Mount L2.

( ) Starting with Q1, install all transistors (see figure 4 for lead identification.)

( ) Install antenna and connecting wires as to length and color shown.

( ) Clip all soldered leads off to the board, and using a 1″ wide "fine" file, file the conductor side of the board until the solder mounds are "flatted" and about 1/32″ to 3/64″ high. Finish with emery cloth



This photo clearly shows the winding and placement of leads for L1. First step in assembling receiver. Coil form is epoxied to P.C. Board — we used Hobbypoxy Glue.

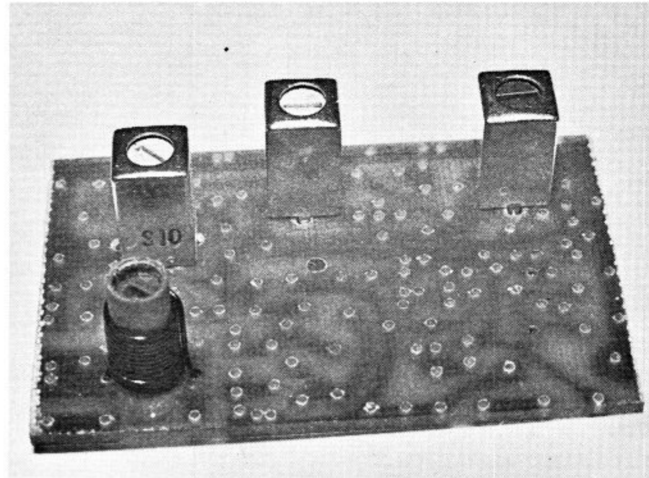
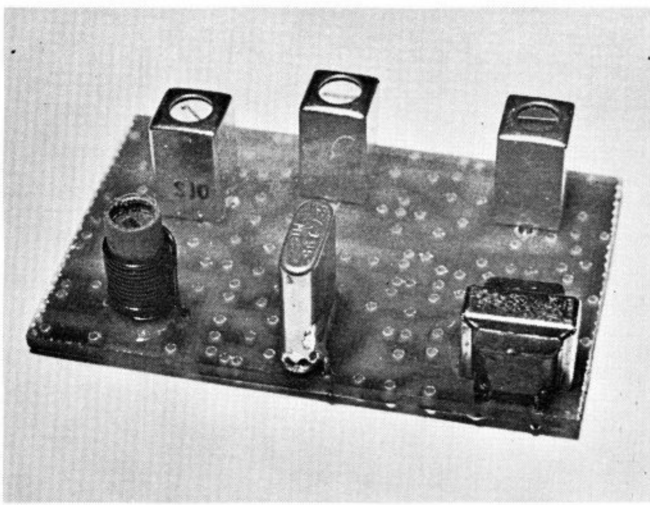


Photo showing installation of T1, T2, T3, World Engines 455 KC IF Transformers. Watch color coding. Holes for mounting lugs must be enlarged for snug fit.



This view shows installation of crystal and T4, 10K:1K Audio Transformer. Note grounding wire soldered to side of crystal can. Exercise caution so as not to destroy seal on crystal.

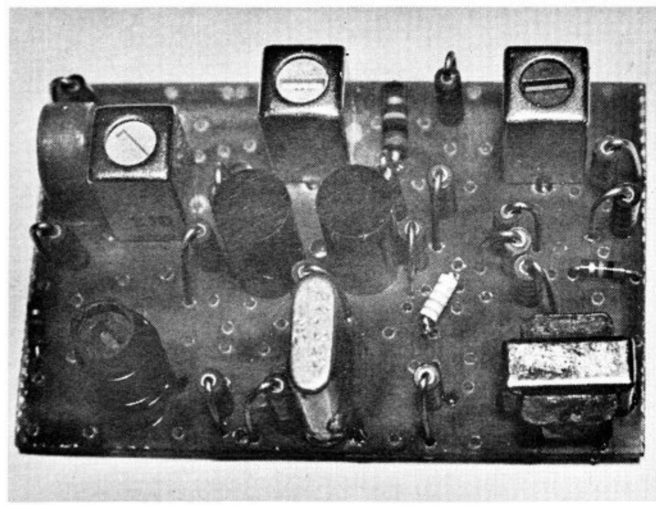
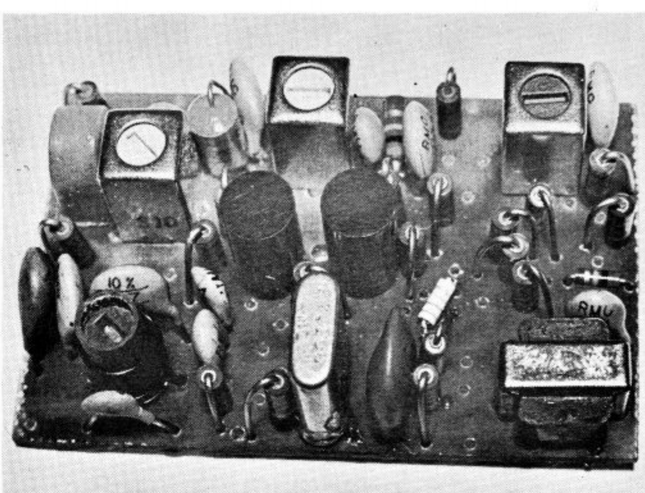
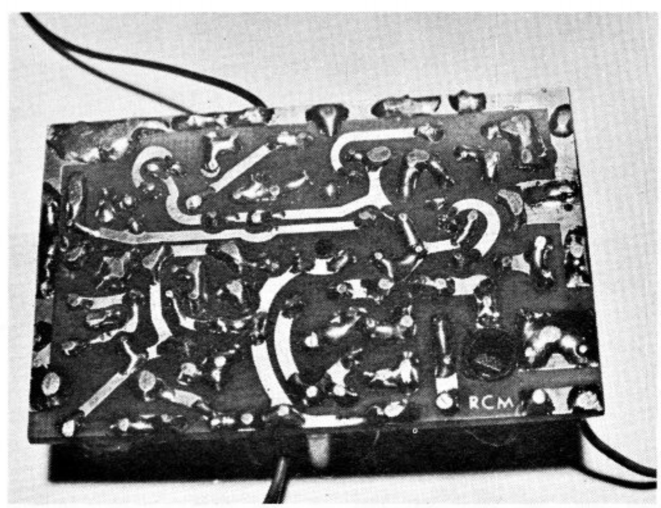


Illustration of placement of resistors R1 through R22. Note FL-1 Clevite transfilter upper left hand corner. Holes must be enlarged to accommodate leads. Be sure to observe polarity on C11 and C14, center of photo.



In this photo, all capacitors are in place, C1 through C18. Observe polarities. Observe proper polamity on C6, C12, and C16, axial lead electrolytics.



Trim all excess leads and solder points on underside of P.C. Board. Clean with dope thinner and a stiff brush. Bevel edges of board with extremely fine toothed file so that neither solder or copper leads can make contact with side of case.

on a flat surface. Visually check all connections and resolder any in question.

( ) Bevel the bottom side of the P.C. board on all sides with the same file to prevent electrical contact of the lands with the case.

( ) Clean the board of all solder resin with a stiff brush and Acetone or Dope Thinner. A toothbrush can be used here if you work fast inasmuch as Acetone will dissolve the bristles and leave a slight non-harmful residue.

PRELIMINARY CHECK OF RECEIVER

( ) Measure the resistance between the black (negative) and green (positive) wires. (Observe meter polarity.) Your meter should indicate approximately 6K ohms. If it is much less, check the board for solder bridges between lands, or improperly mounted components.

( ) If the resistance check was good we can now aply five volts (4 nicads in series). Place your meter (on milliamp scale) in series with the black lead from the receiver. The black meter lead goes to the battery pack negative and the red meter lead goes to the black receiver lead. Connect the green lead from the receiver to the positive side of the battery pack. Your meter should read approximately 4 M.A. If not, recheck the P.C. board for mistakes.

( ) Measure voltages of the different stages as shown on the schematic (voltages are encircled). They should all be within 10 to 20% depending on the meter you use. I used a 20,000 ohms per volt multimeter for all measurements. If all is well so far, and your transmitter is working, you can tune the receiver and make some range checks.

( ) Mount the receiver board in the case (don't forget the insulating sheet).

( ) Temporarily solder two 4.7 to 10K resistors at points X and Y on the overlay.

( ) Place the receiver on a non-metallic surface and extend the antenna.

( ) Place your meter on the lowest voltage range and connect the red lead to the other end of the resistor going to point Y. Connect the black meter lead to the resistor going to point X.

( ) Connect the 5V battery pack to the receiver. Black receiver lead to negative and green receiver lead to positive. The meter should read slightly negative (backwards). This is proper and no cause for alarm.

( ) Collapse the transmitter antenna, turn it on and place it about ten feet from the receiver.

( ) Adjust the IF transformer and antenna cores for maxium reading on meter (meter should be reading in the proper direction now).

( ) Increase the distance between transmitter and receiver as you tune so that final tuning results in a very low meter reading when the receiver is peaked (this prevents AVC overload and allows for sharper tuning.) You can remove the transmitter antenna for final tuning or have a friend walk down the street with the transmit-

PARTS LIST FOR RECEIVER

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURERS' NUMBER
C1	62 PF	RMC	SM-62
C2	27 "	"	SM-27
C3	250 "	CRL	DD 251
C4	.05	RMC	M12 .05 MF
C5	.05	RMC	"
C6	15 MFD. Elec. (Axial Leads)	World Engines	CL-156
C7	.001	RMC	SM .001MF
C8	.001	RMC	"
C9	.05	RMC	M12 .05 MF
C10	.05	RMC	"
C11	40 MFD. Elec. @6V (P.C. Leads)	World Engines	FPC-40-B-O
C12	1 MFD. Elec. (Axial Leads)	" "	CT-105
C13	.001	RMC	SM .001 MF
C14	40 MFD. Elec. @6V (P.C. Leads)	World Engines	FPC-40-B-O
C15	.1 MFD.	CRL	UK10-104
C16	2.2 MFD. Elec. (Axial Leads)	World Engines	CT-225
C17	4 PF	RMC	SM-4
C18	10 "	"	SM-10
D1	Germanium Diode	Ohmite	1N34
FL-1	Transfilter	Clevite	TF-01A (455 KC)
L1	12T #24 Tapped 3 Turns on C.T.C.	Form 2170-3-3 Modified.	
L2	12 uh RFC Choke	World Engines	ES755
Q1	155T1C	" "	155T1C
Q2	2N384	RCA	2N384
Q3	155T1C	World Engines	155T1C
Q4	155T1C	" "	"
Q5	2N3640	Fairchild	2N3640
Q6	2N2924	G.E.	2N2924
Q7	2N3640	Fairchild	2N3640
R1	10K 1/10W	Ohmite	LIDSM
R2	47K ¼W	"	"
R3	1K "	"	"
R4	47K "	"	"
R5	1K "	"	"
R6	47K "	"	"
R7	10K "	"	"
R8	1K "	"	"
R9	10K "	"	"
R10	4.7K "	"	"
R11	470 "	"	"
R12	47K "	"	"
R13	10K 1/10W	"	"
R14	270 ¼W	"	"
R15	10K "	"	"
R16	1.5K "	"	"
R17	100K "	"	"
R18	22K 1/10W	"	"
R19	470 ¼W	"	"
R20	1K "	"	"
R21	10K "	"	"
R22	100K "	"	"
T1	455 KC Input IF Transformer (Yellow Dot)	World Engines	— — —
T2	455 KC Interstage IF Transformer (White Dot)	" "	— — —
T3	455 KC Output IF Transformer (Black Dot)	" "	— — —
T4	10K: 1K Audio Transformer	" "	— — —
Crystal	Frequency Desired	" "	— — —
— —	Receiver Case	LMB	SL-MOO
— —	2⅛" x 1⅜" Piece of 1/64" Insulation Sheet	World Engines	— — —
— —	Sheet Metal Screw #2 or 3 x ¼"	" "	— — —
— —	P.C. Board	" "	— — —
— —	#24 Enameled Wire (24")	— — —	— — —

ter.

( ) Borrow a set of high impedance headsets from your ham friend and connect them between the white and green receiver wires. Use a .05 MFD. capacitor in series with the white lead. You should hear a "buzzing" noise when the transmitter is turned on.

( ) Borrow a yardstick from your understanding wife and tape the receiver and battery pack at one end, extend the antenna lead up the stick and secure it at the top with tape. Connect the headset, and with your buddy holding the transmitter, start walking across the "boon-docks." Your range should exceed ¼ mile on the ground. Take your tuning wand along, and when the signal gets "raggedy," peak up the antenna core. Do not adjust the IF's as they should be adjusted with the meter. Ground range will depend on terrain and system tuning. All of my systems to date were still going strong at 3/5 of a mile over a cement runway.

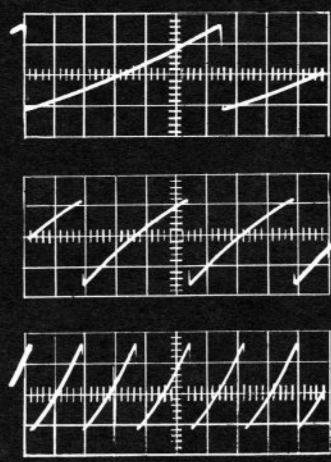
PARTS LIST FOR RECEIVER

Since size is an important factor for the receiver parts, substitution will require careful selection. Every part in the receiver should be easily obtained from your parts dealers except for the parts marked "World Engines" in the "Manufacturer or Source" column. Most parts' houses have catalogs for the different component manufacturers which they give free to buyers. Sizes are generally listed and you can cross reference parts to those they carry in stock.

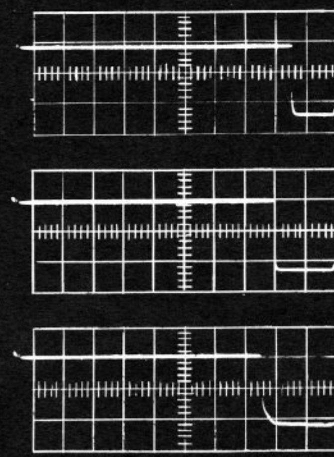
I do not recommend substitution of any parts' **values** in the receiver unless you thoroughly understand the circuitry and can analyze the circuit parameters with proper test equipment.

ERRATA TO ARTICLE II TRANSMITTER

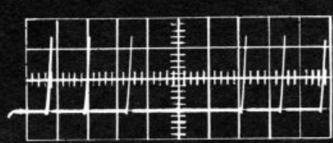
1. **Figure 2**
   a. Top waveform should be marked 6.5 MS not 6.5 us.
   b. Second waveform should be marked $\overline{B}$ not B.
   c. Third waveform should be marked B not $\overline{B}$.
2. **Schematic**
   a. R5 should be 330 not 300.
   b. Wire pointing downward from bottom half of off-on switch should be marked "Y."
   c. Wire connecting J1 and J2 should be marked "black."
3. **Construction Overlay**
   The .05 capacitor below L3 and L4 is not shown on schematic or listed in parts list. Draw it in on schematic in parallel with C23 and list it as C25 in parts list. It is a Centralab type UK20-503.



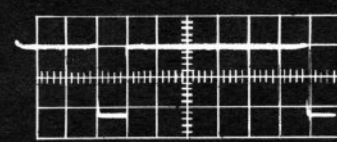
Output of pulse generator taken at point A showing effect of varying R23 and R30.



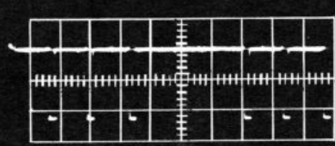
Collector of Q6-500 us/div. 2 volts/div. showing effect of stick movement.



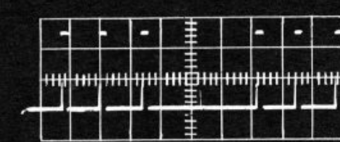
Base of Q10 1ms/div. 2 volts/div.



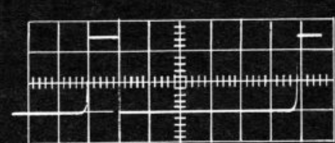
Collector of Q10. 200 us/div 2 volts/div.



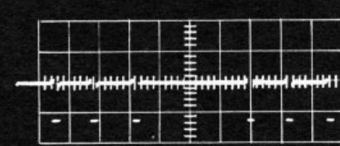
Collector of Q10. 1ms/div. 2 volts/div.



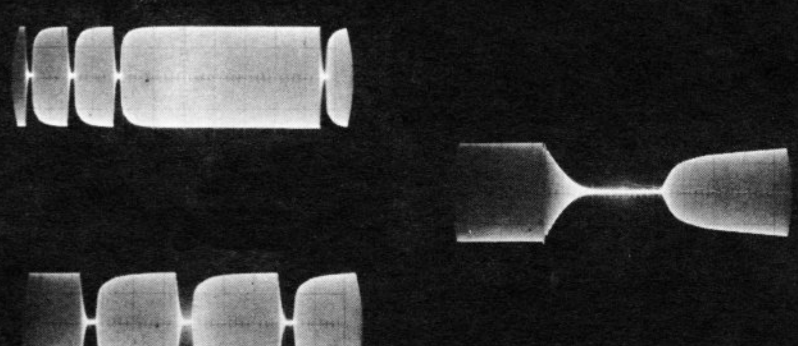
Collector of Q11. 1ms/div. 2 volts/div.



Collector of Q11. 200 us/div. 2 volts/div.

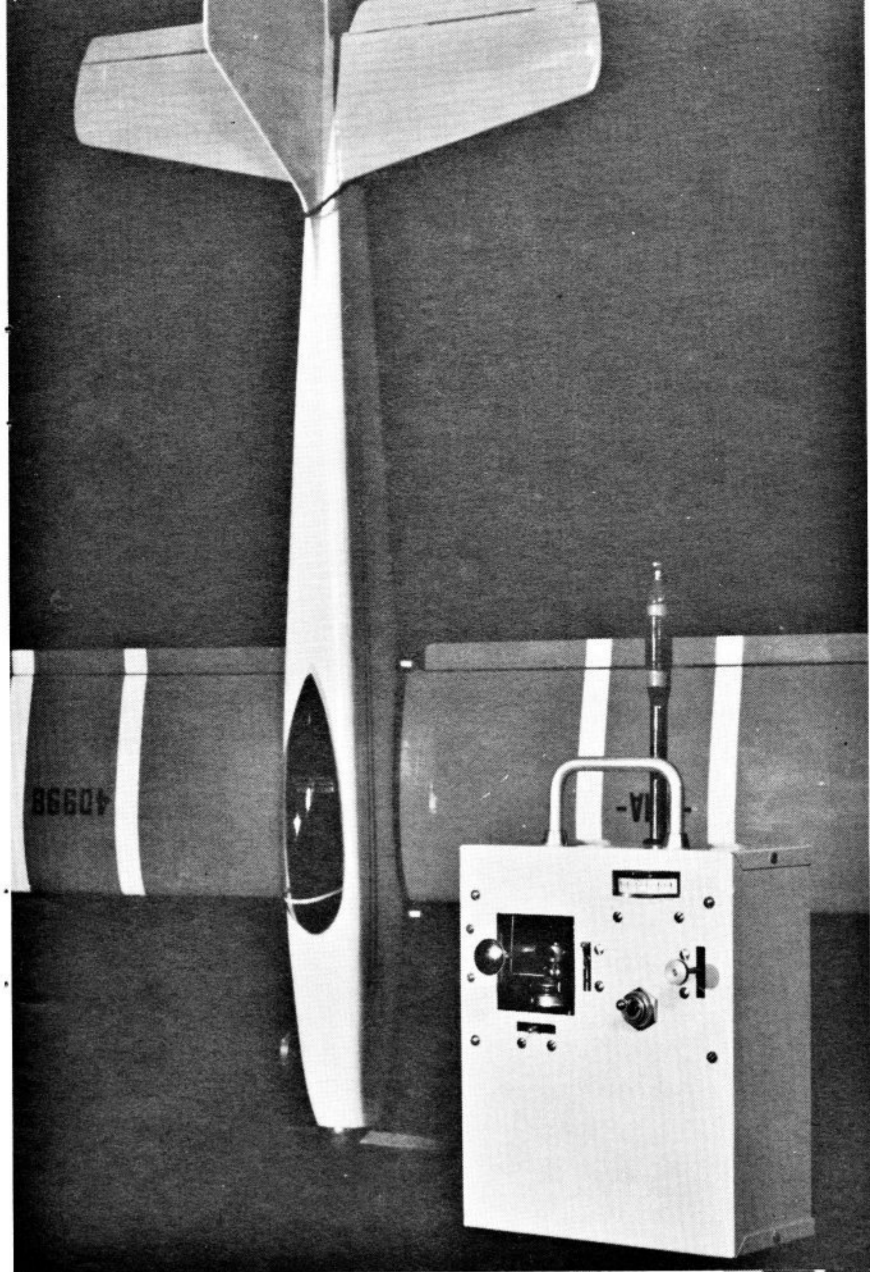


Base of Q11. 1ms/div. .5 volts/div.



RF output at various settings of time base.

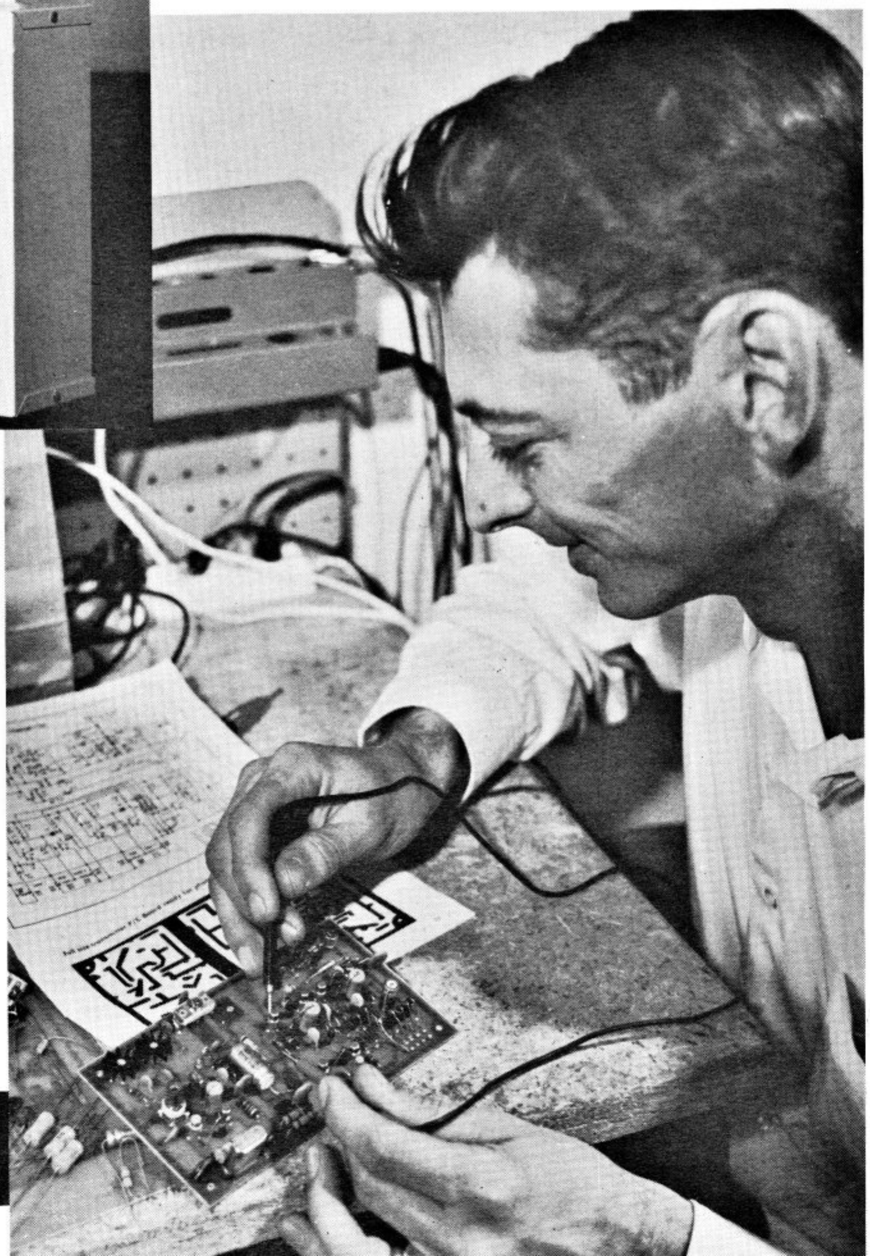
COMING NEXT MONTH: PART V OF THE RCM DIGITRIO CONSTRUCTING THE DECODER

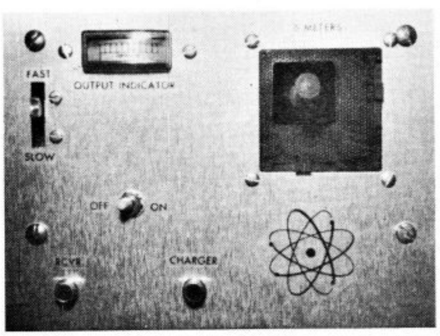


RCM DIGITRIO

Part V: Constructing the Decoder

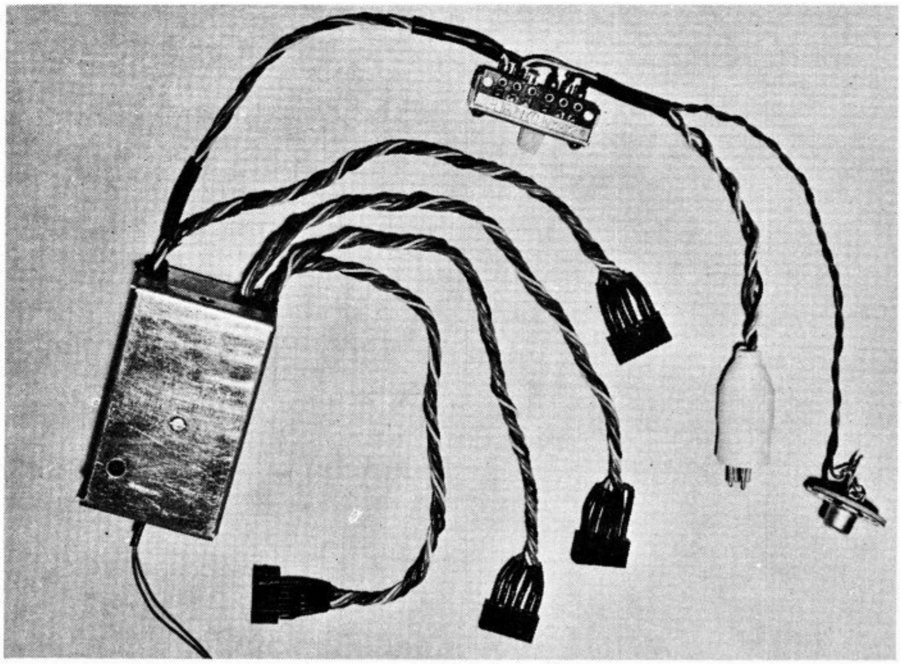
ED THOMPSON
RCM Contributing Technical Editor

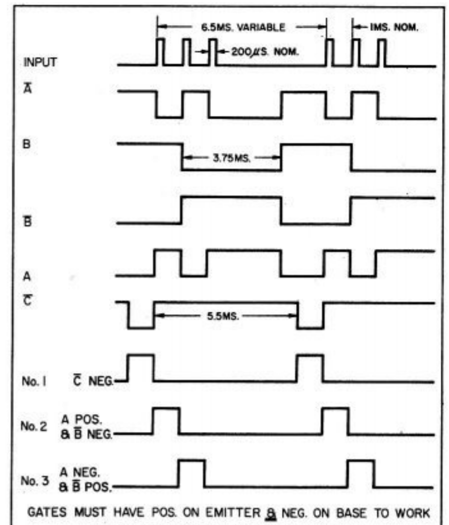




Top: Bryce Petersen's Digitrio modified for left hand operation. RCM "Patriot" in background. Above: Digitrio with Bonner stick assembly. Xmtr is on 53 Mcs. Both modifications will appear in a future article. Right: Slim Snelling working on his Digitrio transmitter board.

An RCM Technical Feature





DIGITRIO DECODER WAVEFORMS

The completed receiver and decoder with switch, battery connector, charging jack, and four servo connectors in place.

Preface

I RECENTLY had the opportunity to spend a couple of days at World Engines so that Jack Port could evaluate the Digitrio and I could get a first hand look at their operation. Jack Port, John Maloney and myself spent the better part of one day at the local flying site. We flew both the Digitrio and the Controlaire 5 Proportional System. After John scrounged up some fuel, a glo-plug, battery, etc., from the local flyers we got in some good flights, having installed the Digitrio in a C.G. Falcon "56" with an O.S. Max 35 up front. To sum up, I had an enjoyable visit in Cincinnati and met some very nice people, capping it all off with a steak dinner, courtesy of World Engines. I would like to express my thanks to Jack and John for their hospitality.

Dave Holmes, who sent the scope pictures of the transmitter waveforms, came through with the receiver scope pictures in this article – his unit being on 50 MC. Dave changed C2 to 18 PF, L1 to 7T tapped at 1 turn, L2 to 4 uh and inserted a 6 meter crystal. To date, all works well. Bernie Murphy is also building a Digitrio and said he will include his comments in a future kits and pieces column.

I asked Don recently if any electronic projects had come in for the design contest that I could evaluate for him. I was disappointed to hear that not many had been submitted to date. I know there are a lot of good ideas around and hope that some of you experimenters will pass on your goodies to the rest of us.

Here are a few questions based on letters I have received about the Digitrio and my answers:

Q. Can a commercial stick be used with digitrio?

A. *Yes. In fact, there are some already built using the Bonner stick assembly. I am building one on 6 meters with a Bonner stick and will present it at a later date.*

Q. You mention that World Engines is kitting the system but fail to mention when or what the price will be?

A. *It is not the purpose of this series to advertise any commercial items. See the World Engines advertisements or write to them directly for information. The kits will be released concurrently with each article and prices will be announced by World Engines.*

Q. Are you going to design circuitry for other makes of servos, four channel operation, 3+1, commercial stick installation, 6 meter conversion, etc.?

A. *If I don't get writers cramp first, I'll write about anything you want. I'll present the articles in the order of most letters received.*

Q. Can I obtain advance information in order to complete my system?

A. *This has been covered before and the answer is no, due to the pressure of time.*

Q. Will a designer-approved kit be produced in the United Kingdom?

A. *I don't know. I have received letters from manufacturers in the U.K., but don't yet know their intentions. I have not as yet approved any foreign kits. Exportations will export to foreign dealers and I suggest that overseas readers see their local World Engines dealers.*

Q. I would like to build a Digitrio but only in a four channel version, when will this information be available?

A. *As stated previously, what I write is based on reader response and this is one of the least requested items to date.*

Q. Will I have to purchase commercial servos and modify them for Digitrio? If so, I don't see how I can build the system for $200.00.

A. *No. The servos will be built up like the rest of the system using only World Engines' mechanical servo parts. It is possible that World Engines will offer the servo built up for the Digitrio, however at a higher price.*

Q. Since you have me interested in the Digitrio can you recommend a good book on transistors?

A. *Yes. I think the Department of the Army T.M. 11-690 is an excellent book. It can be purchased for $1.25 from Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.*

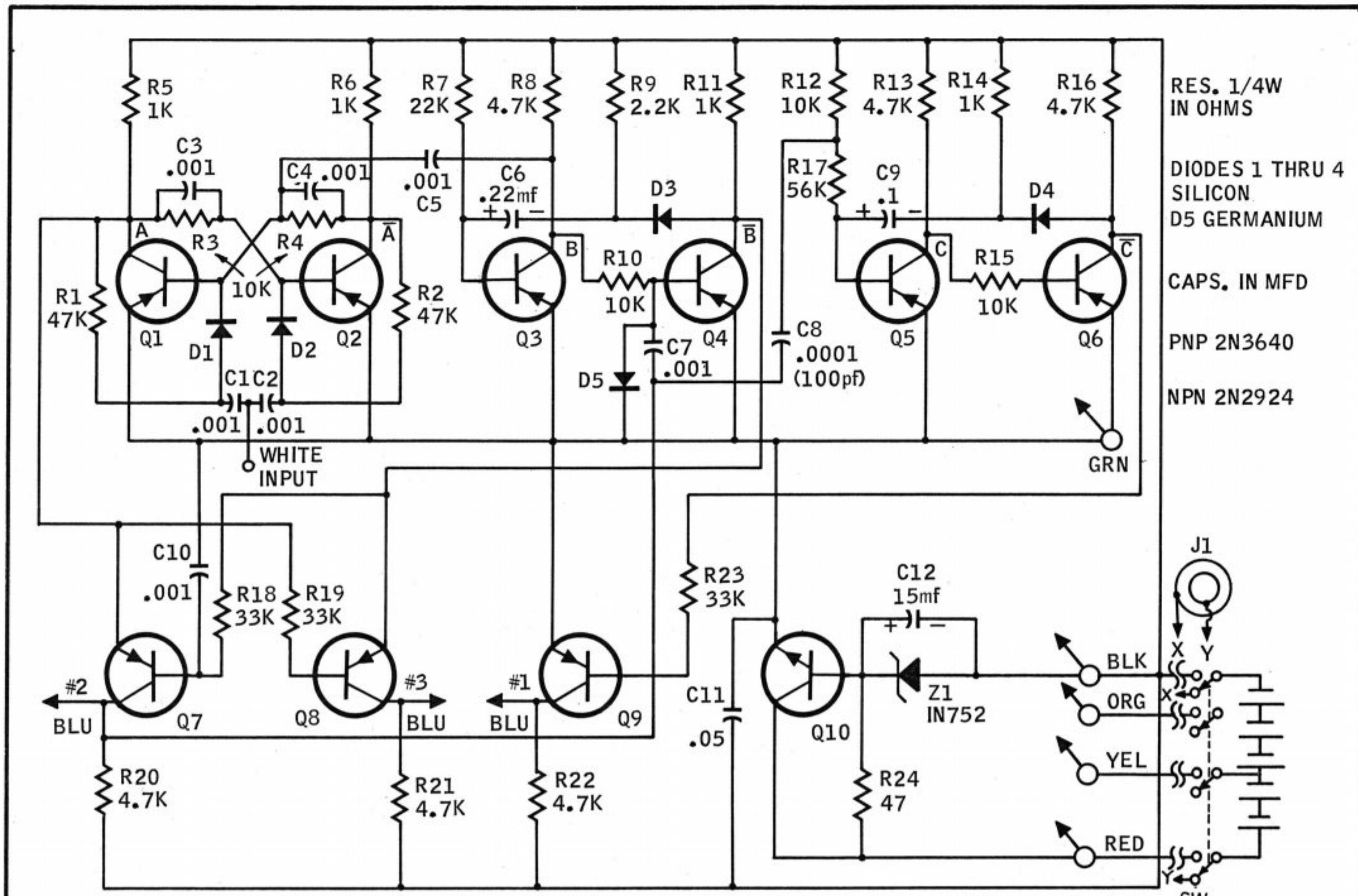
Q. I missed the first two issues of your Digitrio article and hope you can help me obtain them.

A. *Try writing to the RCM Circulation Department, P. O. Box 1128, Laguna Beach, California, for any back copies.*

THEORY OF DECODER

Most of the circuits in the decoder were covered briefly in the first article. One flip flop, two one shots, and two gates (Q9 is merely an amplifier) are used to count/sort the pulse trains into separate channels. Constant reference to the decoder waveforms will be necessary to grasp its operation.

The input to the decoder is a replica of the transmitted signal. Q1 and Q2 (flip flop) are triggered by the leading edge of each pulse. This produces square waves at both collectors (Point A and A). The width of these pulses are determined by the width **between** the leading edges of the pulses in the incoming pulse train. Since Q1 and Q2 cannot be in the same state at the same



SCHEMATIC - DIGITRIO DECODER

time A and A will be inverted replicas of each other.

Q3 and Q4 (B and B) form a one shot that is used to reset the flip flop during the sync pause. It also assists the flip flop sort Channels 2 and 3.

Q5 and Q6 (C and C) form another one shot that is used to measure the time between the #1 pulses in the pulse train. The time between #1 pulses is compared with the timing of this one shot to produce the motor control pulse.

Q7 and Q8 are the output gates for Pulses 2 and 3 respectively. Q9 is the motion control output transistor. Q10 in conjunction with Z1 provide regulated voltage for all the timing circuits including the reference generators in the servos. It also provides regulated voltage for the receiver. J1 is wired to the off side of the switch and is used as the charging jack.

Let's start with the action of the flip flop (Q1 and Q2) and first one shot (Q3 and Q4). Assume that Q2 and Q3 are conducting, Q1 and Q4 are cutoff and we are waiting for the first pulse. This places a negative voltage on the emitter of Q7 and base of Q8 (from collector of Q1). There is also a negative voltage on the base of Q7 and base of Q8 (from collector of Q4), under these conditions neither Q7 or Q8 is forward-biased so they're not conducting.

When the first pulse arrives it changes the state of the flip flop. The collector of Q1 goes to ground and Q2 goes negative. This places the emitter of Q7 and base of Q8 at ground potential. Since the first one shot didn't change state we now have Q7 forward-biased with Q8 still cut off. **The circuit will remain in this condition until the second pulse arrives.** The latter changes the state of the flip flop again and Q1 goes negative while Q2 goes to ground. So we're back where we started (at least for a pico second)! Q7 cuts off because we remove its emitter ground at Q1's collector when Q1 goes negative.

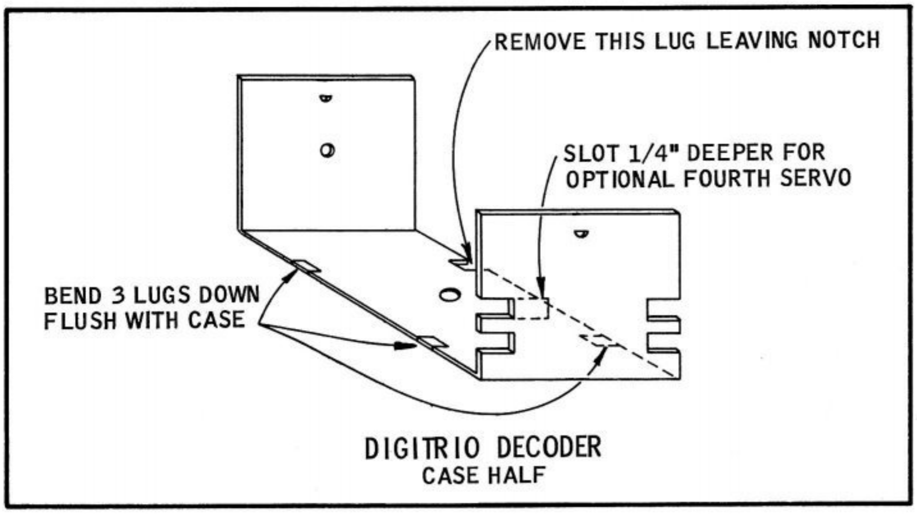
Let's review quickly: The first pulse caused Q7 to conduct and the second pulse cut it off again. So we have a positive square pulse at Q7's collector. The pulse width is determined by the distance between Pulses 1 and 2. Since we vary this distance at the transmitter by moving the stick we can also vary the width of the pulse at Q7's collector.

When Q7 cuts off (collector going negative) a negative-going pulse is impressed on the base of Q4 via C7 causing this one shot to change state and start timing. B goes negative and B goes to ground. This places a ground on Q7's base (it stays cut off) and a ground on Q8's emitter (it's base is negative from Q1's collector) so Q8 conducts. It will remain conducting until Pulse 3 arrives.

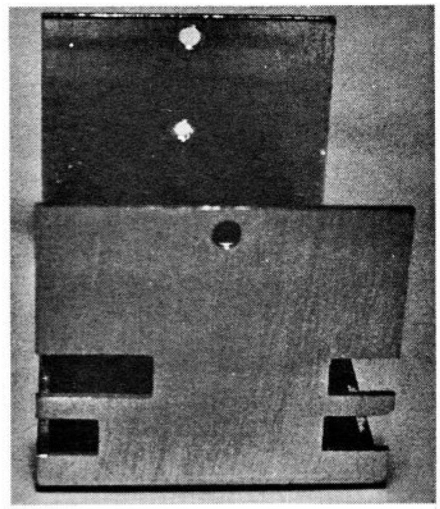
When Pulse 3 arrives it changes the state of the flip flop again and Q8 cuts off because Q1's collector places a ground on Q8's base. We also place a ground on Q7's emitter but Q4 is still holding Q7's base at ground so neither Q7 or Q8 is conducting.

After 3.75 MS has lapsed the one shot will return to its quiescent state (Q3 conducting – Q4 cut off). When it changes state Q3 going to ground transfers a positive pulse via C5 to Q1's base changing the flip flop's state at the same time. This resets the decoder (Q2 and Q3 conducting – Q1, Q4, Q7 and Q8 cut off) and it is now waiting for another pulse train. Therefore the second pulse not only turns off Q7 but turns on Q8. The width of the pulse at Q8's collector then is the width between the second and third incoming pulses and width is determined by stick movement at the transmitter. The uninterrupted carrier between pulse trains is the "sync pause." During this sync pause the first one shot returns to its quiescent state resetting the circuit.

As you can see we intentionally skipped the #1 output pulse. This is how it works. As stated before, the #1 incoming pulse causes Q7 to conduct (collector goes positive). This transfers a positive trigger pulse to the junction of R12 and R17 via C8. This triggers the second one shot which begins timing. Q (C) conducts placing ground on Q9's base cutting it off. Approximately 5.5 MS later this one shot returns to its quiescent state with Q6 go-



DIGITRIO DECODER
CASE HALF



ing negative. This places a negative voltage on Q9's base and it conducts. It will remain in conduction until the second one shot is triggered again when the next #1 pulse arrives. It arrives approximately 1 MS later triggering the second one shot which causes Q9 to cut off. So we have a positive pulse at the collector of Q9 whose width is determined by the interval between #1 incoming pulses and is controllable at the transmitter. Q10 is an emitter follower with its base voltage regulated at 5.6V by Z1. R24 sets the operating point of the Zener and C12 filters voltage excursions. The voltage at Q10's emitter will be this Zener voltage less the base to emitter drop of Q10. It should be approximately 4.8 – 5.1 volts depending on the tolerance of the two devices. C11 is merely a by-pass capacitor.

I recommend that you re-read the theory as many times as necessary for a complete understanding. It may help you analyze symptoms leading to malfunctions if you have to troubleshoot the circuit later on.

PREPARING THE P.C. BOARD AND CASE

( ) File slots in end of case as shown in the drawing. If you want to operate an aileron servo in parallel with the rudder servo, file one slot ¼" deeper as shown by the dotted lines. This will allow for the additional servo leads.

( ) Square and size the board with a fine file. File out the two notches as shown on drawing.

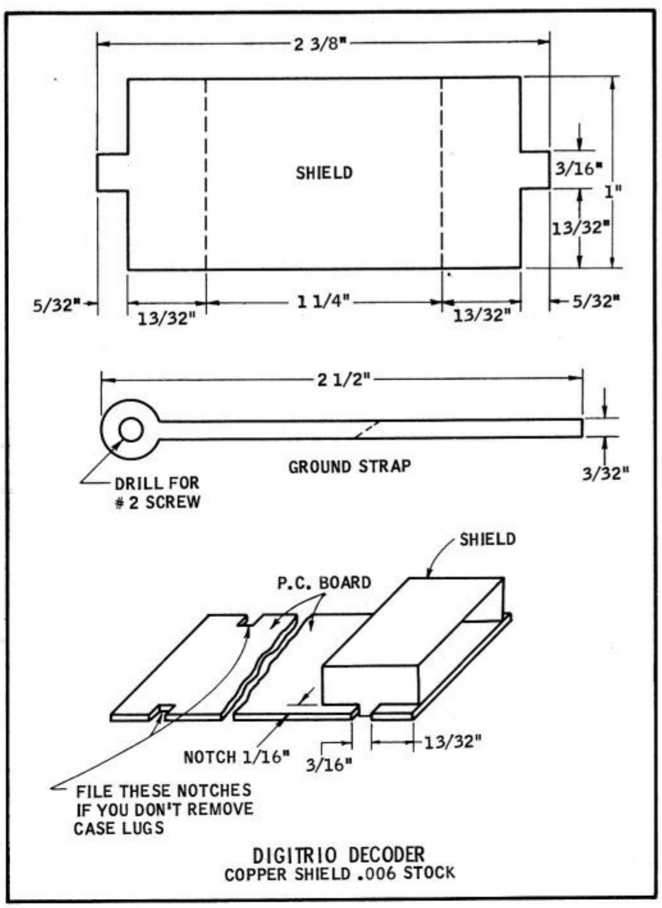
( ) Bend three of the case lugs down flush with rest of case and remove the lug shown on case drawing. If you wish you can use the other three lugs for better case rigidity by filing four notches in P.C. board.

( ) Center the insulating sheet and P.C. board, copper side down, in the case with the five large round lands at the end where you made the slots. Drill the mounting hole slightly undersize so the mounting screw can tap itself into the board.

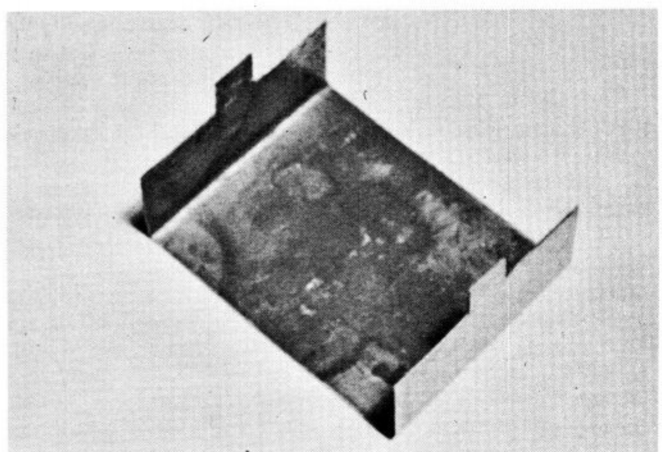
( ) Remove the P.C. board and insulating sheet and enlarge the mounting hole in the case to match the diameter of the mounting screw.

( ) Secure the insulating sheet with contact glue (do the same to receiver also).

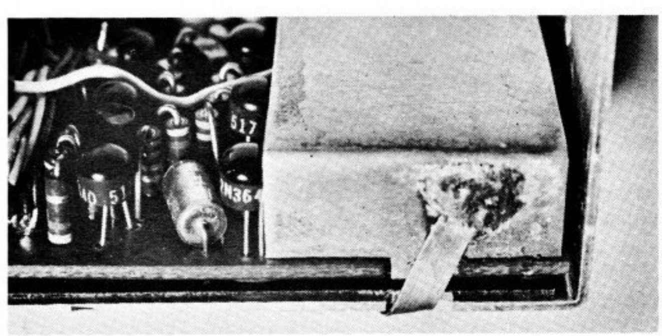
( ) Drill all holes in the P.C. board

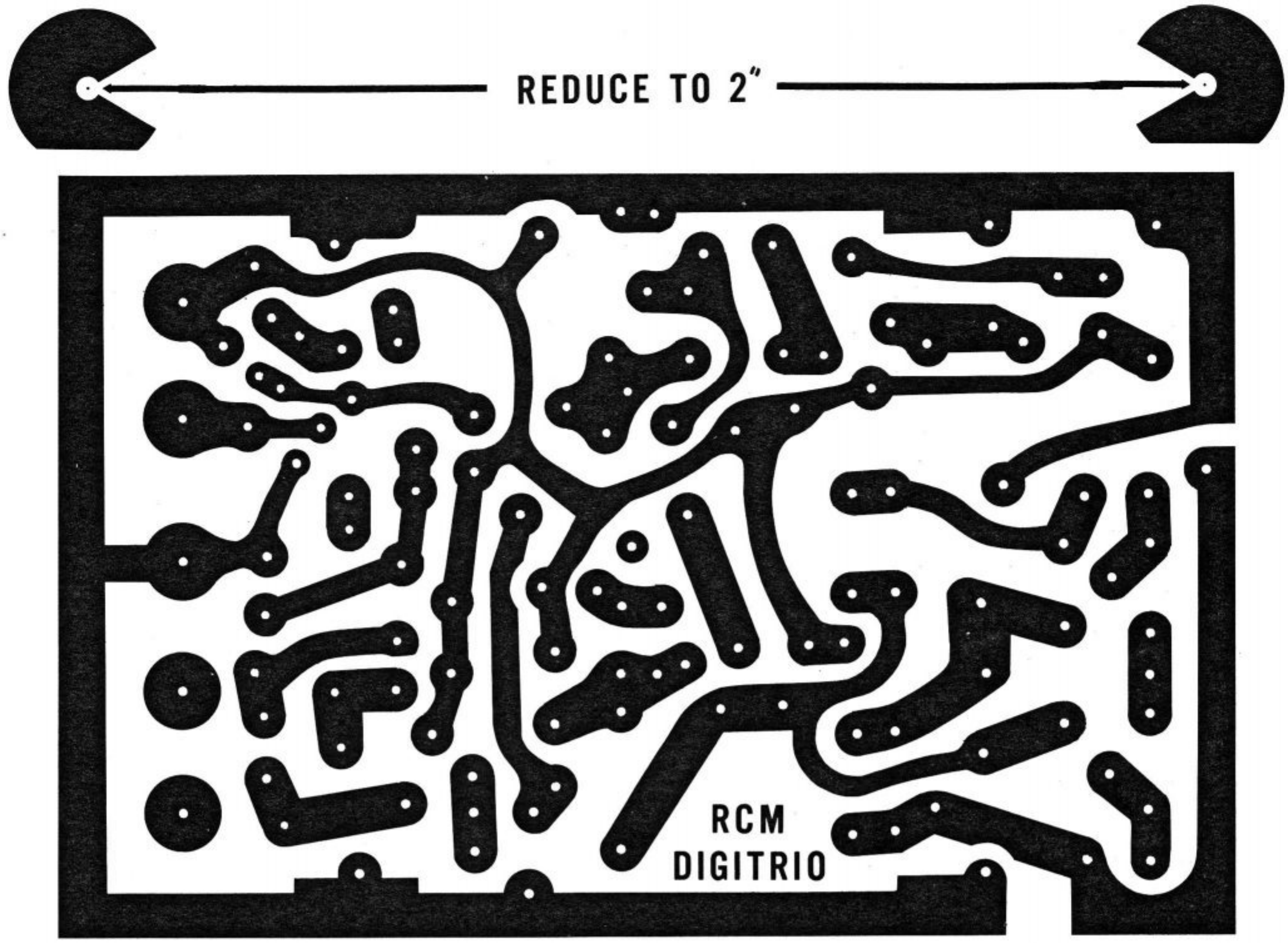


DIGITRIO DECODER
COPPER SHIELD .006 STOCK



Top photo shows completed decoder shield. Photo below shows shield and ground strap in place.





Decoder PC board shown three times full size. Actual size PC board shown at left. Either can be used for photographically reproducing the circuit board.

with a 1/32" drill except the very small lands which should be drilled a little smaller. If you don't have a smaller drill be careful or you'll tear the lands off the board.

( ) Enlarge the holes in the five large round lands at one end of the P.C. board to 1/16".

( ) Place a 6" square piece of emery cloth on a flat surface and "sand" the copper side to remove all burrs.

( ) Clean the copper side with scouring powder until it is bright and shiny.

NOTE: If board was purchased from World Engines it will be silver plated and the last two steps will not be necessary.

( ) Make the copper shield and ground lead as shown on the drawing and check for fit. Do not install this shield yet.

WIRING P.C. BOARD

( ) Install all resistors close to board.

( ) Install diodes including Z1 observing polarity. The bar should be up on all diodes.

( ) Install all disc caps.

( ) Install tantalums (two each — .22 negative up and .1 positive up) observing polarity.

( ) Install 15MFD cap observing polarity.

( ) Install transistors (make sure mounting screw will clear collector lead on Q8). Mount Q1, 2, 3, 4, 7 and 8 slightly higher than adjacent resistor leads to provide platform for copper shield to rest on.

( ) Install the copper shield as shown in drawing and check for clearance. A piece of electrical tape on the underside of shield will insure against unintentional grounding of components.

( ) "Flat" the lands to 1/32"-3/64" with a fine file, bevel the edges and clean board with acetone or dope thinner.

( ) Cut four 9" pieces of orange, yellow and green hook up wire. Cut five 9" pieces of black. Cut four 9" pieces of red. Cut three 12" pieces blue. Cut one 9" piece of white.

( ) For the three sets of servo leads take one each yellow, orange, green, red, black and blue and group them (route all blue and white wires as shown in photo). For battery leads take one each red, black, yellow, orange and group them. Group the above leads so that two sets come out of each side of the board.

NOTE: For coupled aileron rudder take an extra 9" red, blue, yellow, orange, green and black and insert them as shown by dotted lines on the construction overlay and make an extra servo group.

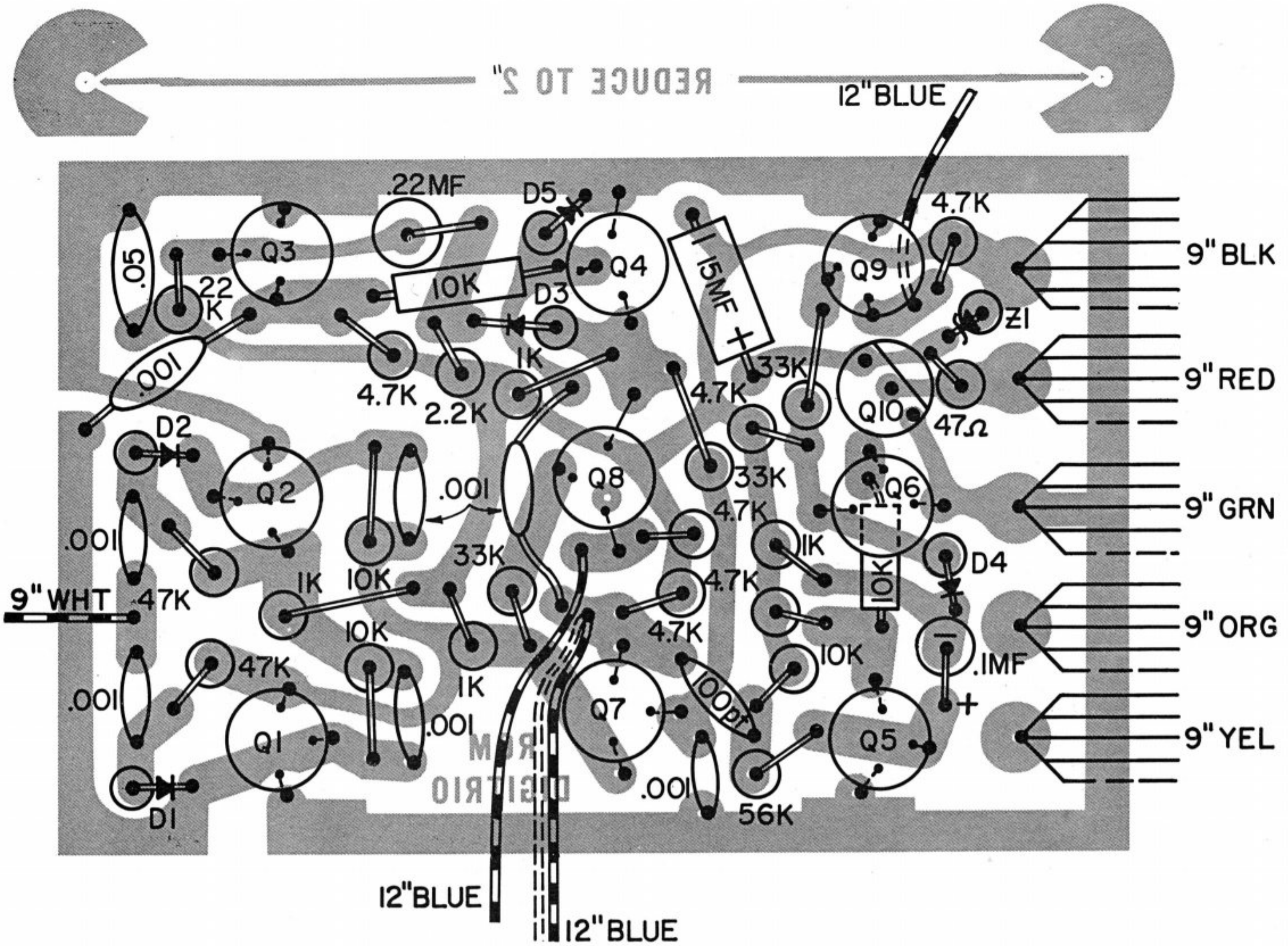
( ) Take the remaining black, green, and white wire and group them for the receiver.

( ) Place a 3/16" long piece of large Controlaire heat-shrink tubing over each set of wire as close to the board as possible.

( ) Slip a 1/4" grommet over each set of wires.

( ) Mount the decoder in the case and form the three servo and battery wires so that the grommets slide into the slots.

( ) Twist and cut the servo leads to the length desired and solder servo



connectors as shown in the drawing. Use a 1″ piece of large heat-shrink tubing to hold each group of wires at the ends and small heat-shrink tubing over each pin.

( ) Wire the switch to the battery leads using heat-shrink tubing as on the servo leads. Wire the charging jack at this time also.

( ) Cut a piece of red, orange, yellow, black wire to length desired for leads between switch and battery connector. Using heat-shrink tubing as usual, solder one end of these leads to the switch and the other to the male battery connector as shown in the drawing. Don't forget to put the connector shell over the leads first. You can wire the plug to match your reed battery pack if you match the plugs and voltages correctly.

( ) Wire five each 600 MA batteries as shown on schematic and drawing and solder female battery connector to the leads.

NOTE: The copper shield is necessary to prevent interference from the decoder which would otherwise be picked up by the mixer. The ground strap insures a good connection between the shield and case and must be used.

Substitution of parts or part values here could be hazardous unless you fully understand the circuit and can test it properly.

As you can see no adjustments (variable resistors, etc.) are used and all timing adjustments will be made at the transmitter which I'll cover in the last article.

CONNECTING RECEIVER AND DECODER

( ) Insert the decoder board into its half of the case and position the servo leads in the slots.

( ) Using the ground strap under the mounting screw secure the board in place. Run the ground strap to the notch in the case and bend it over. Solder the ground strap to the shield (see photo).

( ) Remove the black, green and white wires on the receiver board.

( ) Cut the black, green and white wires on the decoder board to 3″.

( ) Replace the black, green and white wires removed from the receiver with the wires from the decoder board.

( ) Mount the receiver board into its half of the case.

( ) Run the antenna lead through the hole provided in the decoder half of the case. Slip a 1″ piece of small heat-shrink tubing over the antenna lead to protect it.

( ) Slide the case together and check for fit.

PRELIMINARY CHECKOUT

( ) Measure the resistance between any red and black wire at one of the servo plugs (observe polarity red to red, black to black). You should read approximately 5,000 ohms.

( ) Reverse the meter leads and you should read approximately 1,000 ohms.

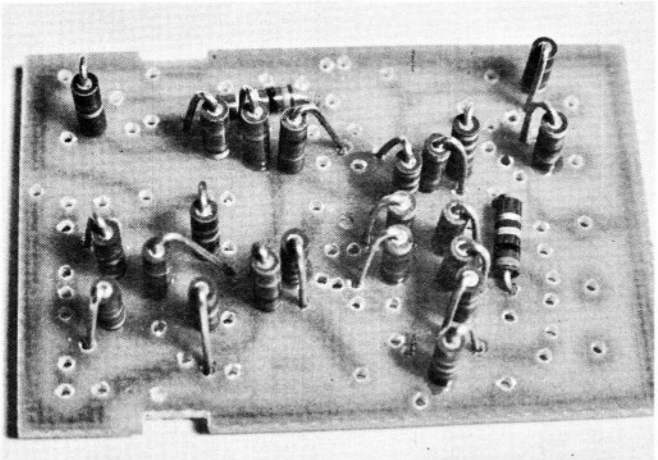
( ) Measure the resistance between any green and black wires at one of the servo plugs (red to green, black to black). You should read approximately 13,000 ohms.

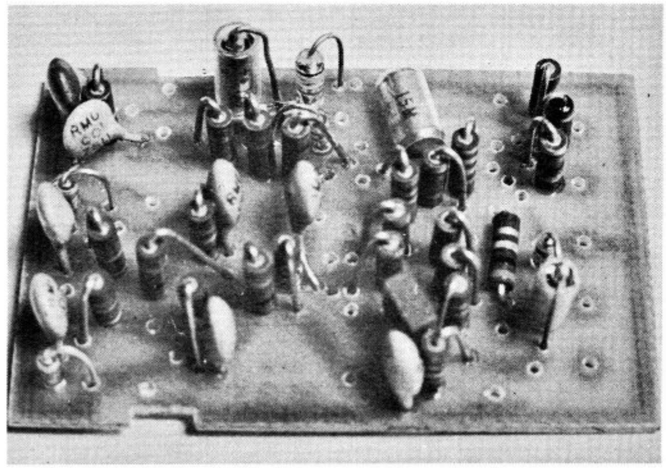
( ) Reverse the meter leads and the meter should read approximately 1,000 ohms higher.

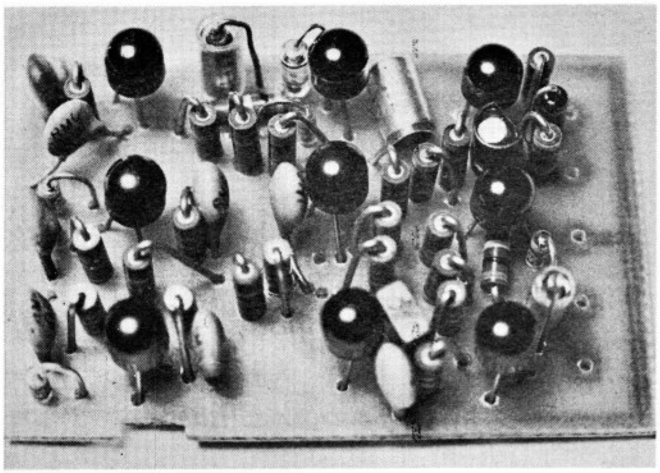
( ) Connect the battery and measure the voltage between any green and black wire (red to green, black to black). You should read approximately 5V with the switch turned on. If not turn the switch off immediately and check the polarity of Z1.

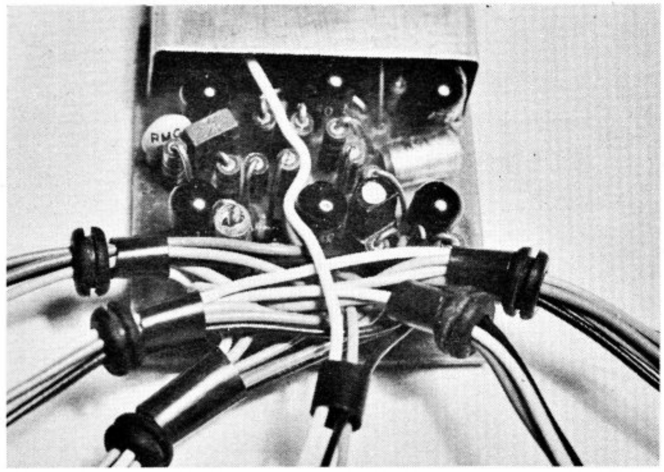
( ) With the transmitter and receiver-decoder operating you should hear a buzzing sound with a high impedance headset connected between the blue and green wires at each servo plug (use a .05 in series with one of the headset leads).

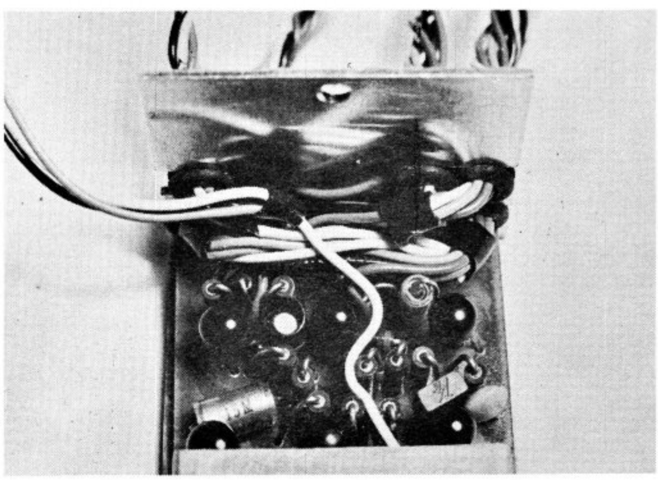
( ) If you have a scope or access to one you can check the decoder waveform as shown in the drawing.

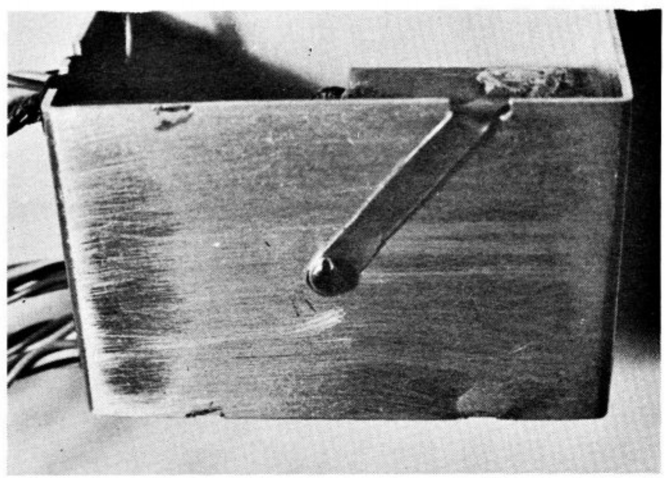


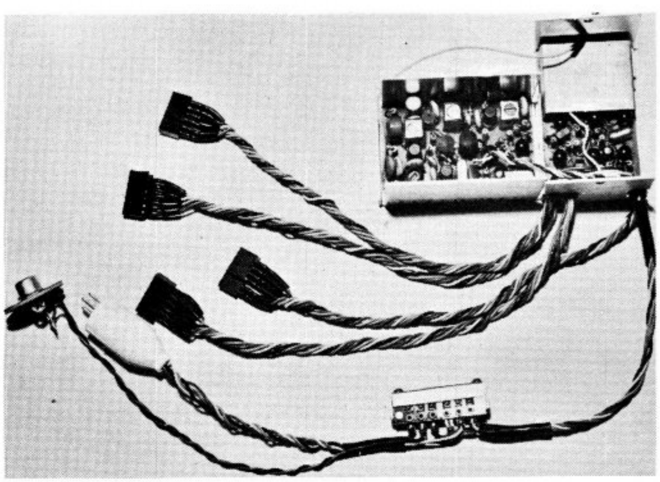




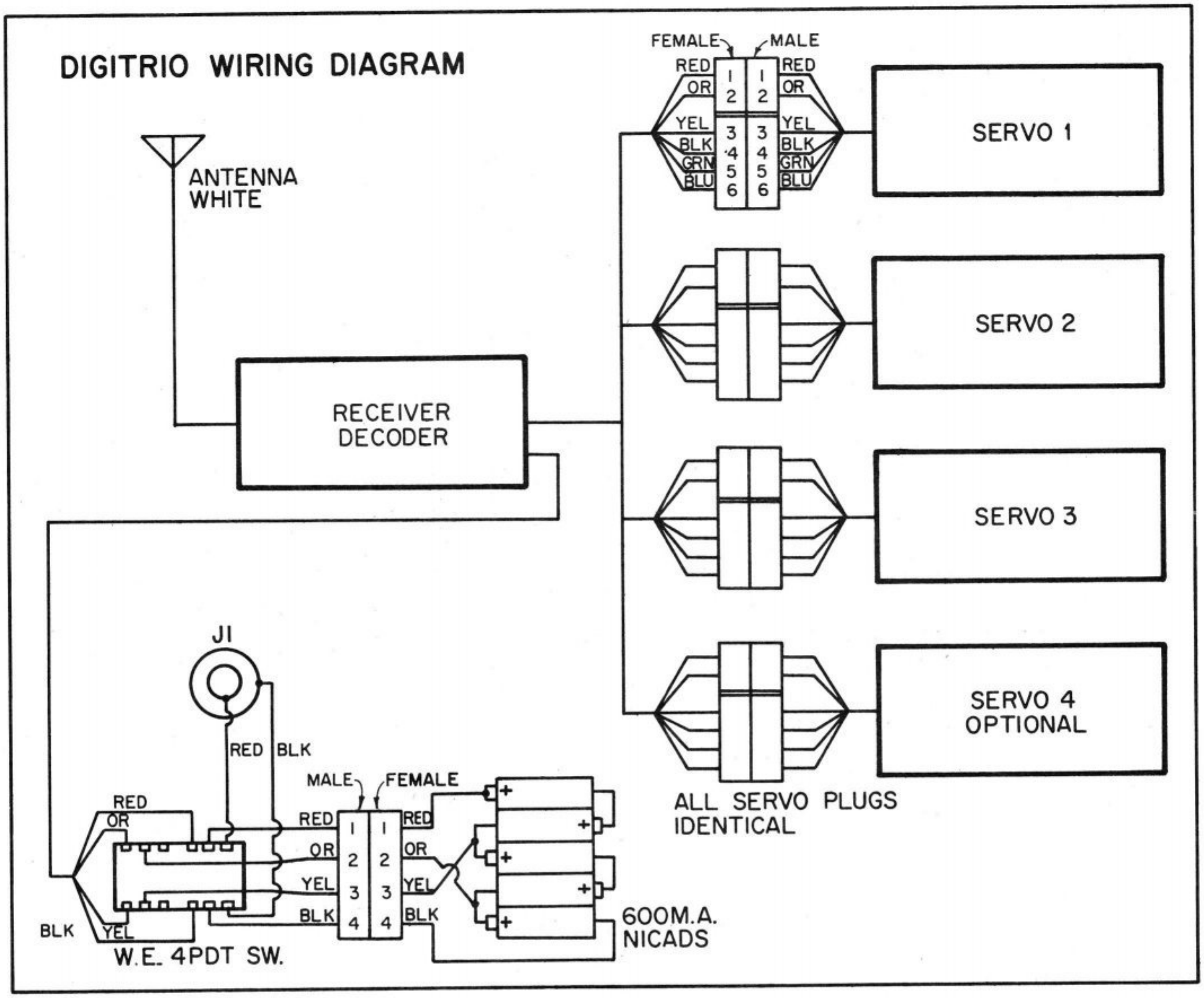


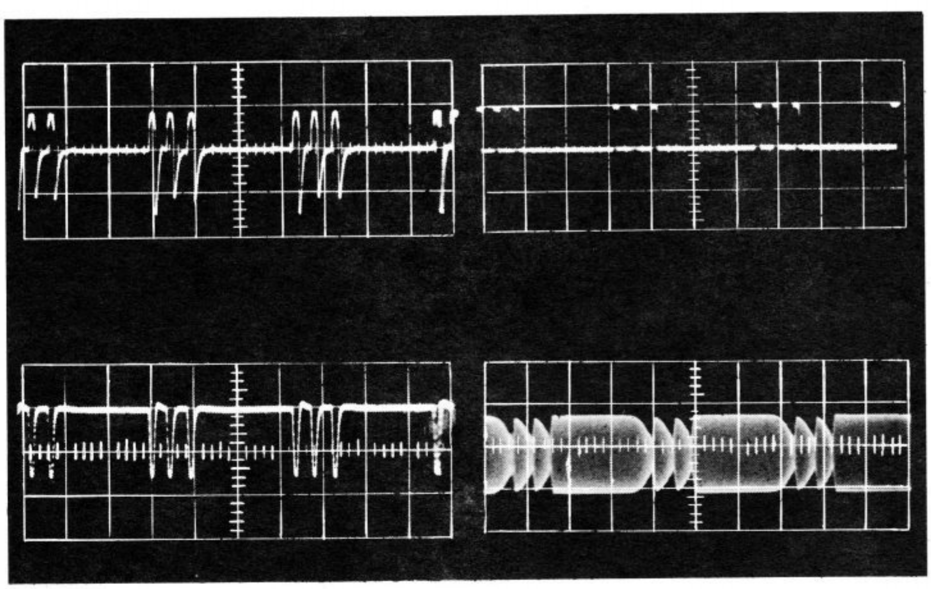




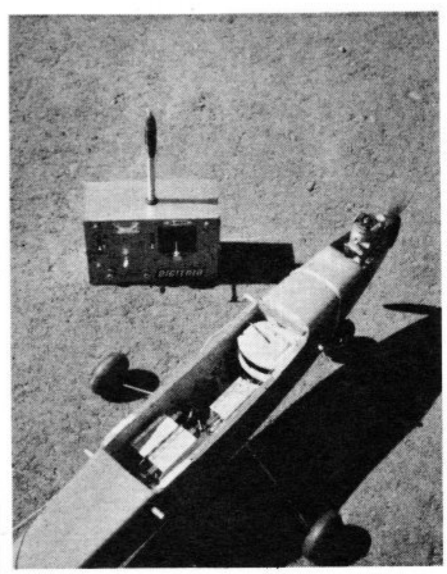


1st row, left: All resistors in place on decoder board. Note notches for shield. 1st row, right: Capacitors and diodes added. 2nd row, left: Adding the decoder transistors. 2nd row, right: Servo wiring with thermoshrink and case grommets installed. 3rd row, left: Decoder board mounted in LMB case. Heat lamp used on thermoshrink. 3rd row, right: Ground strap from decoder shield to case. Left: Completed receiver-decoder unit with all plugs, switches, and jack installed.





Dave Holmes supplied these scope traces from his 50Mc Digitrio receiver. Top, left: Collector Q7 (output) 5V/div 2ms/div. Top, right: Collector Q5 5V/div 2ms/div. Above, left: Diode load (R10) .2V/div 2ms/div. Above, right: Collector Q3 (3rd IF) 2V/div 2ms/div.



The Digitrio installed in an S.T. 23 powered CG Falcon 56. Trimmed 0-0 degrees, a good combination for the sport flier.

NOTE: Don't be concerned if waveform widths are not exactly as shown. They should be close however and we will adjust the transmitter later on to suit your particular system.

ERRATA

SEPTEMBER ISSUE

1. Figure 2—First waveform should be labeled 6.5 MS not 6.5 US.
2. Schematic—R5 should be labeled 330 ohms not 300 ohms.
3. C25 should be added to schematic in parallel with C23. It should be added to parts list as C25 .05 MFD Centralab Part #UK20-503.
4. The following will clear up questions about overlay components going to the wrong pots:
   Change pot lead labeling in upper left corner of construction overlay to read—R38, R35, R34 and R31 left to right.

NOVEMBER ISSUE

Change pot labeling in November issue on Digitrio stick assembly drawing so pot designations are reversed (i.e., R34 to R38 and R38 to R34).

Change text so that pot numbers (R38 and R34) and (R35 and R31) are reverse also on Page 35 of November issue under "Assembling Transmitter."

The above may sound like a lot of changes but they have no effect on construction or operation. They are merely pen and ink changes.

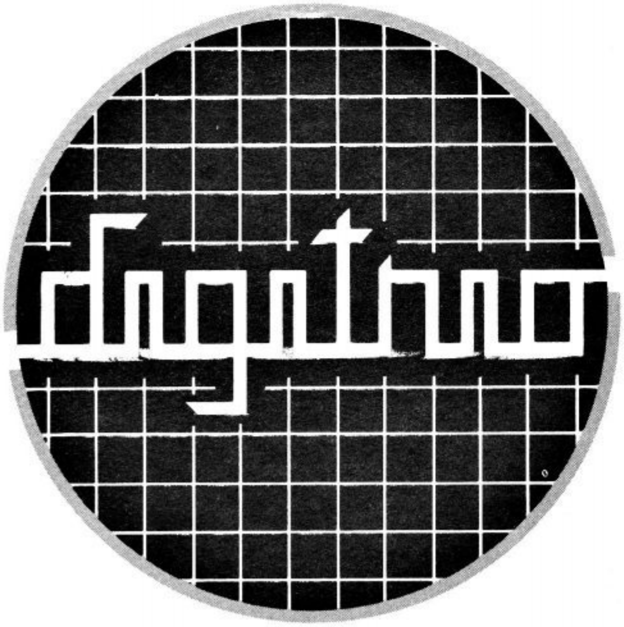
Above: Rusty Fried with Digitrio-Falcon combo at Phoenix "Arcs" flying site. Right: Two shots from our readers during construction of their RCM Digitrios.

PARTS LIST FOR DECODER

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURERS NUMBER
C1	.001	RMC	SM .001
C2	.001	"	"
C3	.001	"	"
C4	.001	"	"
C5	.001	"	"
C6	.22 Tantalum	T.I.	SCM224FPO35D2
C7	.001	RMC	SM .001
C8	.0001 (100 PF)	"	SM 100
C9	.1 Tantalum	T.I.	SCM104FPO35D2
C10	.001	RMC	SM .001
C11	.05	"	ERIE Z5E
C12	15 MFD (Axial Leads)	W.E.	— — —
D1	Silicon Diode	"	DHD 806
D2	" "	"	"
D3	" "	"	"
D4	" "	"	"
D5	Germanium Diode	Ohmite	1N34 or Equivalent
Q1	2N3640	Fairchild	2N3640
Q2	"	"	"
Q3	"	"	"
Q4	"	"	"
Q5	"	"	"
Q6	"	"	"
Q7	"	"	"
Q8	"	"	"
Q9	"	"	"
Q10	2N2924	G.E.	2N2924
R1	47K ¼W	Ohmite	LIDSM
R2	47K "	"	"
R3	10K "	"	"
R4	10K "	"	"
R5	1K "	"	"
R6	1K "	"	"
R7	22K " 5%	"	LIDED
R8	4.7K "	"	LIDSM
R9	2.2 K "	"	"
R10	10K "	"	"
R11	1K "	"	"
R12	10K "	"	"
R13	4.7K "	"	"
R14	1K "	"	"
R15	10K "	"	"
R16	4.7K "	"	LIDSM
R17	56K " 5%	"	LIDED
R18	33K "	"	LIDSM
R19	33K "	"	"
R20	4.7K "	"	"
R21	4.7K "	"	"
R22	4.7K "	"	"
R23	33K "	"	"
R24	47 ohm ¼W	"	"
Z1	Zener Diode (5.6V)	T.I.	1N752

MISCELLANEOUS PARTS

#26 Hook-up Wire (2 Pkg.)	W.E. or Bonner	— — —
9" Large Heat-Shrink Tubing	W.E.	— — —
15" Small Heat-Shrink Tubing	W.E.	— — —
3 Female Servo Connectors	W.E.	— — —
1 Battery Connector	W.E.	— — —
P.C. Board	W.E.	— — —
Switch 4 PDT	W.E.	— — —
4 ¼" Rubber Grommets	W.E.	— — —
1 2⅛" x 1⅜" x 1/64" Piece of Insulation Sheet	W.E.	— — —
1 #2 x ¼" Self-Tapping Screw	W.E.	— — —
1 Piece Copper 2⅜" x 1½" x .006	W.E.	— — —



CONSTRUCTING THE DIGITRIO SERVOS

BY ED THOMPSON

Contributing Technical Editor

THE Digitrio is still going strong. It survived two crashes this month due to a dead battery in the receiver pack. My test pilot ignored short range and erratic motor control on repeated flights until the inevitable happened. That's right, I said two crashes – the second exactly as the first – a result of incomplete testing, ignoring instructions and hoping for the best!

Don't let this happen to you! Above all, follow instructions and don't fly until your system is operating perfectly. If you are going to use your old reed battery pack, check it under load first. You can have defective cells that may not show up with your reed system but will cause you grief with the Digitrio. Both of the crashes this month followed the same pattern. After the surface charge dissipated one cell completely discharged. This allowed a couple of satisfactory flights followed by a "prang." During the satisfactory flights, however, the motor control was erratic due to insufficient range, and if this warning had been heeded trouble could have been averted.

I checked one reed pack after experiencing excessive noise in the system to find all the cells bad except one which the owner had just replaced. This same pack had previously been used with a reed system and according to the owner performed satisfactorily.

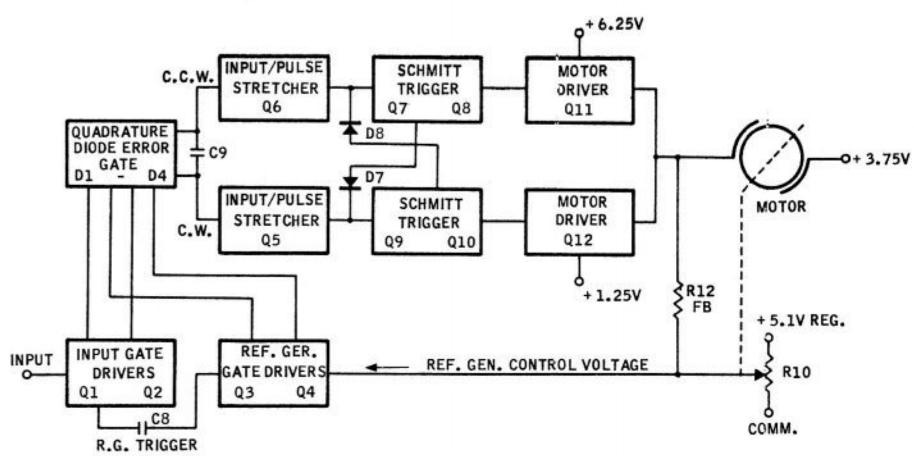
In all fairness to my nicads I must admit that they have been subjected to severe discharge rates and occasional overcharges while testing the system, so, the nicads were not to blame. The point is this: if the system is not operating perfectly or changes characteristics (especially after prolonged consistent operation) don't be lulled into a false sense of security, keep it on the ground until it is right.

In testing some transmitters with more than average power output I found some RF feedback. The shield described at the end of this month's article will prevent this condition. Install it whether you are having this trouble or not. If you don't install it send me your broken crankcases – I collect them!

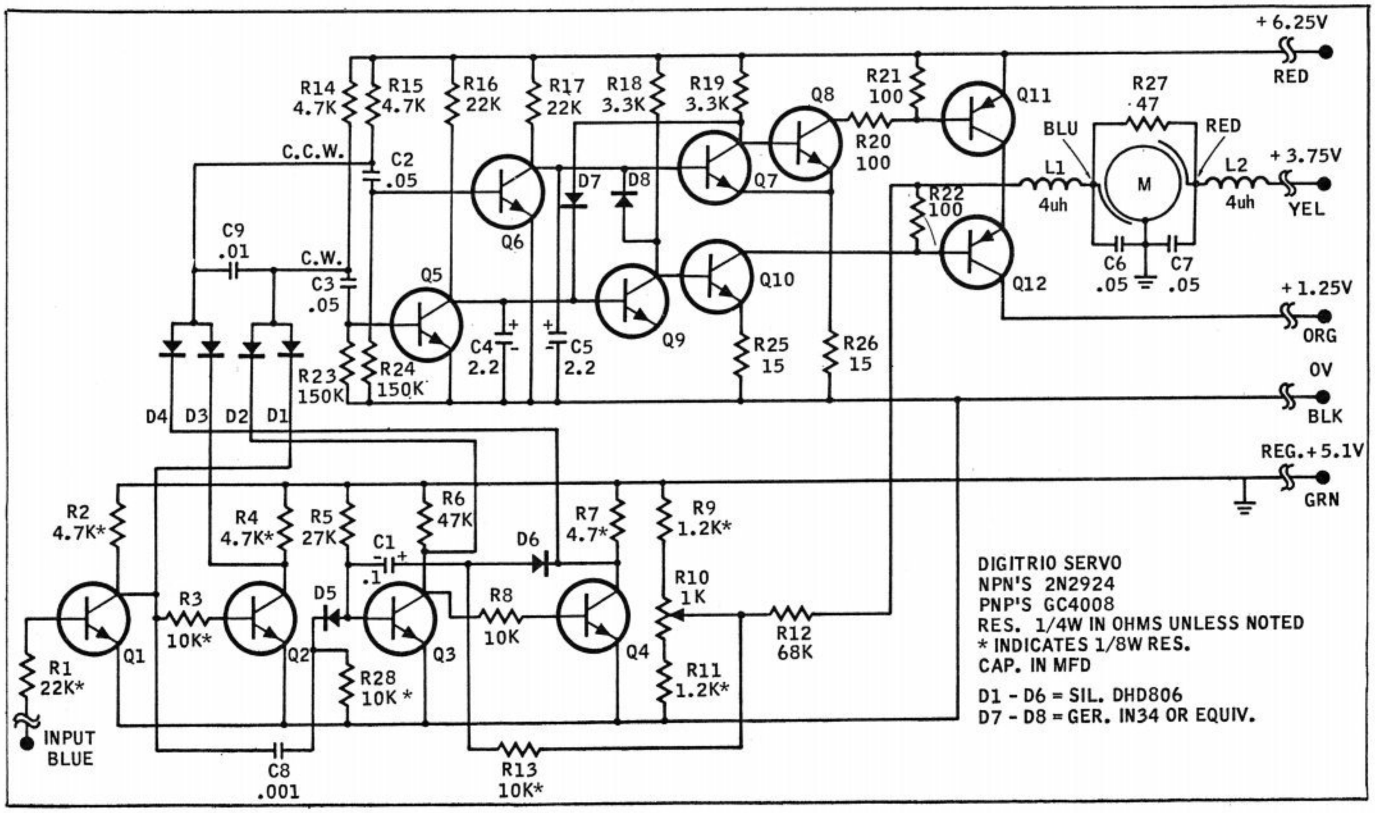
Rusty Fried flew the Digitrio to fourth place in Class II at the Annual Arizona Invitational Meet sponsored by the ARCS of Phoenix. Not bad, considering that all the Phoenix and Tuscon pros showed up. He used a Tauri with a Supertigre 23. Those boys from Tuscon are tough to beat, "especially to the hamburgers!"

THEORY OF SERVO

For want of a starting place let's consider the action of D1. D1's anode is connected to R14. D1's cathode is connected to Q1's collector. One side of C3 is connected to the D1-R14 junction and the other side to the base of Q5. Assume that Q1 is conducting. This forward-biases D1 and the voltage at the junction of R14-C3 is at ground. If we now cause Q1 to cutoff,



DIGITRIO SERVO BLOCK DIAGRAM



the voltage at the R14-C3 junction will rise to the positive voltage applied to the top end of R14 (in this case +6.25 V). This positive voltage will be transferred across C3 forward-biasing Q5 which will conduct. The base to emitter resistance of Q5 and R23 will discharge this positive voltage and a pulse will result. Q5 will conduct for the duration of this pulse. When Q1 conducts initially a negative pulse will result but Q5 will ignore it. Therefore each time we cause Q1 to alternately conduct and cutoff a positive pulse will appear at Q5's base causing it to conduct.

D2 is connected to the R14-C3 junction also and operates in the same manner except the positive pulse to Q5 is controlled by Q3. It is important to note here that if either diode is forward biased (either Q1 **or** Q3 conducting) the voltage at the R14-C3 junction cannot rise positive.

Q1/D1 and Q3/D2 work in conjunction with each other to control the positive pulse to Q5's base. Since Q5 is the input stage to the CW half of the servo amplifier the action of Q1 and Q3 controls the servo motor rotation in that direction.

The action of D3 and D4 is identical except they are controlled by Q2 and Q4 respectively. The resulting pulse in their case is delivered to Q6 (CCW half of the servo amplifier). R15, C2 and R24 form these pulses. So we can supply an input pulse to either half of the servo amplifier by controlling the operation of Q1 through Q4 which in turn controls the diode error gate (diodes D1 thru D4). Assume that the servo is in the neutral position and no input pulses are being applied to R1.

In this quiescent state Q2 and Q3 are conducting – Q1 and Q4 are cutoff. Q2 and Q3 in conjunction with D3 and D2 respectively will place a ground at the R15-C2 and R14-C3 junctions. R10 is mechanically coupled to the output arm and will be centered – this will give a nominal pulse width of 1 MS when we trigger the reference generator (one shot formed by Q3 and Q4). If we now apply a 1 MS positive pulse to R1 we will cause Q1 to conduct and Q2 to cutoff. The leading edge of this pulse also triggers the reference generator (via C8 and D5) and Q3 cuts off while Q4 conducts. This action happens simultaneously and now we hold the pulse producing resistor/capacitor junctions at ground with Q1 and Q4. Since the changeover was instantaneous (we merely swapped diodes) no positive pulse appeared at either Q5 or Q6. At the end of 1 MS the reference generator will return to its quiescent state – Q3 conducting and Q4 cutoff. Since our input pulse is also 1 MS Q1 will cutoff and Q2 will conduct at the same time the reference generator changes state. So we again merely swapped diodes and no servo input pulses were produced. This action is the same regardless of the servo position as long as the input pulse to R1 matches the reference generator pulse. In other words the diode gate is balanced and no error pulses are produced. Let's assume that the reference generator will produce a 1 MS pulse and our incoming pulse is .5 MS wide. We will again trigger the reference generator at the leading edge of the pulse, cause Q1 to conduct and Q2 to cutoff, and swap diodes. The incoming pulse will cause Q1 to cutoff and Q2 to conduct at the end of .5 MS. Since Q3 is still cutoff (reference generator still has .5 MS to go before returning to its quiescent state) Q1 cutting off will allow the R14-C3 junction to rise positive producing a positive error pulse at Q5's base. Q2 and Q4 are now both holding the R15-C2 junction at ground so no pulse is produced here. When the reference generator returns to its quiescent state Q3 will return the R14-C3 junction to ground and the circuit is ready for another incoming pulse to compare. We will produce a negative pulse at Q5's base when the R14-C3 junction is grounded but Q5 will ignore it. Under these conditions Q5 will receive a positive error pulse each time the incoming pulse is sampled. This will cause the motor to turn in a CW direction. As the output arm moves it changes the position of the wiper on R10 to shorten the pulse width of the reference generator. The servo will continue to move until the output arm has positioned R10's wiper to cause the reference pulse and incoming pulse to be identical in width (in this case .5 MS). No error pulses are produced now and the servo will stop.

Assume now that the reference generator will produce a .5 MS pulse and we apply a 1 MS pulse to R1. Again we trigger the reference generator, cause Q1 to conduct, Q2 to cutoff and swap diodes. The reference generator returns to its quiescent state at the end of .5 MS (Q3 conducting and Q4 cutoff). Q2 is still cutoff (the incoming pulse has .5 MS to go) and Q4 cutting off allows the R15-C2 junction to rise positive placing a positive error pulse on Q6's base. The servo motor will now run in a CCW direction until R10 is positioned to cause a 1 MS reference generator pulse. Again no error pulses are produced and the servo will stop.

I have used only three examples of pulse comparison but the action of the servo is infinite. It will respond any time the incoming and reference pulses are not identical, regardless of where the servo is positioned or where the stick is moved up to the limits of its travel.

The servo amplifiers consist of an input/pulse stretcher stage, Schmidt trigger and motor driver. Let's consider the CCW half first. Q6 is normally cutoff and R17 holds Q7 in conduction. Since R26 is common to both Q7 and Q8's emitter the base to emitter voltage of Q8 is essentially O V and Q8 is cutoff. The voltage drop across R26 is now dependent upon Q7's conduction. This places Q11's base at the same voltage as its emitter and it is cutoff.

If we apply a positive pulse to Q6's base its collector will go toward ground and remove forward bias from Q7. This allows Q7's collector to go positive forward biasing Q8. The voltage drop across R26 is now dependent upon Q8's conduction and the positive voltage at Q7's emitter is regenerative to Q7 tending to cut it off even further. Actually there is a discreet level at which the regenerative action takes place giving a threshold voltage for Q6 to work against. This gives a defined on and off voltage for Q11's base. When Q8 conducts the junction of R20 and R21 goes toward ground (negative as far as Q11's base-emitter junction is concerned). This forward biases Q11 which conducts. Q11's collector goes to +6.25 V which places 2.5 V across the motor (the other side of the motor is at +3.75 V). This 2.5 V is positive at the Q11/Q12 junction with respect to the battery side (yellow lead). We must convert the short input pulses into a smooth DC voltage to run the motor. C5 is charged to +6.25 V by R17. When Q6 conducts it discharges C5 rapidly due to the low resistance across Q6. It charges much more slowly through R17 when Q6 is cutoff so it holds the collector voltage below Q7's forward-bias point between pulses. This "stretches" the pulses into a smooth DC voltage for the motor. The action of the Schmidt trigger provides Q11 with either a full on or off voltage with a discreet operating point.

The CW half of the servo amplifier is identical up to Q12. When Q12 conducts the Q11/Q12 junction goes to +1.25 V. Since the battery side is at +3.75 V we have a 2.5 V voltage across the motor of opposite polarity than before. Therefore the motor turns in the opposite direction.

D7 and D8 are used to prevent Q11 and Q12 conducting simultaneously (if they do, a short, through Q11 and Q12, would practically exist between the red and orange leads). This, incidently, could play havoc with the decoder by falsely triggering the different stages. At first glance this "double conduction" may look unlikely, however, since the servo "resolution" is so high it is susceptible to minute variations of pulse width caused by noise, etc. Since we are "stretching" the pulses this could cause both sides to conduct simultaneously. If Q6 is conducting first it will forward bias D8 removing the positive voltage at Q9's collector so that Q10 cannot conduct even if Q9 loses forward bias. If Q5 conducts first it forward biases D7 and the same thing happens to Q7/Q8. Due to other circuit considerations perfect protection is not possible, but it is more than adequate.

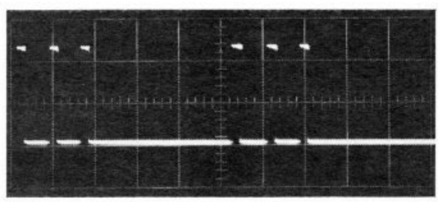
L1, L2, C6, C7 and R27 are used to minimize motor noise and are quite effective. C9 is used to prevent "trash signals" caused by differing rise and fall times of the components from producing false error pulses to the servo amplifiers. R9 and R11 limit the servo travel electrically. The values can be adjusted for use with control sticks having different throw measurements than "Digitrio." Increasing their value will cause more travel and vice-versa. Resistance values of 1.5K work well with the "Bonner Stick Assembly."

R12 is used for voltage feedback to prevent output arm "overshoot." It feeds back voltage to R10's wiper that opposes the voltage change necessary for correcting its position. The closer the wiper is to the correct position the more pronounced its effect. It causes the output arm to "dampen" into its corrected postion. If voltage is applied to an electric motor and then removed, the shaft will continue to rotate for a while due to inertia. This would cause the servo to coast past the corrected position and in turn be driven back whereupon it would again coast and the arm would "oscillate" trying to find the precise stopping point but not being able to. This would go on unless some mechanical damping was present or the dead band was sufficient to allow it to coast to a stop. Electrical feedback is used here to allow a minimum deadband and nondependence on mechanical damping. The reference generator is voltage regulated to prevent trim drift. The component values have all been carefully worked out and what may appear as an innocent change could lead to decreased performance.

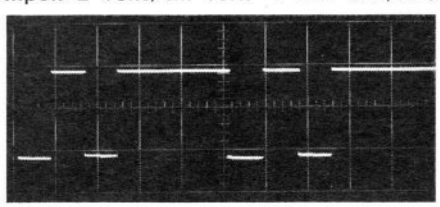
PREPARING P.C. BOARDS

( ) Make the composite P.C. board

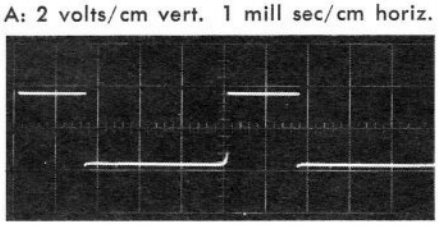
Dave Holmes submitted the following scope traces from his decoder. Dave's Digitrio on 6 meters.



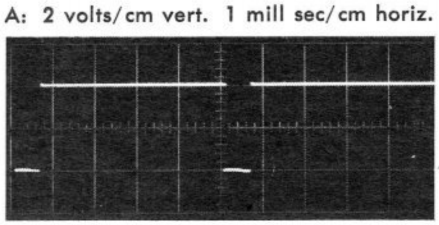
Input: 2 volts/cm vert. 1 mill sec./cm.



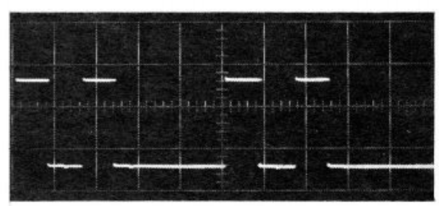
A: 2 volts/cm vert. 1 mill sec/cm horiz.



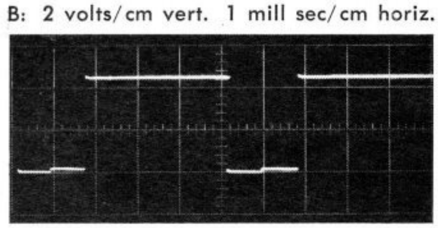
A: 2 volts/cm vert. 1 mill sec/cm horiz.



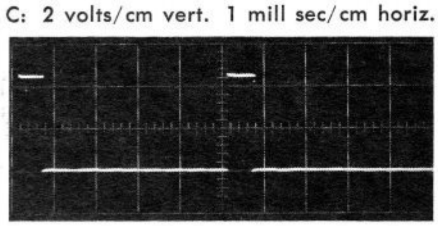
B: 2 volts/cm vert. 1 mill sec/cm horiz.



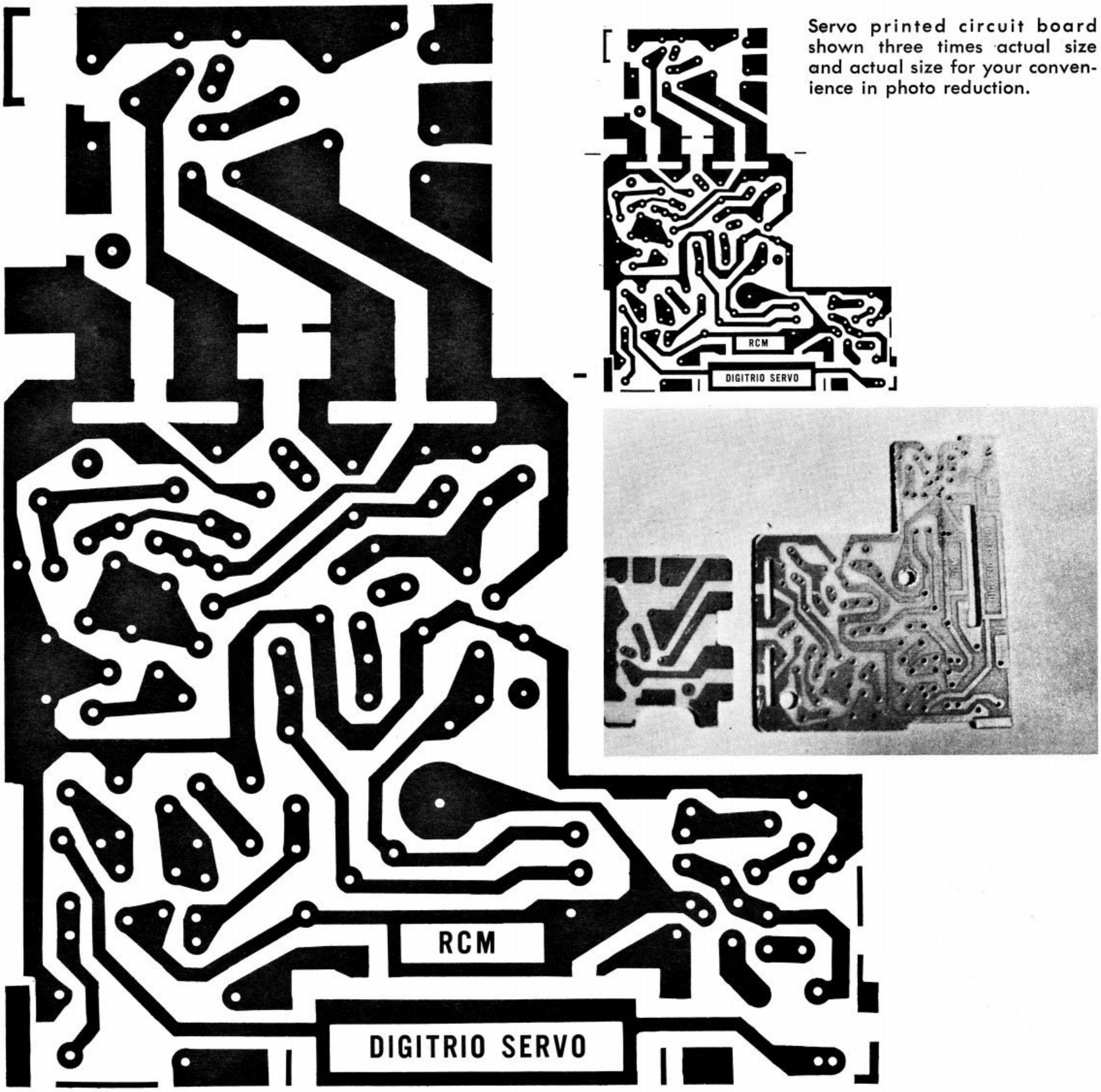
B: 2 volts/cm vert. 1 mill sec/cm horiz.



C: 2 volts/cm vert. 1 mill sec/cm horiz.



2 volts/cm vert. 1 mill sec/cm horiz. Outputs all same.



Servo printed circuit board shown three times actual size and actual size for your convenience in photo reduction.

with 3/64″ stock and clean thoroughly.

( ) Drill all holes with a #65 drill. Enlarge mounting hole and hole B in the main board with a #42 drill. There may be an extra die hole in the board if purchased from World Engines but it will not be used. It will be in the upper right-hand corner of the main board (copper side down).

( ) Drill hole A in the auxiliary board with a #31 drill.

( ) Remove all burrs around holes in copper lands.

( ) Saw two thin slots as shown for insertion of brass wiper later on — use a thin Xacto saw.

( ) Make cutout for R10. See construction overlay for exact position (fit but do not install R10 at this time).

( ) Cut the two boards apart where shown with a fine Xacto saw.

( ) Place main board on C frame and position it so that the board fits into the notches at the front of the frame and with downward pressure at rear of the board it presses into place. Front edge of the board should be flush with front of the C frame. File the board to fit.

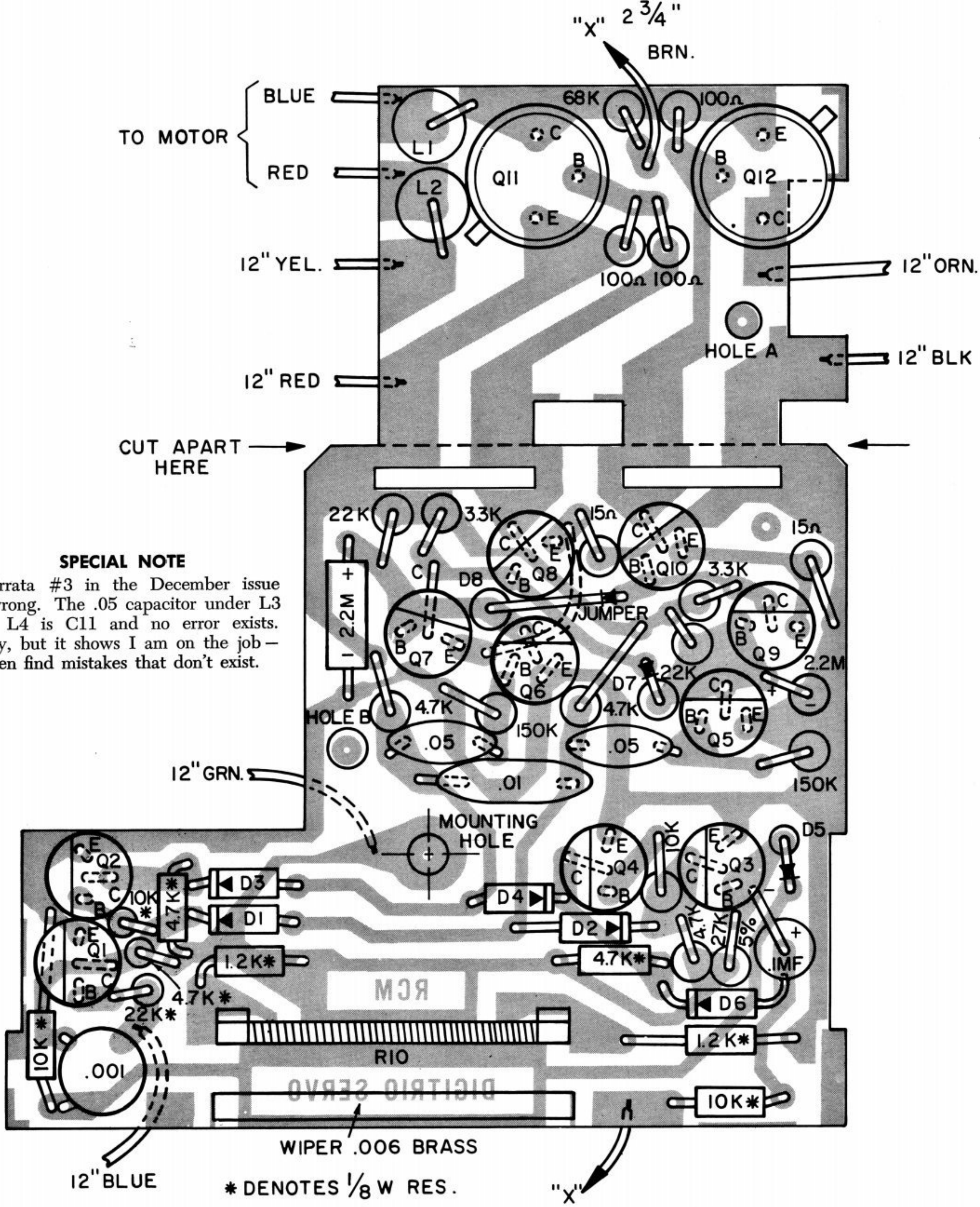
( ) Fit auxiliary board into place filing as necessary so that the notches in the board fit firmly and the auxiliary board goes all the way down against the main board.

PREPARING SERVO MECHANISM

( ) Refer to figure 1 and insure that the red dot is at the bottom of the motor as shown. If not remove motor mounting screws and rotate motor. Tighten motor screws in either case.

( ) Scrape paint from heads of screws in back of motor.

( ) Cut leads to ½″ and solder .05 disc capacitors as shown—be sure "hot" capacitor leads don't short to motor frame. Heat-shrink tubing can be used on the "hot" capacitor leads for insurance. The easiest way is to solder leads while they are straight and then bend the capacitor down along the side of the motor.



SPECIAL NOTE

Errata #3 in the December issue is wrong. The .05 capacitor under L3 and L4 is C11 and no error exists. Sorry, but it shows I am on the job – I even find mistakes that don't exist.

( ) Solder 47 ohm resistor as shown.

( ) Solder 1″ red and blue wires to motor as shown. Do not solder the other ends to the auxiliary board yet.
NOTE: Make sure that no component, wire or solder mound is equal to or exceeds the height of the plastic cap on the motor or a direct "short" will exist when the cover is installed.

( ) Refer to the servo instruction sheet supplied with the mechanism for checking gears, etc.

WIRING THE MAIN P.C. BOARD

( ) Install all quarter-watt resistors flush with board and straight up and down.

( ) Mount the two germanium diodes D7 (bar down) and D8 (bar down) observe polarity – make sure D7's lead doesn't short to the 4.7K lead adjacent.

( ) Mount 2.2 MFD electrolytics, observe polarity.

( ) Mount .1 tantalum, observe polarity. Be sure your tantalum has an insulated cover or it may short to "C' frame.

( ) Mount two each disc .05's.

( ) Mount the .01 disc. Center the body midway between the two .05's as shown on overlay.

( ) Mount the .001 disc capacitor. It must be mounted close to the board and bent over flush and parallel with the board.

( ) Mount all silicon diodes observing polarity. The ones laying down must be flush against the board. These silicon diodes must be DHD 806's due to physical size requirements – normal size diodes will

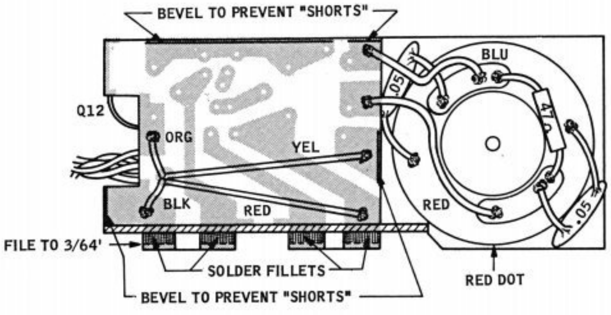


FIGURE 1 REAR VIEW

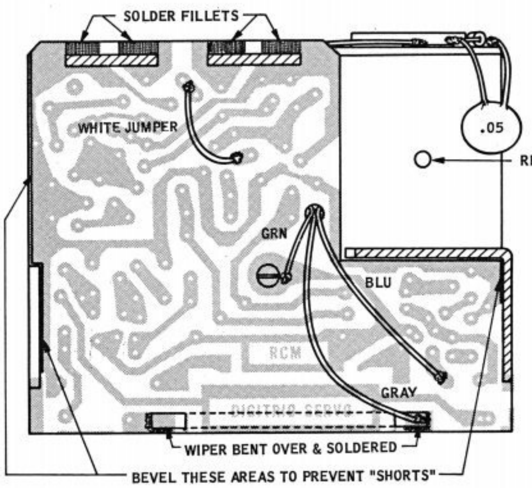


FIGURE 2 BOTTOM VIEW

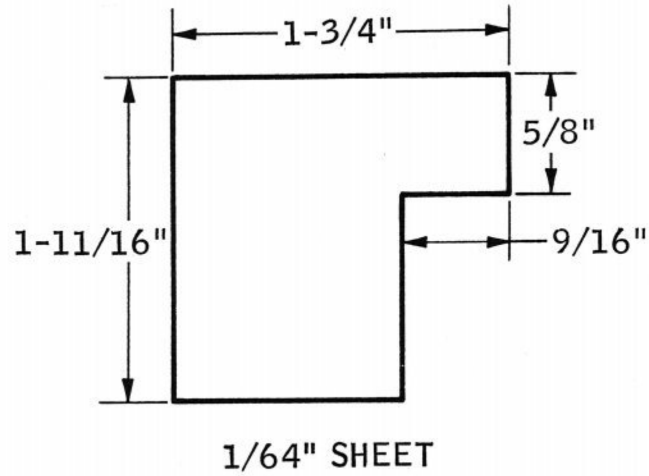


FIGURE 4 INSULATING SHEET

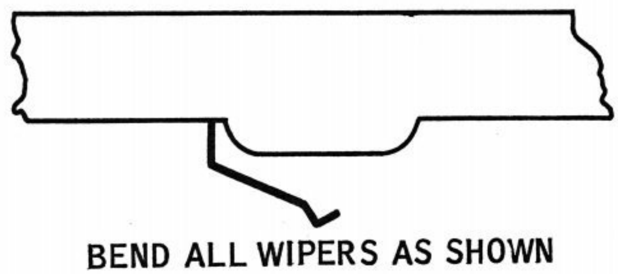


FIGURE 3 WIPER ARM

not fit.

( ) Mount all 1/8-watt resistors. These are shown by an asterisk* on the overlay and schematic. The ones laying down must be flush with the board.

( ) Mount all 2N2924's. Note all collector leads must be bent out (refer to overlay for correct installation). Mount all transistors so they are approximately the same height or slightly higher than the 1/4-watt resistors overall including leads.

( ) Fit the main board onto the C frame and check for correct alignment (front edge of P.C. board should be flush with front edge of C frame). Insert and tighten mounting screw. (If Q3 and/or Q4 will not permit correct alignment, loosen the mounting screw and reheat their solder joints allowing them to shift slightly while applying corrective pressure to front edge of board.) NOTE: The emitter leads of Q3 and Q4 are close to the C frame. If sufficient clearance cannot be obtained file notches in C frame for insurance against shorting.

( ) Make sure the motor body or C frame does not come into contact with any component lead. Bend any leads that are close to touching to provide adequate clearance. Insure that no lands come in contact with the C frame. Inspect carefully the areas pointed out in the photos and drawings as potential "shorts." Use an Xacto knife or file to bevel the board in these areas removing enough copper to insure against accidental shorting. NOTE: The C frame and motor are grounded to 5.1 V and any contact in the areas mentioned will be a direct short to the battery supply.

( ) Remove the board and with a fine file flat the solder mounds so that they are 1/32″ to 3/64″ high.

( ) Clean the board of all solder resin and foreign material with acetone or dope thinner.

( ) Install white insulated jumper routed as shown on overlay by dotted lines.

( ) Mount the resistance element so that only about one quarter of the element is above the surface of the P.C. board by bending the tabs over at the bottom and soldering them. Be careful from now on so you don't damage this element.

( ) Install the wiper in the slots at the front edge of the board. Take care here so that the wiper lays perfectly flat against the board. Bend the wiper over on the copper side and solder the ends to the lands provided. The proper position of this wiper is slightly rearward of the front edge of the board approximately 1/128″ — don't mount it flush as it may short to the top of the servo cover. Be careful you don't scratch, dent, etc., this wiper during installation.

( ) Do not install gears or operating arm at this time (we will do this later during final assembly and wiring of servo).

WIRING AUXILIARY BOARD

( ) Mount Q11 and Q12 flush against board. Enlarge lead holes slightly if they won't go all the way against board.

( ) Mount the 1/4-watt resistors making sure that their leads don't contact transistor cases.

( ) Mount L1 and L2 making sure leads don't come into contact with transistor cases. Enlarge the holes where the choke body fits so they will mount close to the board.

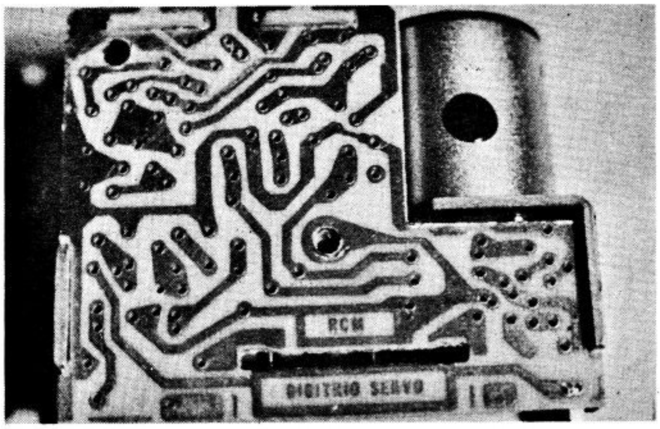
( ) Fit the auxiliary board into main board and check for clearance. If necessary some of the components on main board may have to be mounted lower on the board.

( ) Remove the auxiliary board and flat the solder mounds 1/32″ to 3/64″ high with a fine file.

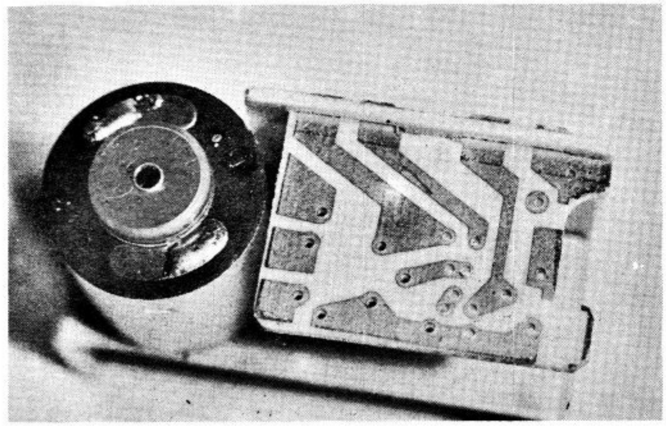
( ) Clean the board with acetone or dope thinner.

CONNECTING THE TWO P.C. BOARDS

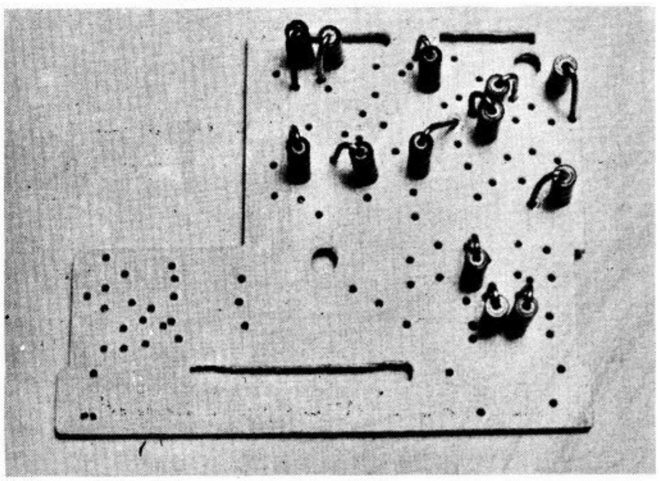
( ) Insert auxiliary board into main board and solder in place. Make solder fillets at the four soldering



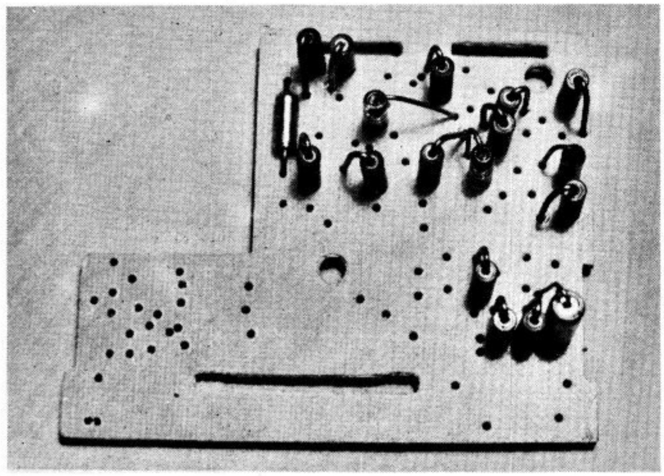
Main PC board fitted to "C" frame.



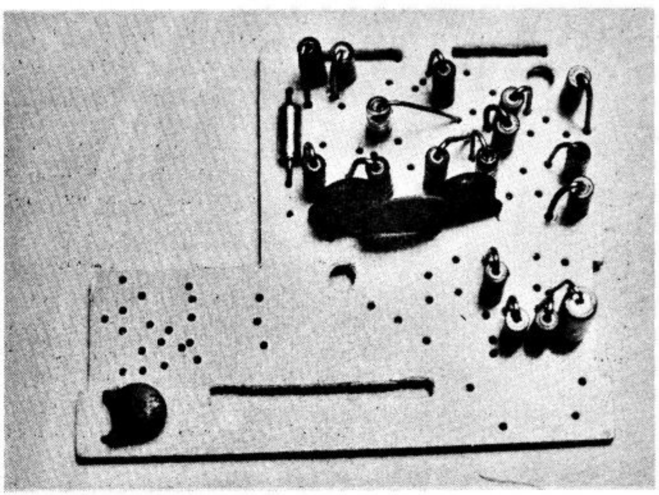
Interlocking auxiliary PC board in place.



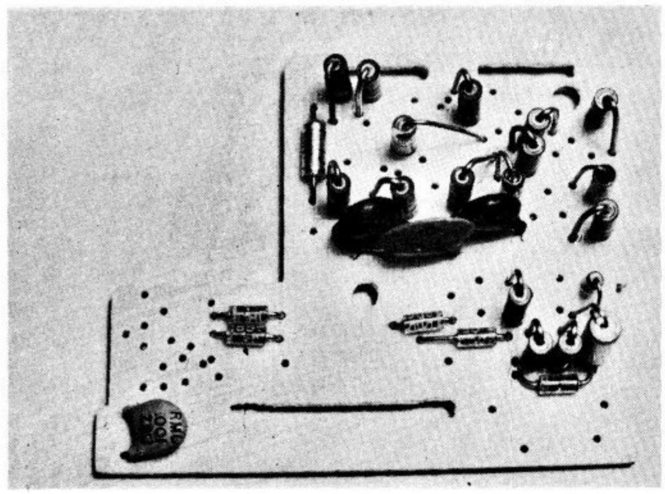
Main PC board with ¼ watt resistors installed.



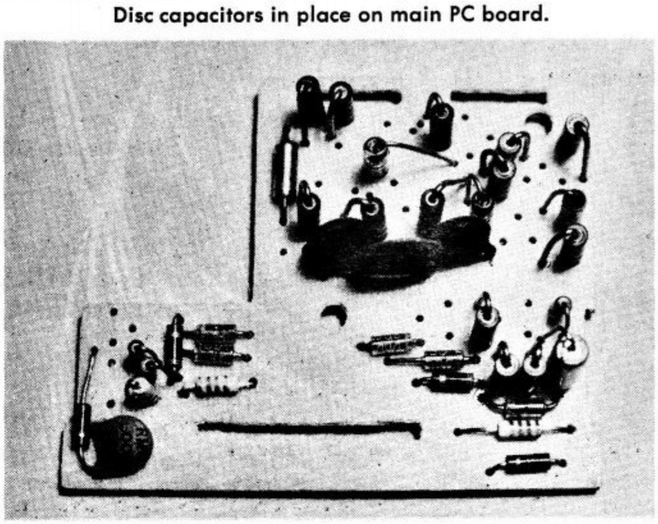
Main PC board with electrolytics added.

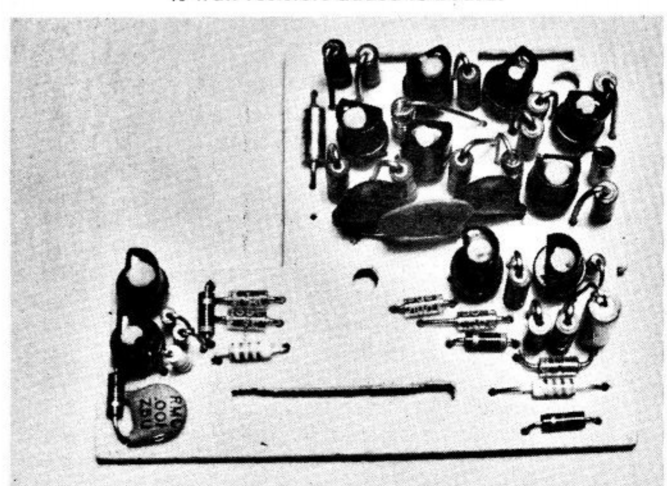


Disc capacitors in place on main PC board.

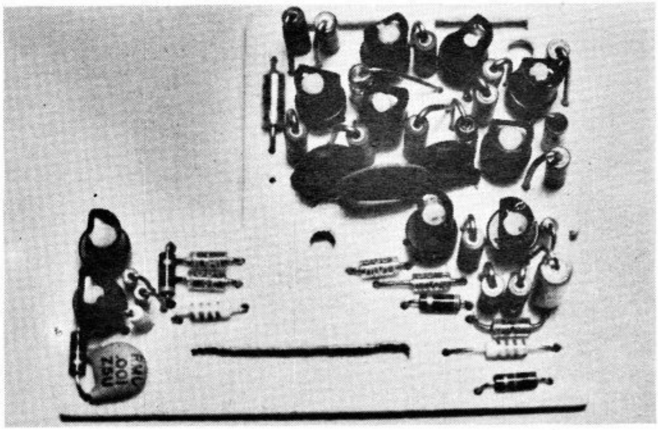


⅛ watt resistors added to board.

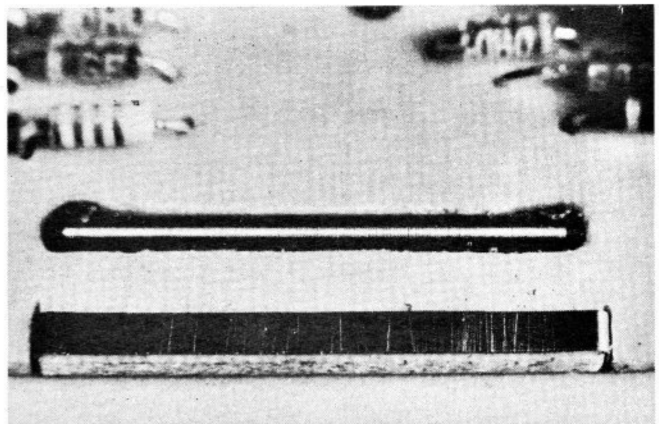




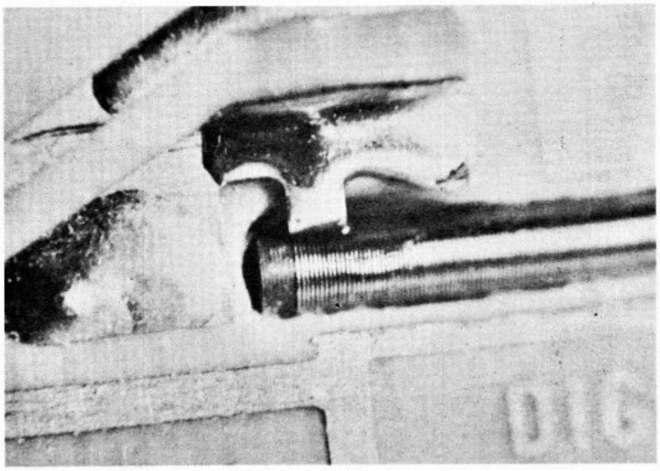
Transistors added in place on main board.



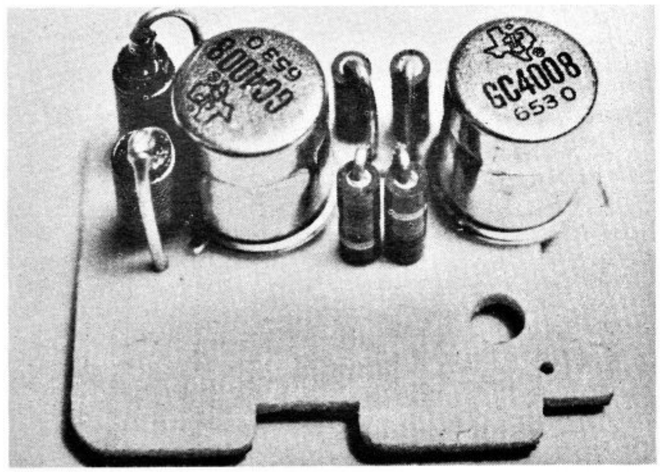
Main board now completed except for wiper and pot.



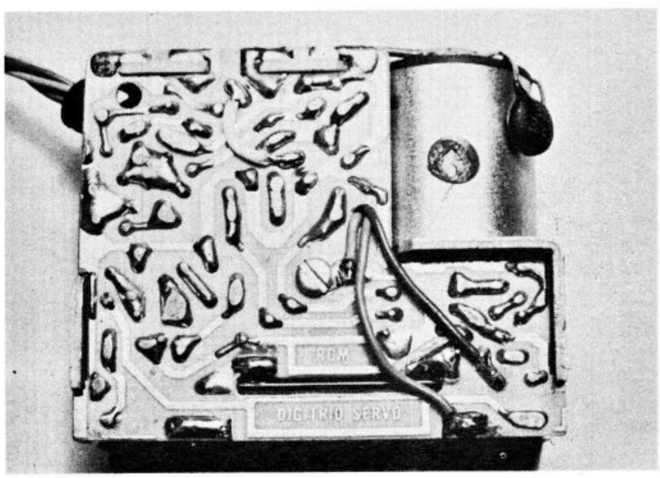
Wiper and pot installed. Follow text carefully when installing.



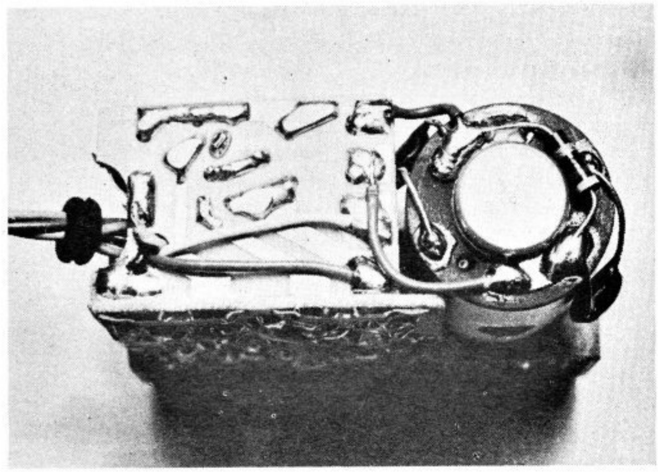
Closeup of pot tab soldered to copper PC land.



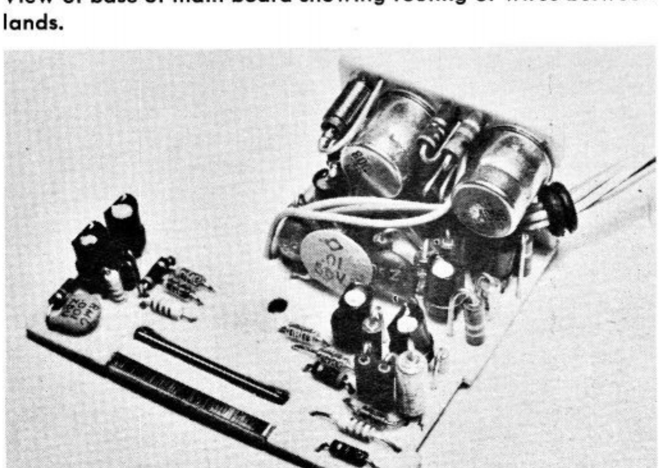
Auxiliary board with transistors, resistors and chokes installed.



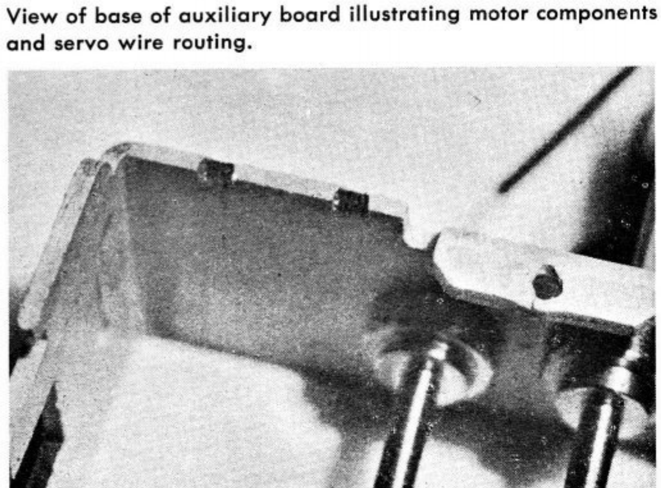
View of base of main board showing routing of wires between lands.



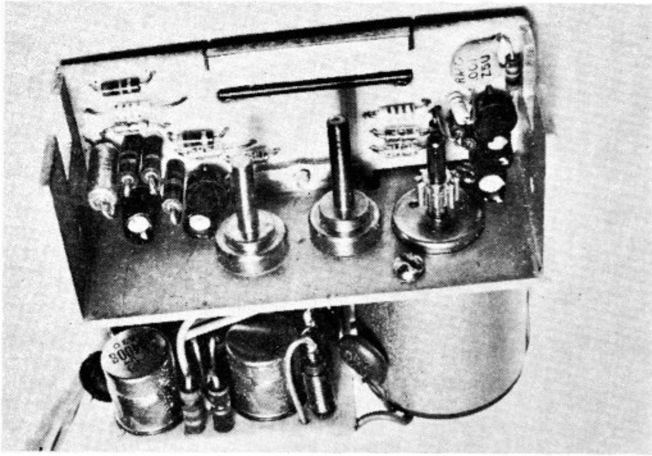
View of base of auxiliary board illustrating motor components and servo wire routing.



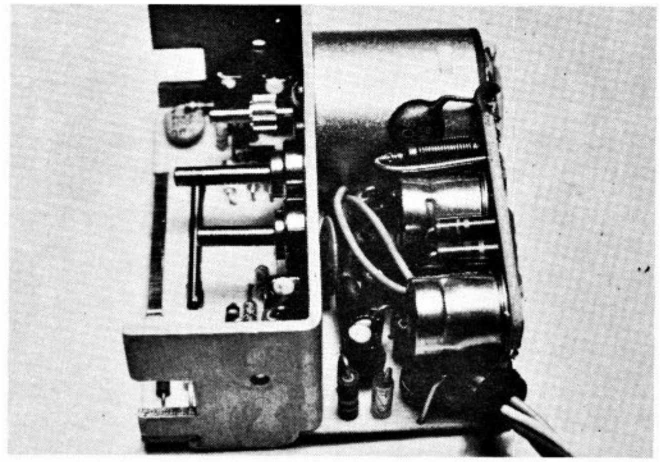
Completed servo amplifier.



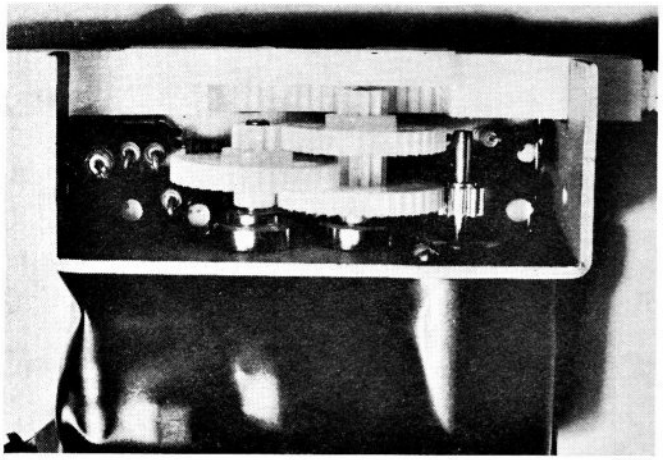
If necessary, notch C frame with file for transistor clearance.



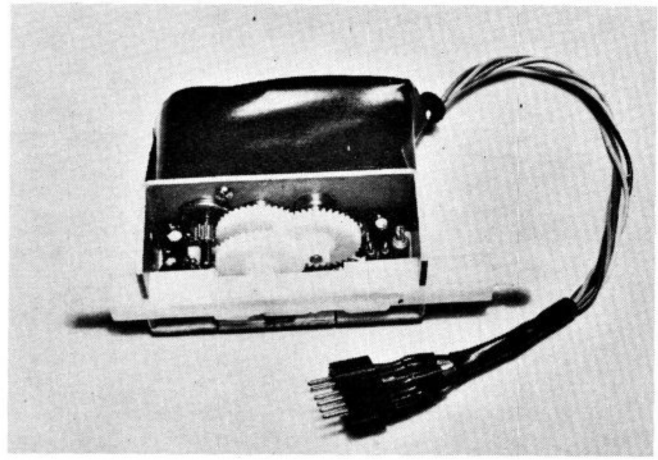
Amplifier installed on "C" frame. Gears and output arm removed in this photo.



Another view of servo assembly showing auxiliary board and servo motor.



Gears and output arm installed. Note plastic electrical tape around base of frame.



Completed servo less case halves.

points. (Make sure auxiliary board is pushed down flush on main board and at a right angle to it.)

( ) Cut 12" pieces of black, orange, red and yellow hook-up wire.

( ) Solder them as shown in figure 1 and insert them through hole A in the auxiliary board.

( ) Cut 12" pieces of blue and green and a 2¾" piece of brown hook-up wire.

( ) Solder them as shown in figure 2 and insert them through hole B in the main board.

( ) Route the blue and green wires over the top of main board components so they come out at the cutout in the auxiliary board along with the four leads from the auxiliary board.

( ) Insert and solder the other end of the brown wire into the vacant hole between Q11 and Q12 (68K ohm lead).

( ) Slip a ¼" grommet over the servo lead wires to hold them in place and out of the way.

NOTE: All wires should be routed between solder mounds. If any wire is routed over a solder mound it will be pressed down by the cover and may cause a "short."

FINAL WIRING OF SERVO

( ) With completed amplifier on the C frame make a check for last minute clearances, wiring, etc.

( ) Secure the amplifier with the mounting screw and again check for clearances, etc. Make sure the inside .05 motor capacitor doesn't short against any lands on the auxiliary board (see figure 1). Bevel the board if necessary.

( ) Solder the blue and red motor leads as shown in figure 1. Leave some "slack" in the wires to prevent breakage by vibration.

( ) Bend the wiper arms as shown in figure 3.

( ) Put the gears and push/pull arm in place one by one and work the servo by hand (use the second idler gear when fully assembled). Insure that the gears and/or arm do not rub or hit any component. If necessary trim the "knob" slightly on the bottom of the output arm to clear the .001 capacitor.

NOTE: When inserting or removing the output arm be careful the wipers or R10 are not damaged. Jack Port recommends using a thin piece of insulating sheet as a "shoe horn."

( ) Check alignment of wiper arms on R10 and brass strip making minor adjustments if necessary. The middle arm is not used and should "ride" between the brass strip and R10. Tension of wipers will be correct if they extend to bottom edge of P.C. board with output arm in line with C frame slots.

( ) Twist the servo leads together and slip a 1" piece of large heat-shrink tubing over them.

( ) Cut your leads to desired length (6" is about average).

( ) Unravel the end of the leads for about 1".

( ) Tin each lead and slip a ½" piece of small heat-shrink tubing over each wire.

( ) Clean and tin each pin of the connector where you are going to solder.

( ) Solder all wires as shown in previous wiring diagram.

( ) Slip the heat-shrink tubing in place and heat with a match or by rubbing your soldering iron over it. A match works better but may discolor the wires.

FINAL ASSEMBLY OF SERVO

( ) Remove output arm and gears.

( ) Check overhang on Q12 as per figure 1. It should not extend beyond edge of P.C. board.

( ) Bevel areas of P.C. board shown in figures 1 and 2 to provide clearance between copper lands and cover.

( ) Wrap a ¾" wide piece of black electrical tape around motor and P.C. board as shown in photo. This will give additional protection against accidental contact between case and components, especially Q12's case which is internally connected to its collector lead.

( ) Place top cover (with output arm cutouts) in position and adjust until top edge is flush with top edge of C frame. If holes in case and C frame don't line up "carve" away aluminum with an Xacto knife inserted in the cover holes.

( ) Tighten the cover in place with two each #2 x ⅛" screws.

( ) Insert gears and output arm—check final tension and alignment at this time.

( ) Center and cement insulating sheet, provided with servo, to bottom cover with contact glue.

( ) Slip on bottom cover and tighten securely with four #2 x ⅛" screws.

( ) Check output arm for binding. There should be a slight amount of "play" in all directions when worked by hand. If not adjust the cover. Do not attempt to operate the servo mechanically or gears may be damaged.

( ) Save mounting kit for installation.

PRELIMINARY CHECKOUT

( ) Measure the resistance between the black and green wire (black to black meter lead and green to red meter lead). You should read approximately 1.2K ohms. If you read a "short," check for shorts in the areas pointed out in the article.

( ) If the above reading is normal, and with the meter still connected, squeeze the servo case all over while observing the meter for shorts. If any show up during this check, correct the trouble before proceeding.

( ) Make the same check with the red lead connected to the red meter lead and black to black meter lead. You should read approximately 1.5K ohms and not show a short while squeezing; correct the trouble here also before proceeding.

( ) Run the same check between the black and orange lead. The normal reading is approximately 1.7K ohms.

( ) Run the same check between the black and yellow lead. The normal reading is approximately 1.6K ohms.

NOTE: While the above tests are not very scientific they may prevent "pranging" an airplane later on.

( ) If you have a good understanding of the circuitry you can check

SERVO PARTS LIST

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURER'S NUMBER
C1	.1 MFD Tantalum	T.I.	SCM104FPO35D2
C2	.05 Disc	Erie	Z5E
C3	"	"	"
C4	2.2 MFD (axial leads)	W.E.	CT 225
C5	"	"	"
C6	.05 Disc	Erie	Z5E
C7	"	"	"
C8	.001 Disc	RMC	SM .001 MF
C9	.01 Disc	CRL	CK 103
D1	Silicon Diode	W.E.	DHD 806
D2	"	"	"
D3	"	"	"
D4	"	"	"
D5	"	"	"
D6	"	"	"
D7	Germanium Diode	Ohmite	1N34 or equiv.
D8	"	"	"
L1	4 uh RFC	W.E.	4 uh RFC
L2	"	"	"
Q1	2N2924	G.E.	2N2924
Q2	"	"	"
Q3	"	"	"
Q4	"	"	"
Q5	"	"	"
Q6	"	"	"
Q7	"	"	"
Q8	"	"	"
Q9	"	"	"
Q10	"	"	"
Q11	GC 4008	T.I.	GC 4008
Q12	"	"	"
R1	22K ⅛ W	Ohmite	LIDVS
R2	4.7K "	"	"
R3	10K "	"	"
R4	4.7K "	"	"
R5	27K ¼ W 5%	"	LIDED
R6	4.7K ¼ W	"	LIDSM
R7	4.7K ⅛ W	"	LIDVS
R8	10K ¼ W	"	LIDSM
R9	1.2K ⅛ W	"	LIDVS
R10	1K Wirewound (Linear)	W.E.	1K SPL
R11	1.2K ⅛ W	Ohmite	LIDVS
R12	68K ¼ W	"	LIDSM
R13	10K ⅛ W	"	LIDVS
R14	4.7K ¼ W	"	LIDSM
R15	4.7K ¼ W	"	"
R16	22K "	"	"
R17	" "	"	"
R18	3.3K "	"	"
R19	" "	"	"
R20	100 "	"	"
R21	" "	"	"
R22	" "	"	"
R23	150K "	"	"
R24	" "	"	"
R25	15 "	"	"
R26	" "	"	"
R27	47 "	"	"
R28	10K ⅛ W	"	LIDVS

MISCELLANEOUS — ALL ITEMS AVAILABLE FROM WORLD ENGINES

Servo Mechanism with Cover, Insulating Sheet, Screws and ¼" Grommet
Male Six-Pin Servo Plug
Servo Mounting Kit
Package Hook-up Wire
No. 2 x ¼" Screw
Set P.C. Boards
1" Large Heat-Shrink Tubing
4" Small Heat-Shrink Tubing
Wiper —$\frac{5}{64}$" x 1¼" .006 Brass Stock

For Complete Set of Miscellaneous Items Plus R10 Order DTSM-1.

For Complete Servo Including Electronics Order DTSC-1.

NOTE: Again physical size will limit substitutions. Before you purchase substitute items make sure they will fit; don't buy them on an assumption.

your complete system now. If not (and no local Einsteins are available), spend the rest of the month getting your plane ready.

Next month I'll explain final tuning and testing as well as trouble shooting and preventive maintenance.

NOTE: If you don't know exactly what you're doing or the system is not operating perfectly — wait — don't fly it — you were warned! While waiting you can also recheck all construction for errors, replace all components you substituted hoping they might work (chances are they won't), straighten out all shortcuts you took, etc.; in other words make sure your system is according to the articles. If it is not, please don't tell anyone it's a Digitrio.

Give it another name like "Mickey-Mouse-itrio."

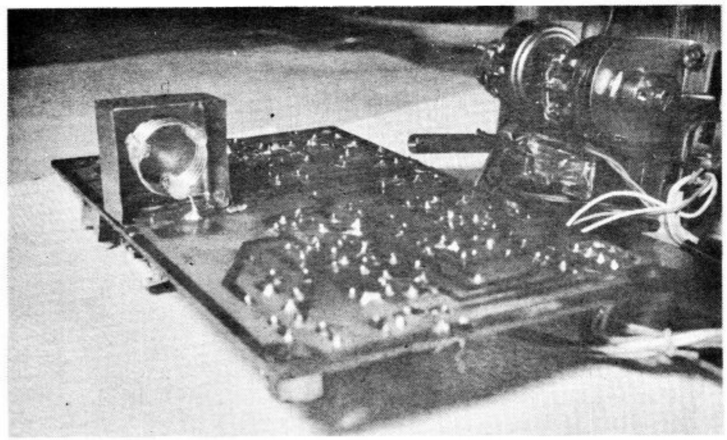
ADDING COPPER SHIELD TO TRANSMITTER

Some Digitrio transmitters have exhibited RF instability with the antenna retracted or removed. This is due to RF radiation from L5 entering the base circuit of the final amplifiers Q2 and Q3. With the antenna fully extended (assuming resonance) the impedance at the base of the antenna is relatively low and radiated RF voltage of L5 is minimum.

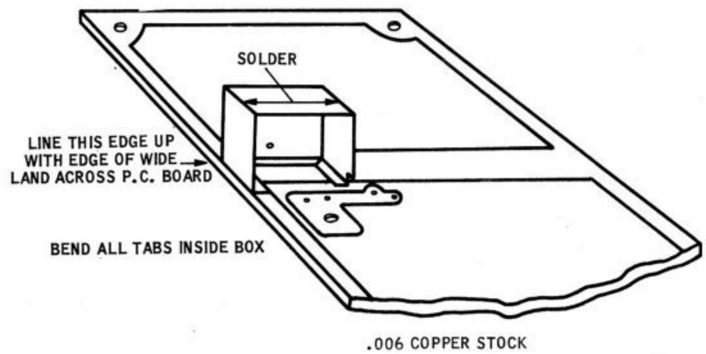
When the antenna is retracted (non-resonant) or removed the impedance rises as does the radiated RF voltage of L5. This can cause regeneration. The solution of course is to reduce the effect of L5's radiation when the antenna is non-resonant or removed. The copper shield described below will accomplish this and is easy to install. I recommend its use even if you are not having this trouble.

( ) If your Digitrio is already built remove L5.
( ) Cut the shield as shown and clean it thoroughly.
( ) Bend it to shape and check for fit.
( ) Pre-tin all surfaces to be soldered and solder top joints.
( ) Place it in position and solder it to the P.C. board. Use enough heat to allow "wet" solder flow insuring a tight "RF" bond.
( ) Drill a 1/16" hole for L5's lead and install L5. Use a piece of small heat shrink tubing over the lead sticking through the shield to prevent shorting.

NOTE: Center L5 in the shield compartment and insure that it does not contact the shield at any point. L5 will have to be moved over slightly toward the antenna mount and a short extension of L5's opposite lead may be necessary if L5 was previously installed. As a further precaution C4 and C5 should be mounted close to and bent over flat against the board to minimize stray RF pickup by their plates.

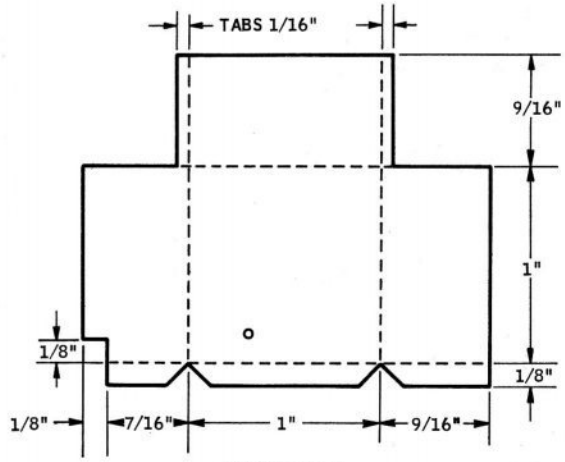


RF shield added to transmitter P.C. board. Below: Pictorial for adding shield.

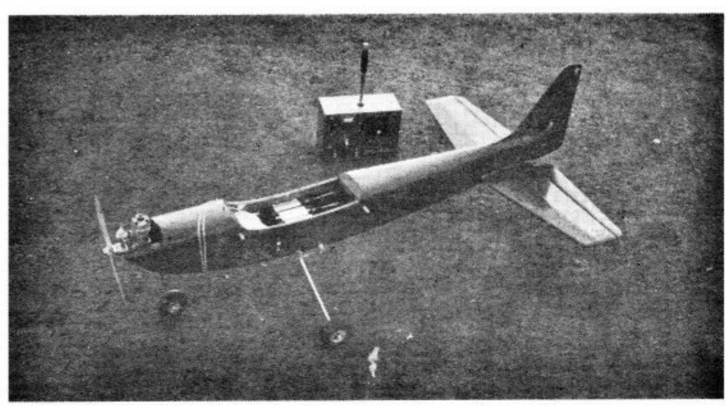


DIGITRIO TRANSMITTER SHIELD

Full size pattern for thin copper RF shield. Below: Ed Thompson's Tauri with Digitrio.



PATTERN 1 = 1



Miami, Florida, Dec. 30th: Dave Holmes of Virginia takes 1st place in Class II Novice and 2nd place Open Pylon at King Orange Internats using RCM Digitrio. Modified C.G. Falcon used in Class II, Midwest Hustler Delta in Pylon Event.

RCM DIGITRIO: FINAL SYSTEM ALIGNMENT

PART VII BY ED THOMPSON

PREFACE

ANY radio system is only as good as the care taken to adjust and check it out. If you have not bothered to read the previous articles thoroughly, followed instructions, or substituted parts without complete understanding of their use in the circuits, now is the time to read the articles thoroughly, go over your equipment and install the proper parts. The staff at RCM has spent many, many hours trying to insure successful duplication of the Digitrio, but we cannot make up for mistakes or sloppy craftsmanship by individual readers. Your system will only work as good as the efforts you put into it! Since there are only a few completed Digitrios flying at the present time I am not able to pass on the experience of many modelers at this time. For the benefit of all the readers RCM welcomes your letters pertaining to your experiences with the Digitrio. We will compile this information and publish it for all to benefit. If you make any changes or improvements please state why you did so and the results.

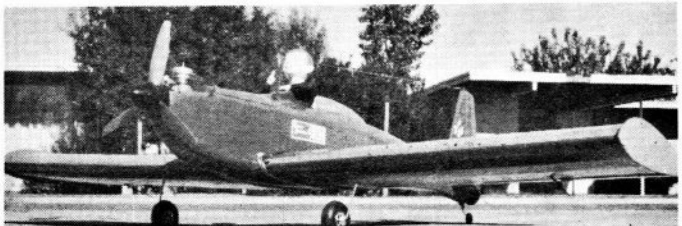
The letters for a four-channel system have been increasing and I will start packaging the "Digiquad" as soon as possible. I have several circuits built and tested and all that remains is to log one hundred flights or so to prove their reliability. I have circuits using SCR's, trigistors and plain old transistors. The one I select will be based on reliability, reasonable cost and ease of duplication. At the present time the transistor circuit looks like the best bet because most of the parts in the decoder could be used over again. It consists of two flip-flops and a one shot. It also has provisions for adding a fifth channel. The biggest problem is the mechanical changes to the transmitter. The only change in the airborne part of the system will be exchanging the decoder board with the new one and adding a servo.

I have been flying the present system as three-plus-one for the last month and will present this modification in next month's issue. Fearless Leader has designed a trainer, and Dick Smith and I have designed a contest type airplane to take advantage of the Digitrio's small size, low weight and continuity of control. Both will be presented in a forthcoming issue of RCM.

I will cover each component part of the system giving alignment instructions, preventive maintenance and pass on to you some of my experiences with the different circuits.

TRANSMITTER

The transmitter should be tuned up according to instructions in the November issue. These instructions pertain to RF tuning. The coder was adjusted when the pots were placed in the center



Upper right: Dave Holmes with 'Super Falcon' and Digitrio — winning combination at recent King Orange Internat's. Left: Dick Smith's 'Digifli', small multi designed for the Digitrio.

of their travel. Here are some things I have found necessary to insure best results from the transmitter:

1. **Problem** — Unstable operation of the 200us one shot (Q10 & Q11). This can be caused by two things. If Q10 has an above normal base emitter resistance, D4, D5 and D6 in combination may divide the base current to ground. Also RF radiation from the antenna may cause spurious triggering of this one shot.
   Solution — Insert another diode in series with the bottom of D4, D5 and D6 and base of Q10. Install a .01 MFD capacitor from collector to emitter of Q10. See figure 1.
2. **Problem** — Oscillator tuning not pronounced enough. This can be caused by operating Q1 too high on its collector current curve. This will occur especially if Q1 is replaced by a "hotter" transistor than specified, like a 2N708.
   Solution — Increase the value of R3 until the peak is well pronounced — 330 ohms is about optimum for 2N708's or "hot" 2N706's. Also replace C3 (.1) with a .01 to retain proper pulse shaping.
3. **Problem** — Excessive collector current of Q2 and Q3. This can be caused by excessive drive, "hot" transistors in the final or combination of both.
   Solution — Lower the value of C4 and C5 and in extreme cases remove them entirely to obtain collector current of approximately 100 MA. Collector current can be measured by lifting the cold end of L6 and inserting an MA meter.
4. **Problem** — RF feedback, especially with antenna collapsed or removed. This is caused by direct RF radiation of L5. This situation is exaggerated by the use of "hot" transistors which increase power.
   Solution — Install the shield as described previously.
5. **Problem** — Z1 burning out. This is probably caused by incorrect installation or "shorting" wires together while checking the transmitter.
   Solution — Install Z1 as shown on the overlay (with the bar toward Q9). Tape the ends of the pot leads to prevent shorting. Make sure there are no metal objects under the transmitter board during checkout — such as clipped resistor leads, nuts and bolts, etc.
6. **Problem** — Meter pegs when antenna is inserted or removed. This is caused by accidental "shorting" of antenna and ground.
   Solution — Turn off the transmitter before installing or removing antenna.

Before using the transmitter make sure that the RF signal is perfectly clean. Listen to a monitor and a clean buzzing sound should be heard with no "fuzzyness." Place your hand near the loading coil deliberately detuning the antenna and note if the signal is still clean. Retract or remove the antenna and note if the signal is still clean. Run through the tuneup procedures once more, noting if the meter peaks cleanly. If it does not have a smooth peak you probably have a little feedback. If you have an oscilloscope the signal can be observed by placing a diode between the vertical input connectors and running a 36" piece of hookup wire from the "hot" input connector. This will give you a visual display of the output signal and any trouble can be easily observed. I would suggest the scope treatment before using the transmitter (there is bound to be someone in town who has one — try your ham friend, TV technician, etc.) In any case your transmitter must be checked by an FCC licensee prior to operation. Take the RCM articles with you to assist him in this certification check.

Here are two acid tests for the output of the Digitrio. These tests will not detect regeneration but will visually indicate the radiated power.

1. With the antenna removed place a G.E. #47 pilot lamp **with a .01 MFD capacitor,** in series, across the antenna connector to ground and observe its brilliance. This is RF voltage lighting the lamp. The lamp should glow at approximately one half brilliance.
2. With a full charge on the batteries it may be possible to light an NE-2 neon lamp with RF voltage on the antenna. To do so hold the lamp by one lead and touch the other lead above the loading coil. With your other hand tune the antenna by placing it near the loading coil. The NE-2 lamp should light. This again is RF voltage doing the work.

The front panel template shows the P.C. mounting posts too close together — increase the distance between them horizontally by ¼". The only preventive maintenance necessary for the transmitter is occasional adjustment of the stick springs and a drop of oil on the pot shafts.

RECEIVER

Tune the receiver as described in the September issue. If you have any problems the voltage checkpoints should reveal where they are located. Here are some problems and solutions I have encountered.

1. **Problem** — Meter reads negative instead of positive while tuning. This is caused by improper installation of diode D1.
   Solution — Install D1 properly (with the bar up). The picture of the receiver on page 18 of the December issue shows D1 apparently installed backwards. This is due to a shadow and the bar is not visible at the top of the diode.
2. **Problem** — Lack of sensitivity. This can be caused by many things. In one case I had reversed the black and white IF transformer. In another case I used a 10K for R3 and a 1K for R7.
   Solution — Double check installation of all components as per the overlay. Again I would recommend the scope treatment prior to using the receiver. Place the scope leads where the meter is used for tuneup. Check your signal for smoothness with a weak signal. If the receiver is carefully peaked with the meter as described it should correspond to the smoothest signal on the scope. Therefore once you have ascertained that the signal looks good a scope is of no further use for receiver tuning. I would recommend that the IF's be

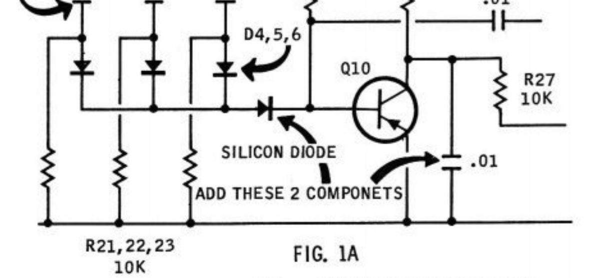


FIG. 1A

200us ONE SHOT MODIFICATION

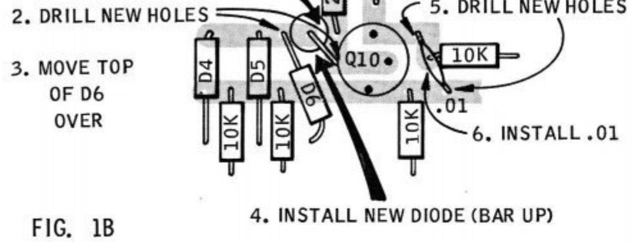


FIG. 1B

200us ONE SHOT MODIFICATION

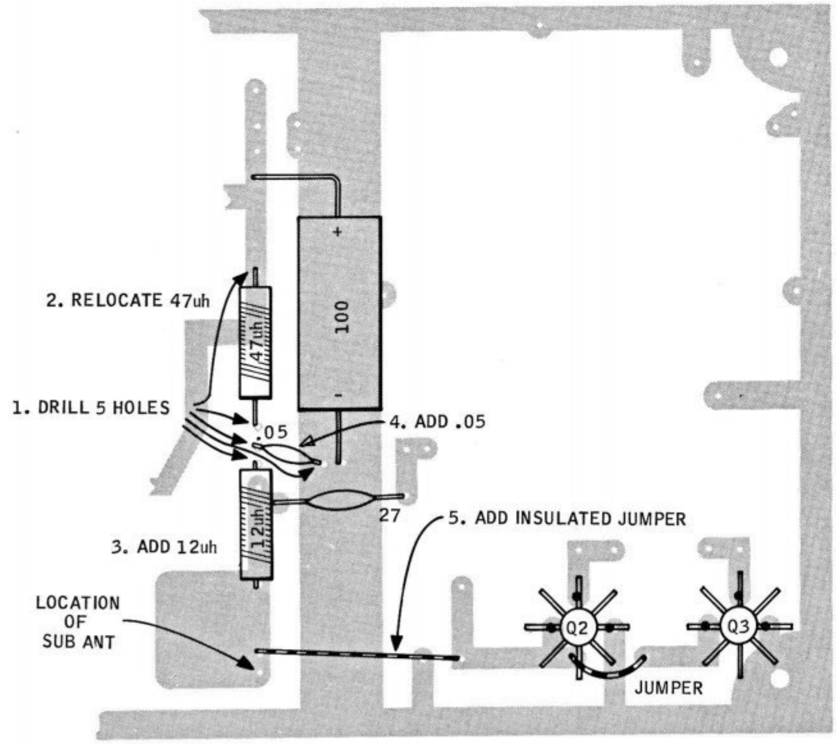


FIG. 2B

MODIFICATION OF TRANSMITTER POWER AMPLIFIER

retuned about twice a year as temperature changes go from one extreme to another.

DECODER

There is no tuning procedure for the decoder. All adjustments and circuit operating parameters are established by resistor capacitor combinations. The scope treatment here will reveal any discrepancies and is about the only way a qualitative check can be made. I have experienced no difficulty with the decoder so cannot pass on any problems or solutions at this time. I would recommend however that you double check the installation of all parts prior to using it—especially the shield installation and grounding strap. On the World Engines kit the grommet slots will have to be deeper to clear the case flange. A hole will have to be drilled for insertion of the grounding strap.

SERVOS

Close observance of the visual aids and instructions in the servo article should preclude any trouble here. I have run into a couple of problems which I'll describe.

1. **Problem** — Servo runs to one end when signal is applied. This is caused by incorrect installation of one or more diodes.
   Solution — Check the overlay carefully for improperly installed components.
2. **Problem** — Servo erratic during vibration check of aircraft. This was due to a "cold" solder joint at the collector lead of one of the motor driver transistors.
   Solution — Check all soldered joints carefully.
3. **Problem** — Motor servo chatters or buzzes with signal applied. This is due to the wide sampling period of the motor control one shot. In some cases it will not allow the extreme resolution the servo is capable of.
   Solution — Replace R14 and R15 (4.7K) with 10K's. This will broaden the resolution slightly and eliminate this condition.
4. **Problem** — Unable to secure full travel of servo output arm (adjustment will be covered later). This is caused again by the nature of the motor control one shot. Due to the demand on the one shot to recover so rapidly circuit components may make full travel impossible.
   Solution — Rather than "digging" into the decoder to replace critical parts simply replace R5 (27K) with a 33K. This will increase the reference generator one shot pulse and allow a longer recovery time for the motor control one shot in the decoder.

Although this has not been a problem, I would recommend that four small holes be drilled and resistor lead remnants soldered where the auxiliary board and main board are joined.

If other problems are encountered with the servo your best bet is to contact the local Einstein for assistance.

One source of trouble is the wearing of the wiper fingers on the output arm. This is not a new problem but it is aggravated by the coarse surface of the wirewound resistance element. My rec-

Artwork illustrates simple modifications to transmitter power amplifier, described in article.

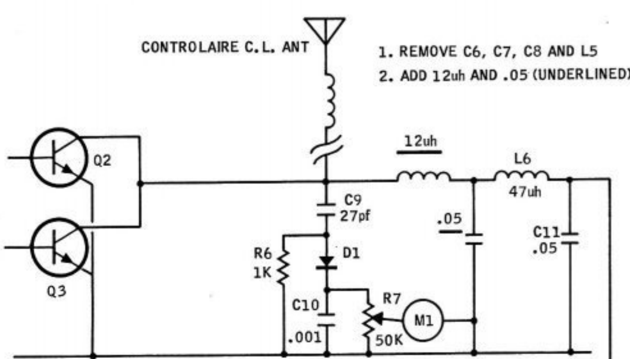


FIG. 2A

MODIFICATION OF TRANSMITTER POWER AMPLIFIER

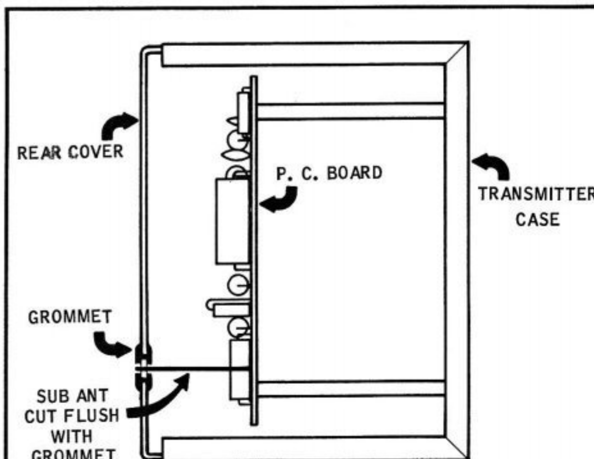


FIG. 2C

MODIFICATION OF TRANSMITTER POWER AMPLIFIER ommendation here would be to replace the output arm when wear becomes excessive. Each servo should be thoroughly checked and cleaned, the wipers retensioned and inspected every fifty flights or so. When you consider the price of an output arm against the cost of a complete aircraft it is easy to arrive at the benefits of output arm replacement. I use "Spra Kleen" produced by G.C. Electronics Co. #8666. It both cleans and lubricates. After wiping clean the gears, etc., spray the solution into the front compartment of the servo and blow away the excess. This will also quiet down a mechanically noisy servo. Each servo can be tailored for more or less resolution by changing R14 and R15. Increasing their values will widen the resolution and vice versa. The operation of the servo as is produces optimum results.

COMPLETE SYSTEM ALIGNMENT

After you are satisfied that all components are in proper operating condition hook the system up making sure the batteries are fully charged and that they are in good shape. Preliminary to final adjustment remove all gears from the servos and reinstall the output arms. Place the output arm in the approximate center of its travel on each servo. Temporarily disconnect the motor control servo, we'll do it last. Adjust the motor control trim pot (R13) inside transmitter to its highest resistance – clockwise looking down on the transmitter with the rear facing you. Turn on the transmitter and receiver – the rudder and elevator servo motors should run. Now move the output arm manually and find the point where each servo motor stops and reverses direction. Manually place the servo output arm between motor reversals until the motor is stopped. By movement of the control stick of the transmitter you should be able to control the direction of motor rotation. If your servos do not meet this condition recheck the centering of the transmitter control pots and try again. If it still does not operate properly you have system troubles and trouble shooting will be necessary to isolate the malfunctioning unit. If only one servo works properly your best bet is a defective servo. If neither works properly swap one with the extra servo and if it does not work either start with the decoder and work your way backwards until you find your trouble. If the servos work properly or you have corrected your trouble you can now disconnect the two servos and connect the motor control servo. With the motor control pot centered adjust the motor control trim pot R13 (inside transmitter) starting from the high resistance end.

Continue adjusting slowly until the motor stops and reverses. You should now be able by movement of the motor control stick to reverse the motor like the other two servos. Turn off the equipment and reinstall the gears and output arms. Turn on the system and note the position of the output arms. Move the stick and note the direction in which the servos travel. Now move the trim levers to see if the servos respond in the same direction as stick movement. If not reverse the yellow leads on the trim pot affected.

Chances are your output arms will not be exactly centered. To center the rudder and elevator servos loosen the trim pot collars and rotate the shafts until centering is accomplished. Place the trim pot levers to the center of their cutout and retighten. To center the motor servo slightly readjust R13.

You should have approximately ½" overall servo throw with 12% trim action on the rudder and elevator. The motor control servo should have slightly more throw. The servo throws can be altered for use with different types of control sticks by changing R9 and R11 (1.2K). Larger values will increase the throw and vice versa. The motor control servo throw can be altered by changing the value of R29 in the transmitter – lowering its value will cause more throw and vice versa. Servo resolution can be checked by slowly moving the trim pot to one end of the cutout. Listening very carefully move the trim pot stick in the opposite direction until the servo starts. You should have about 1/16" to ⅛" movement before the servo starts. Servo tailoring for more or less resolution is described previously under servo comments. If satisfactory motor control operation is not obtainable modify this servo as described previously in servo comments. To peak the antenna coil place the back on the transmitter and remove the antenna. Extend the receiver antenna and with your wife "pumping" the control stick have her back off until servo action is erratic. Peak the antenna core until solid operation is obtained. With your wife backing and you peaking adjust for maximum range. You should get from six to ten feet with solid control even though the servos will become noisy at about four feet. Make any last minute checks and if your conscience bothers you about any shortcuts you may have taken during construction, now is your last chance to repent. "Button up" your servos, check all screws for tightness, etc.

INSTALLATION

Installation of the system does not require more than average care or consideration for a digital system, just pack it in. Here are a few tips that should be followed for best results.

If you are using a shoulder wing aircraft run the antenna out the leading edge of the wing, loop it over the wing dowel and run it back to the rudder. If you are using a low winger run the antenna out the top of the fuselage at the leading edge of the wing and run it back to the rudder. Possibly the best antenna you could use would be a 36" piece of music wire as a vertical antenna. A short length of brass tubing can be epoxied in the aircraft, the end of the wire crimped and forced into the tubing. The main point here is to keep the antenna away from the servos so it does not pick up servo noise. This can shorten range considerably. Do not worry if the controls bind a little. This does not mean that good craftsmanship practices should be ignored however, as a good mechanical linkage system will enhance the system's characteristics. I have used nylon tubing and flexible cable for all control surfaces including aileron and find it hard to beat for easy installation and trouble free operation. Avoid any metal to metal joints by using nylon clevices – especially on the motor control arm. Be sure your servos are shock mounted using the brass bushings supplied. If you mount the servos on a flat piece of plywood, countersink ¼" holes beneath the two servo cover screws to allow free movement. If it is desirable to reverse servo throw it can be accomplished easily at the transmitter. Reverse the outside leads on both the stick and trim pot affected.

PRE-FLIGHT CHECK AND ADJUSTMENT

Make a last minute check of antenna core tuning with the transmitter antenna removed. Adjust all your flight surfaces to neutral with the trim pots centered in their cutouts. Now make a ground range cheek of the system with the antenna installed and completely collapsed. Do not settle for less than 300 feet under these conditions. Make a vibration check with the antenna removed – the range should be approximately the same as when the motor is not running. Turn the transmitter off and install and extend the antenna. You should be able to place the transmitter and receiver antennae within 12" of each other before swamping occurs. If the system appears erratic in any way whatsoever find out why and correct the problem before you fly.

FLYING

If you are not used to flying a digital system you are in for a few surprises. The first one will probably be on takeoff when you pull the stick back and the plane goes straight up into a stall due to over control. The next one will be when you give it up or down and get right or left simultaneously because as you push the stick you will inadvertently veer off to one side or the other, especially during rolling maneuvers. And finally when you flare the plane out for a landing it stalls again due to over control. If you get past your first flight successfully by judicious control stick movement rather than cramming the stick around, your next flight will be better and about your fifth flight you will be truly amazed by our own capability and your friends will soon get tired of your bragging and tell you to "shut your mouth!" Even your wife will get tired of hearing about your new experience. As your proficiency progresses and time and money permits you will go from one plane to another trying to find one to match the system's capabilities.

CONCLUSION

After you are satisfied with the system performance some of the components can be epoxied in place to prevent vibration problems later on. Here are some recommended areas.

- *Receiver* – FL1, Q2, D1, both 40 MFD caps, Q6 and T4.
- *Decoder* – Q10, both tantalums (.1 and .22) and D5.
- *Servo* – .1 tantalum, Q11, Q12, and junction of auxiliary and main board.

In general look for items that appear top heavy, have a large mass or are fragile. The more epoxy you use the harder it will be to repair the equipment later on if necessary.

I have begun simplifying the Digitrio and have just recently completed a modification to the transmitter eliminating some parts and making tuneup much simpler. These changes are shown in the drawing and tuneup requires only peaking the core in L2 with the antenna extended. This also eliminates the troublesome RF radiation of L5.

The final amplifier collector current should be 45-60 MA. Install a subantenna ala Controlaire – you should get approximately two feet of range with the antenna removed. As ways to simplify the circuits are proven they will be published and in a short time with your help, by your letters, the Digritrio should become a commonplace item in the RC modeler's inventory. I am proud of the Digitrio and I think you'll see why when you get yours completed. The entire staff of RCM deserves the lion's share of the credit because the "Digritrio" would not have been possible without them. I have been so swamped with letters that it may seem that replies are slow (which they are). Now that the bulk of the work on Digitrio is completed I will try to be more prompt. Your letters, comments and questions are always welcome.

The Editors of R/C Modeler Magazine would greatly appreciate your assistance in completing the attached questionnaire. It will assist us to determine how we may improve future technical articles similar to the Digitrio series:

R/C MODELER MAGAZINE

P. O. Box 487

Sierra Madre, California

1) I built my Digitrio system from: kit ____ scratch____ both____.
2) My Digitrio: worked right off or with modifications____
   My Digitrio: worked with help of a technician____
   My Digitrio: doesn't work____.
3) How well does your Digitrio work compared to other proportional systems? Excellent____ Fair____ Poor or doesn't____.
4) Did you like the presentation of the Digitrio? Yes____ No____
   (If no, please say why in remarks.)
5) How much experience in electronics do you have? Years____
   In R/C? Years____.
6) How many Digitrios are flying or being built in your area?________.
7) How much (approximate) did it cost you to build the Digitrio?
   $__________.
8) If you had to do it over, would you still build the Digitrio?
   Yes____ No____ (If no, please say why in remarks.)
9) What single thing do you like the most about the Digitrio? ________
   ____.
10) What single thing do you dislike most about the Digitiro? ________
   ____.
11) What other gear do you own? reeds____ single channel____
   proportional____.

REMARKS: ____

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____

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Name ______________________________ **Age** ____

Address ______________________________ **Zip** ________

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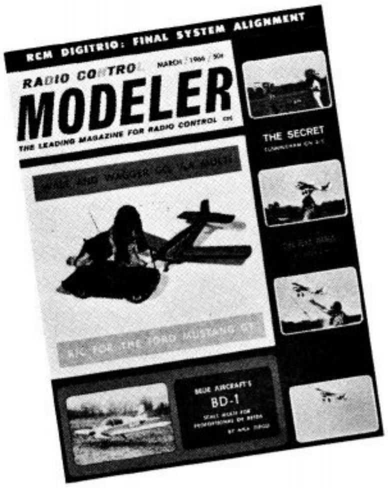

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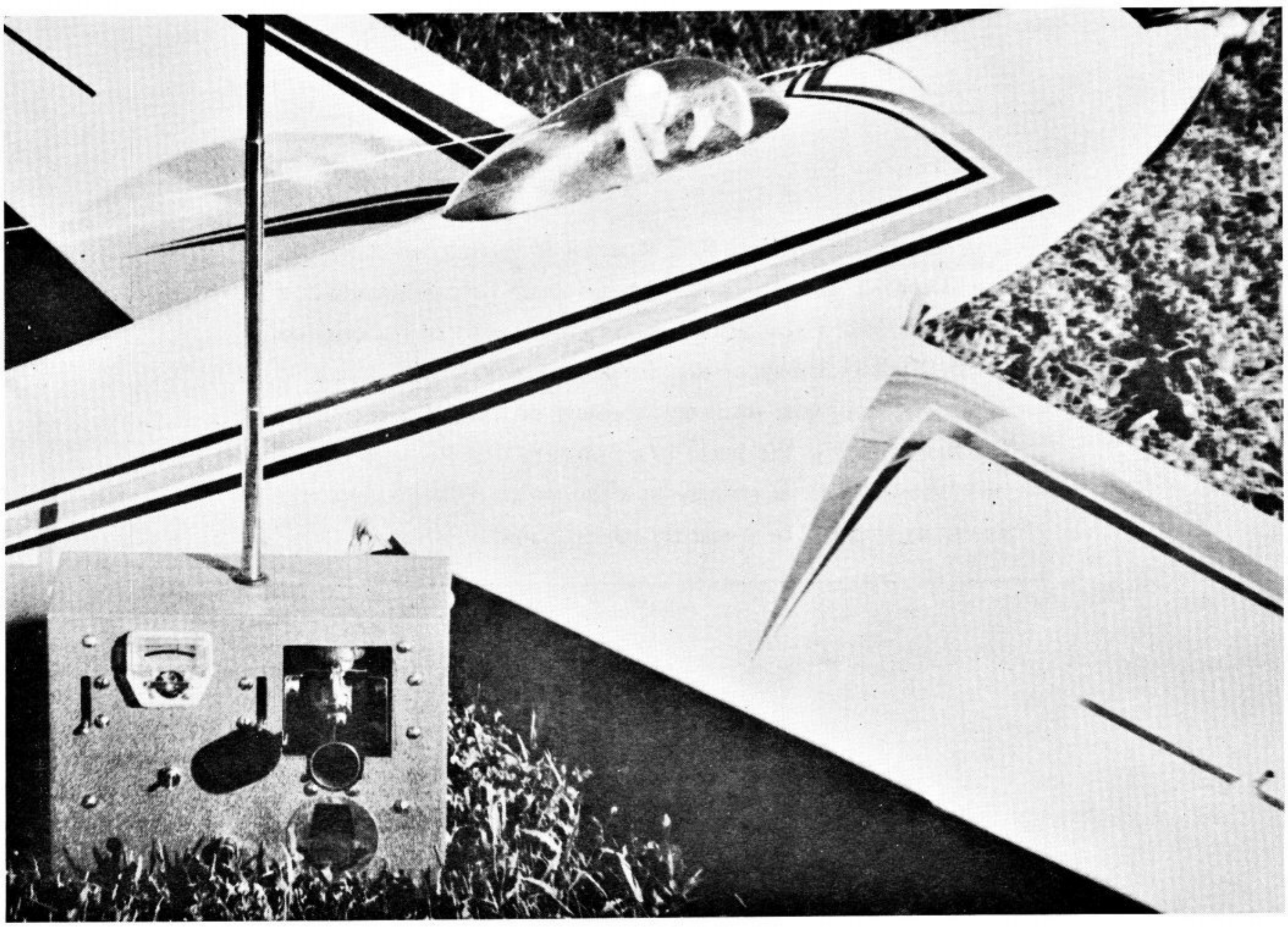
CONVERTING THE

RCM DIGITRIO

TO FOUR-CHANNEL OPERATION



Written By
Ed Thompson

Edited By
Don Dewey

RADIO CONTROL MODELER MAGAZINE

P.O. BOX 487 • SIERRA MADRE, CALIFORNIA

*** NOTE**

Due to popular request R/C Modeler Magazine has reprinted the "Digitrio" exactly as it appeared when first published as a series in 1966. Because this is an exact reprint of the original RCM Digitrio, many prices, stock numbers, firm names and addresses, coupons, etc., are obsolete or have changed since the first printing. We want to emphasize that this reprint has been made available strictly as a service to RCM readers and not as an updated or currently edited book.

DIGITRIO DASH-FOUR

Modifying the

RCM DIGITRIO

To Four Channel Operation

By ED THOMPSON, RCM TECHNICAL EDITOR

R/C MODELER

TECHNICAL FEATURE

DIGITRIO DASH-FOUR

Modifying the RCM DIGITRIO To Four Channel Operation

By ED THOMPSON, RCM TECHNICAL EDITOR

THIS month I have been able to do quite a bit of work on the four channel modification and will be able to complete the articles within about two or three weeks from the date of this writing. A brief discussion of the four channel version may help relieve some of the anxiety for those of you who are patiently waiting.

First of all, these modifications will allow present Digitrio owners to add another channel without performing "major surgery" on their units. The largest and most tedious task will be the mechanical changes to the transmitter in order to provide the additional control function. With this month's article we have included a three-control stick designed by Warren Thomas and Jim Holman of Jonesboro, Arkansas. This stick can be used with your existing Digitrio if it was built per the original article. Although this unit is not the easiest stick to duplicate, it does a good job. Warren and Jim built the prototype on the kitchen table with a minimum of assistance from the machine shop. I have logged well over a hundred flights with this stick, as presented here, and am convinced that a three control stick is the answer to improved flying over the more conventional two-stick arrangement. This is not to imply that you will be able to fly circles around Cliff Weirick simply because you have a three control stick, or that the three control stick is even superior to a two-stick transmitter. This, of course, depends on the individual. But — if you are an average flyer, like myself, you will note an immediate improvement in your flying abilities with the added confidence this type of contol unit affords.

On the other side of the ledger, the three-control stick has been played down by certain flyers with the implication that coordination of the various motions required are physically impossible to accomplish with any degree of proficiency. This is simply not true, and if you haven't tried it — do so! I think a better reason for the lack of popularity of this method of control are as follows:

1. Manufacturers have not come up with a good CLOSED FACE three control stick and the two stick arrangement is better for them from both a production and cost basis.

2. The average flier has not flown a digital system with a three control stick and has no basis of comparison. They are used to BOUNCING a stick from stop to stop and are prejudiced.

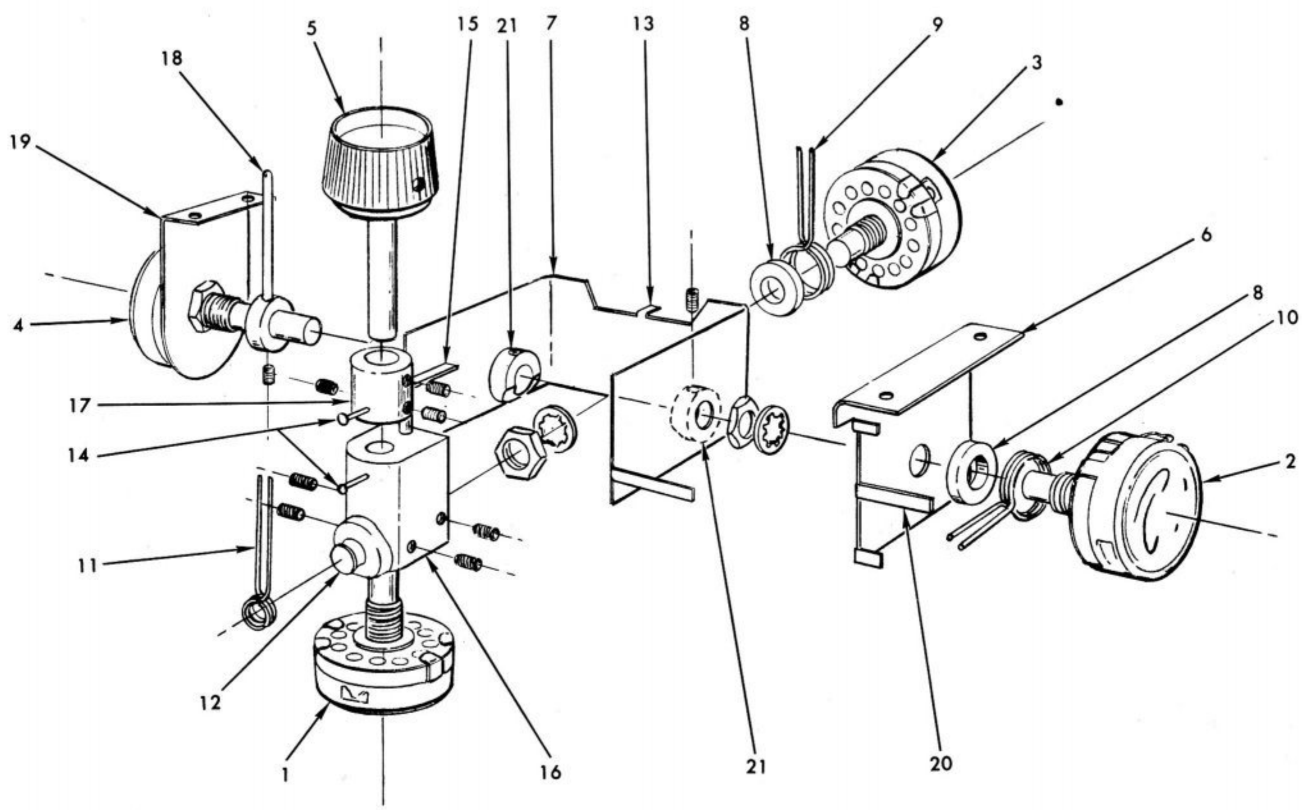
3. A lot of fliers are impressed more with the looks of a transmitter than how it operates. They simply can't live with a gaping hole in the front of their LITTLE JEWEL.

I will make the prediction that, if and when a good commercial, closed-face three-control stick is made available to the R/C modeling public, it will be warmly accepted and gain widespread acceptance.

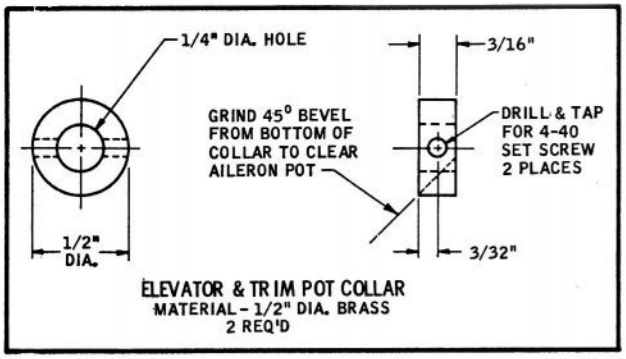
There are two Bonner stick versions of the RCM Digitrio-4. On one version, a single Bonner stick is used with the addition of a pot with a spring centering lever control for rudder added just below the meter. The two stick deluxe version, shown with this article, utilizes two Bonner sticks and conforms to the currently accepted transmitter layout.

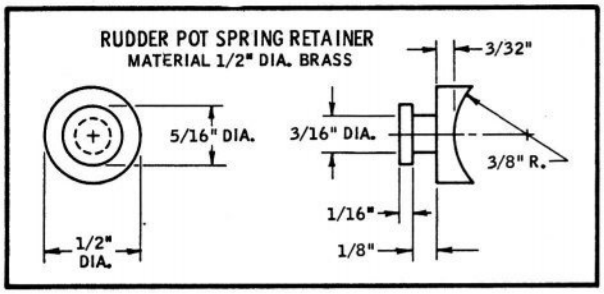
The electronic changes to the transmitter are simple, requiring an auxiliary board containing two more one-shots. After the modification you will use five pulses to obtain four channels. The reason for the **extra** pulse will be apparent after you read about the new decoder. There will be a minor change to the unijunction circuit, eliminating this stage as a control function. It will be retained only as a "clock." I don't particularly like that term — it tends to exaggerate its lowly function of providing a sync pause, and is one of several terms bantered about in advertisements to make products sound like a cross between a Gemini control system and an electronic brain that has been blessed with Holy Water.

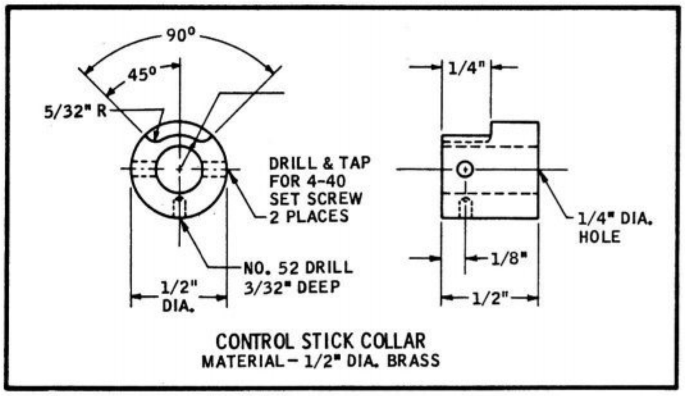
EXPLODED VIEW - COMPLETE DIGITRIO 4 STICK

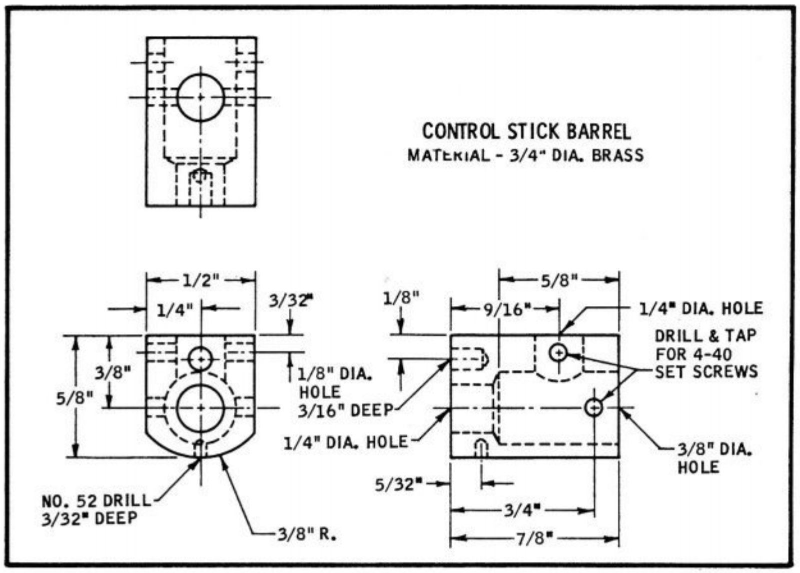


1. RUDDER POT
2. ELEVATOR POT
3. AILERON POT
4. ELEVATOR TRIM POT
5. CONTROL STICK
6. PART "A"
7. MAIN "U" FRAME
8. SPACER (2)
9. AILERON CENTERING SPRING
10. ELEVATOR CENTERING SPRING
11. RUDDER CENTERING SPRING
12. RUDDER SPRING RETAINER
13. AILERON CENTERING STOP
14. RUDDER POST (2)
15. AILERON POST
16. CONTROL STICK BARREL
17. CONTROL STICK COLLAR
18. TRIM POT LEVER
19. TRIM POT BRACKET
20. ELEVATOR CENTERING STOP
21. COLLAR (2) NOTE: COLLARS ARE SOLDERED TO MAIN "U" FRAME







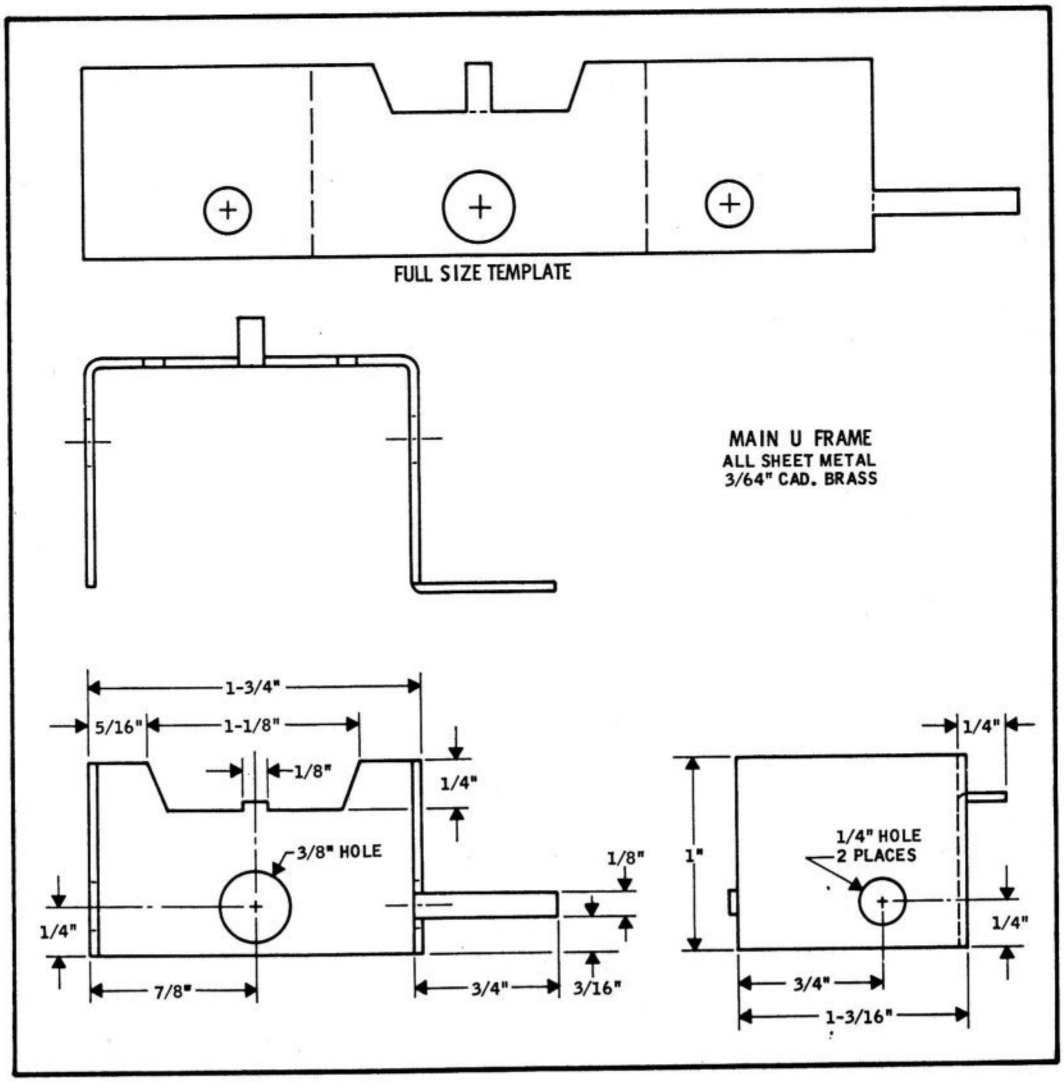


The decoder will be entirely new, and as stated before, will use silicon controlled switches. This will not be a "breakthrough" (another one of those terms I abhor), but what I consider to be a common sense usage of these so-called **new** devices. I say "so-called" new devices because they have been around for some time. This decoder is basically the same as I first used in 1960. At that time I used 3C30's (trigistor) which were anything but inexpensive! Recently, General Electric introduced a low-cost line of these devices, making their use practical. I am using the 3N84 in my decoder, and it might be a good idea to round up four of these before the supply dwindles. The only hobby distributor handling these units at the present time is World Engines. Allied Radio should have them, and any electronic parts distributor should be able to obtain them for you if they want your low-volume business.

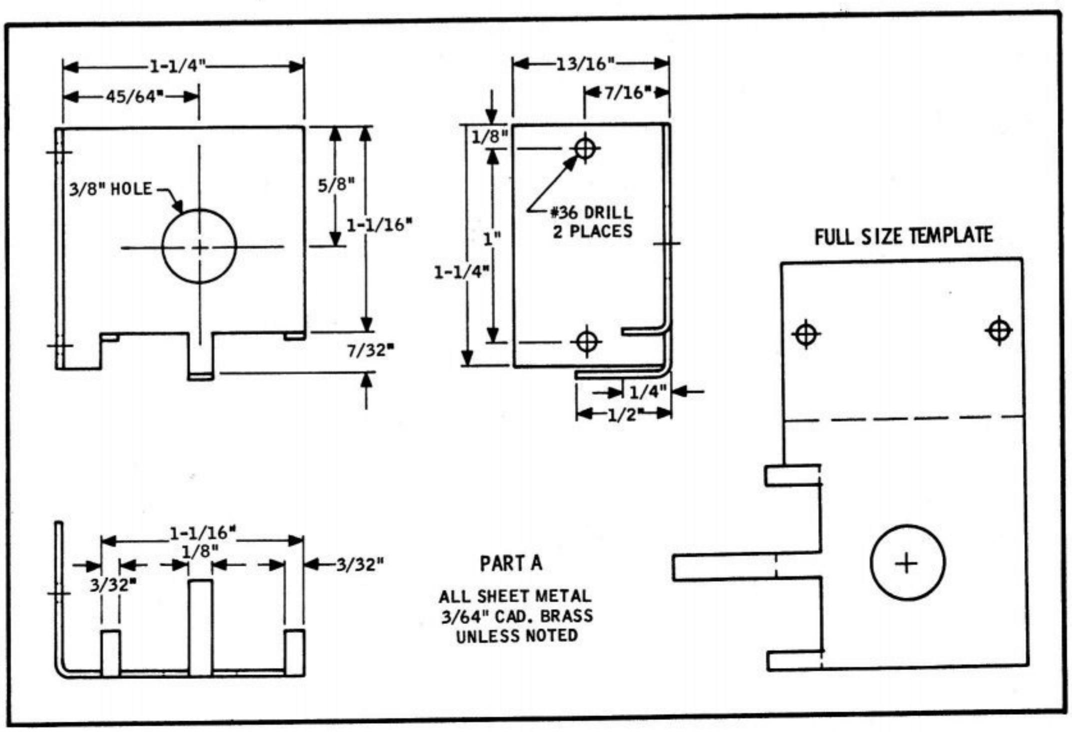
And — before the letters start rolling in about how I sold you out by not extending the present decoding method used on the original Digitrio, let me get **my** licks in. There are many reasons for going to the SCS's. As I said before, I have used this system before, and the only reason I didn't use it on the original Digitrio was because I wasn't aware of a low-cost SCS. The SCS decoder is superior to the original method and this should be enough reason for you not to fret. If you are harboring fears about wasted expense of the present decoder — forget them. Most of the parts on the present decoder can be used for the modification — it was planned this way. Let me say at this point, however, that I don't recomend that the unexperienced Einstein with a 250-watt instant heat soldering gun try it! Care should be taken when parts are transferred from one PC board to another unless you are proficient at salvaging parts or have a local technician handy.

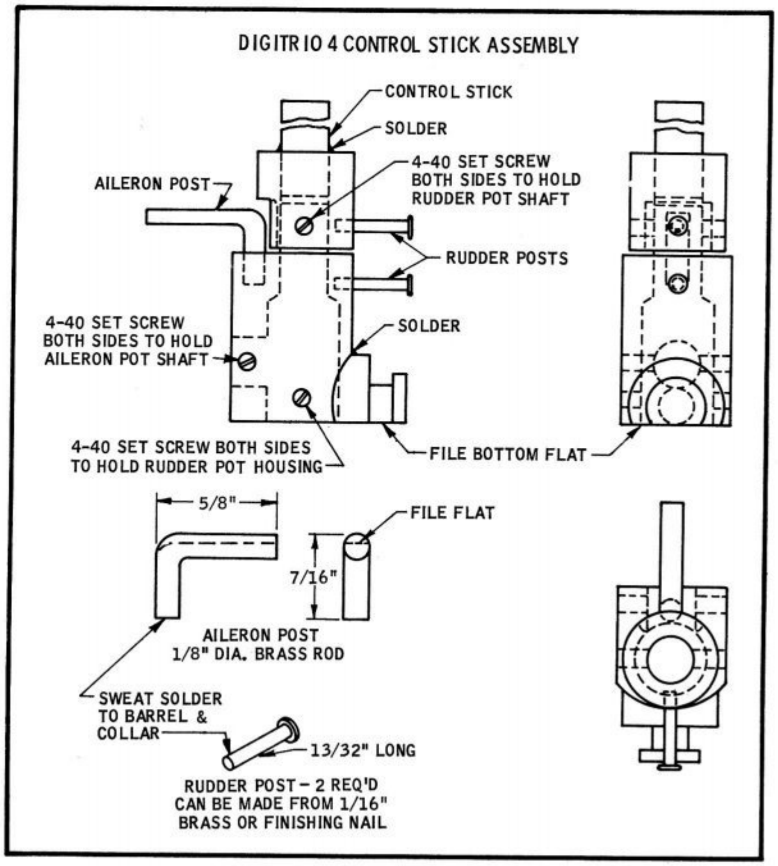
To start with, the new decoder is usable with as many channels as you wish to use with only minor considerations. In other words, it is easily expandable and can be used with one channel, or as many as you can find a use for. It will require one SCS per channel and all channels are operated in series. This eliminates complicated circuit inter-connections, timing circuits, gates, etc. So far, in addition to the four channel versions of this decoder that are currently flying, there are several five, six, and two eight-channel versions performing flawlessly. In order to obtain independence from timing problems, no one-shots are used in the new decoder, or any other type of circuit that is self-completing, except the method of sync, which is more of a passive type and completely non-critical, within reason. This is also why five pulses are used instead of four to obtain four channels. Instead of a one-shot sampling the sync pause for the additional channel, we will turn off the last stage with a pulse from the transmitter. Therefore, the decoder is commanded from the transmitter for all channels, rather than the decoder deciding the length of the additional channel pulse. This will come as a pleasant change to some of you who might be cussing the motor control on the original Digitrio. Also, since no requirements for timing are demanded of the decoder, there is no point where the servos will chatter to warn you of battery discharge. The new decoder will operate smoothly until the batteries are discharged down to their end point voltage and beyond! This increases the flying time per charge on the receiver pack considerably, and it seems as though they will never run down. So, "beware, lest these sintered-plate monsters do you in."

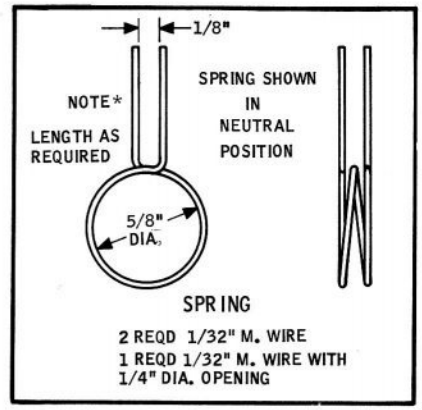
All-in-all, the new decoder is a superior design as compared to the original. It is also a better decoder when used for three channels. Before I am bombarded with letters from all the prophets possessing mystic powers of hindsight, let me say that I consider it as a normal improvement in circuitry that evolves from testing, evaluation, and plain ole' hard work! I don't care to hear all the, "I knew there was a better way" and associated cliches from the latter-day digital experts! If I sound bitter this month, it's because I am! I remember the time that I couldn't find anyone to discuss digital R/C circuits with, but since the Digitrio was introduced I find that some people have be-



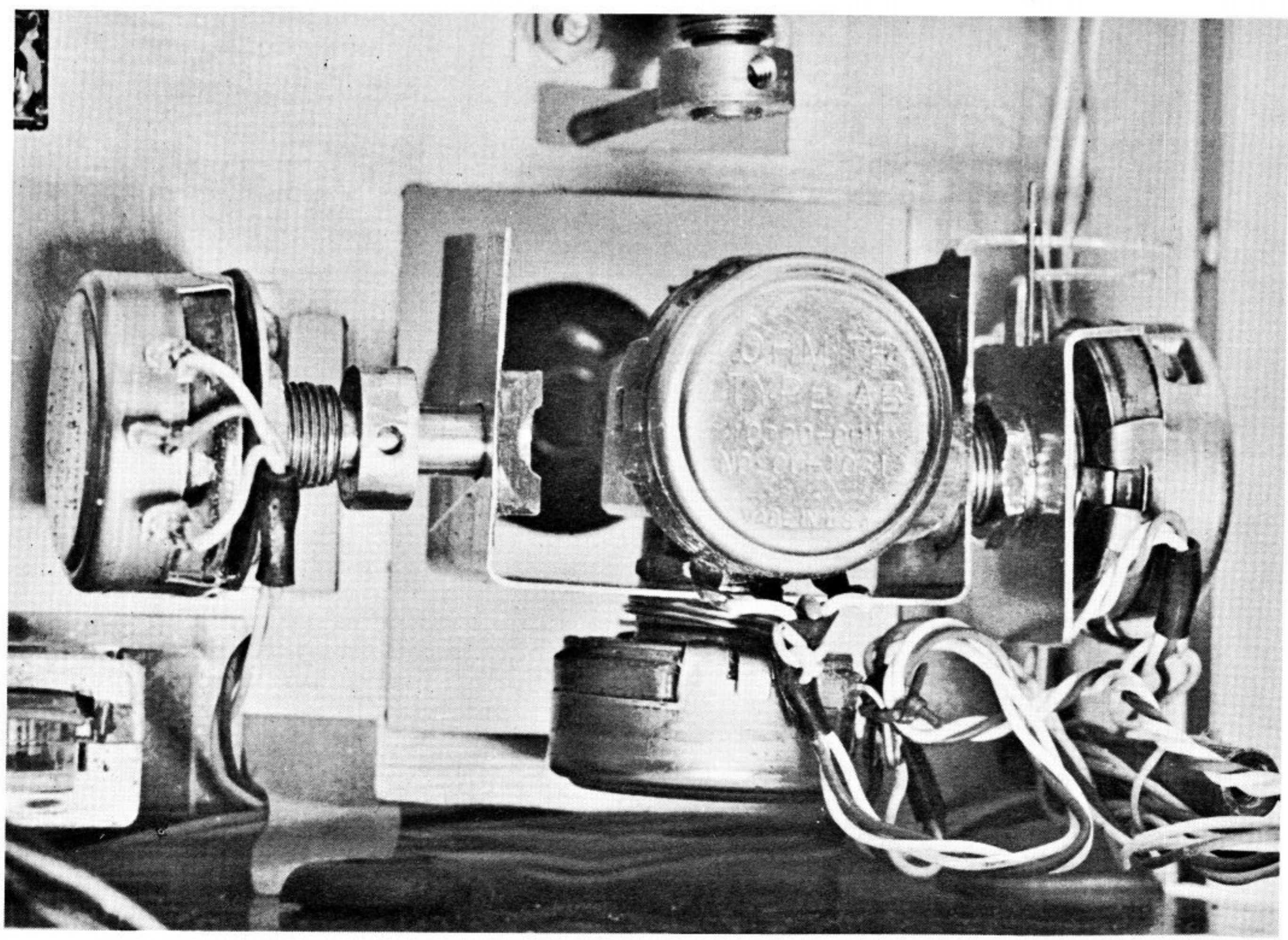
ALL STICK PARTS SHOWN FULL SIZE







come experts overnight and feel that they can modify my circuitry to their own liking and still hold me responsible for the results. As long as their modifications work the system takes on a new name and a magical air of detachment from the Digitrio. Of course when it doesn't work it is simply a lowly Digitrio. All I can say to this is (and I've said it before) if you want to modify, don't call it a Digitrio — give it a new name like the MICKEY MOUSE-ITRIO. This is not to imply that improvements cannot be made to the Digi-



trio — far from it! We encourage originality and hope that we have aroused the experimentors to come up with newer and better systems.

Digital systems are now at the point where they are becoming simpler, both in concept and parts count, than their predecessor ANALOG. They are, in fact, becoming simpler than the MICKEY MOUSE systems that wiggle and wag (except the servos). This, plus the fact that reliability has increased to what we had been accustomed to previously, is going to change a lot of design concepts and the R/C modeler as a whole is going to benefit. R/C radio equipment is starting to emerge from the hold that a certain few had on its advancement. This is due to several things. Number one — I think — is that the R/C modeler of today is not as easy to satisfy as he used to be. He demands higher quality and is fed up with being treated with disregard and having to make do with what is on hand. In the past this was the modelers own fault. Let's take a clear look at why digital came into being. It wasn't because the R/C modelers as a whole demanded a better system, it was simply because a handful of people worked like hell to come up with a better method of control. These same people sunk a lot of money into its development not knowing whether it would pay off or not. Fortunately it was a winner. As a result, a lot of manufacturers jumped on the band wagon. Then, and only then, did you, the modelers, start demanding better reliability of this new system. Right now you have the manufacturers trying to outdo each other for your dollar. Don't lose this advantage by becoming complacent again. Demand even better systems at reduced prices. Tell them what you want and I'll guarantee they will like it. When they can find out ways to please you and give you what you want it puts smiles on their faces and dollars in their pockets.

Now, for the first phase in converting the Digitrio to a Digitrio-4, Jim Holman and Warren Thomas describe their Digitrio experiences and three-control stick fabrication as follows:

"Hey! Did you hear that? Well, if you didn't, it was two fellows in Arkansas yelling shouts of joy at making two discoveries — one a long time ago when RCM magazine was first published, and the other when we were introduced to Ed Thompson and a thing called the Digitrio.

"Digitrio . . . this name was to be in our minds from September 1965 to March 1966, and you know, I don't think now it will ever be off our minds. Here is how it all started.

"Everyone around here was flying reeds — and there's a lot to be said for reeds — but if you haven't flown proportional . . . well, you ain't never flown! So one day my hand was lucky enough to get hold of the only proportional stick in Jonesboro, and a desire was nailed in my mind right then! I had to have a propo system somehow! Jim Holman was already nailed, so I sold my reeds, hocked my wife and kids, and sold the truck! Boy! They nearly sheared the sneeze pin right out of the mud valve! (Tech. Ed's Note: Boy, they sure talk funny 'down in the sticks!') But, before I had a chance to order the monster, the telephone rang. It was my close friend, Jim Holman, and he said — 'Warren, let's build a Digitrio!'

"I said, 'A Digit-what?' I was sure the kickapoo juice had him, but what **had** gotten to him was his copy of RCM.

"Well, you and several thousand other fellows know what ensued. I blasted out to the nearest mag stand, plunked down 50¢ and began looking for an article on a Digi-what! I found it. After several days of wondering whether Ed Thompson knew what he was talking about, and whether we had enough gray matter to build it, off went an order to World Engines.

"World Engines . . . there is another bunch of wonderful people who handle and make it possible for the American model hobbyist to secure just about everything from all four corners of the world. Well, to make a long story short, on a month-to-month basis we constructed the Digitrio while all the skeptics stood around and murmured soft remarks of skepticism every weekend. Every month when a new little pack of black-eyed peas with wires sticking out of them would arrive, we (Jim and I) energetically began the construction of one more digit. Finally, the systems were constructed, and I might add, with ease because of Ed's simple step-by-step method of construction.

"The only thing which gave me any trouble was those damn diodes. Finding anyone who knew how to determine polarity of a diode was murder — all local Einsteins gave us a different answer. Jim and I are not exactly electronic experts so you can see where this left us.

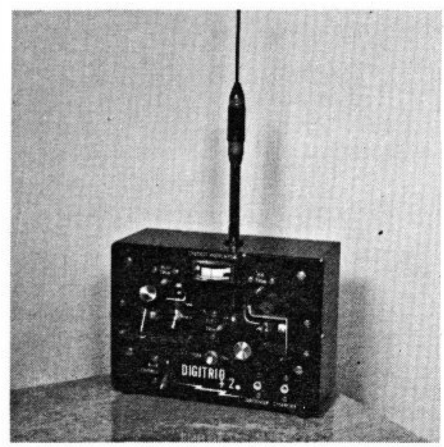
"We had never met Ed Thompson, but we decided now was the time to meet! So we picked up the phone and called him. We still have not formally **met** him, but we feel that we have made another good friend in the R/C world!

"Well, the systems were ready, nicads up, and naturally, rain, sleet, and snow. You name it, we had it! But with Jim Holman, a muddy runway and near gale winds don't mean a thing! So, naturally, a test flight was about to occur. With his engine firewalled, down the runway went the Falcon 56 with a completely new system! Jim flew it magnificently, topping it off with a beautiful landing even though his tiger stopped at 100 feet on a downwind turn. The next flight proved that proportional motor control was to keep Jim on the runway and out of the bean field — an experience that, up to now, we had not enjoyed.

"The weather finally let up on the following Tuesday and the phone rang. You guessed it — Jim, saying 'Let's go digit.' That was for me, so my test flight was to occur . . . and after nearly seven months without flying, I had some apprehensions as to whether I could even find the motor control! But my own system was 'go,' and in another few minutes, we were to see another Digitrio perform flawlessly. Well, Ed — you really did it, and as per your instructions concerning epoxying the components in the receiver and servos — well, came home and epoxied my transmitter! It, by far, took more shaking than the airborne components. We have now turned the skeptics into jello, and we are hearing from one, then another, this phrase — 'Boy, I have to build one of those!' Digitrios, that is!

"We hope you have enjoyed listening to our gab, which brings us to why we are gabbing in the first place. The Digitrio is going dash-four, and Ed threw a challenge at Jim and me concerning a stick assembly that would fit the present case opening. Ed didn't know what he had started, and neither did we when we said, 'Sure, Ed — we'll design one for you!'

5-channel by Don Graves, Pittsfield, Mass.



"Plenty of midnight oil was burned over one idea, then another. Finally Jim picked up a small piece of brass and said — 'What would you say if I said we had the whole thing right here?'

"We had been kicking the idea around, but I thought Jim had a diode in series with his horse and buggy! But as the night wore on, and the sun finally came up, we saw the idea jell until we could finally get the entire assembly in the Digitrio's 1$^{15}\!/_{16}$" case opening.

"Before we begin, let's say a word or three about the construction of the stick. Nothing about it is very complicated. The prototype was constructed on a kitchen table with drill, razor saw, hand tools, and minor machine shop help. One item of concern is the rudder barrel. Your rudder pot is housed in it, and to insure freedom of the rudder pot shaft, some minor polishing and adjustments are necessary, but it won't present any difficulty. (Tech. Editor Note: Here is where the local machine shop will come in handy.) Take care not to tighten the set screws on the rudder pot too tightly. Care must also be taken to insure that all holes for pots and bearings are in line with all their respective centering posts, or your stick will be slightly off center in the transmitter case. (Tech Editor Note: Actually the rudder control shaft will be slightly below center due to the barrel design.) If you have a Digitrio now, you are already on the road, ror part "A" or original Digitrio stick (stationary pot mount and elevator centering post) is used in this stick with the exception of possibly slotting or relocating the mounting holes. Well, enough of the chatter. Brew up a pot of coffee, and let's get on with it. You fellows with Digitrios going now will have the necessary spacers and aileron and elevator springs.

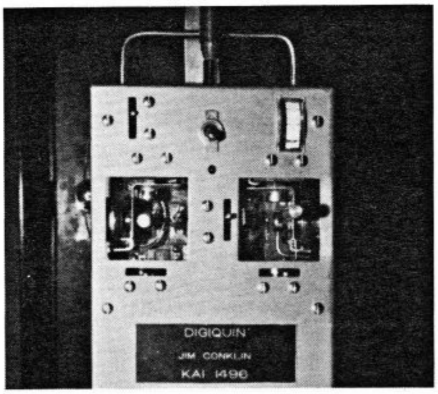
INSTRUCTIONS

( ) First make two collars ½" OD, ¼" ID, 3/16" thick and drill and tap one of them for set screw as per drawing. Next make two 9/16" OD by ⅜" ID by 3/32" spacers. Now make centering springs for aileron and elevator and rudder as per drawings.

( ) Let's make the rudder barrel next. Take a piece of brass round stock ¾" diameter and ⅞" long. Care should be taken to square the ends in relation to the sides. Scribe a line exactly through the center of one end. Measure in ¼" and center-punch on the center line. Drill a pilot hole ⅛" diameter completely through the block. (NOTE: If you have a drill press or access to one, this operation is like shooting fish in a rain barrel. Otherwise, care should be taken to keep the holes straight.) Next, drill with ⅜" drill to within ⅜" of other end (Approx.). Next, continue this hole with ¼" drill. Using the scribed center line as a guide, flat the sides parallel to the line equally to a total width of 9/16". Flat the top side furthest from the center hole until it becomes square with the two sides. You should end up with a total of ½" flat surface on each side.

( ) Now let's locate the aileron pot shaft hole. Do this by scribing a center line full length down the top of the rudder barrel. (NOTE: See drawing defining top, bottom, sides, etc., of rudder barrel.) Starting at back of rudder barrel (end with ⅜" hole), come in 5/16" and center punch on this line. Drill a ¼" hole perpendicular to the ⅜" hole. (NOTE: This

5-channel Digitrio by Jim Conklin of Owensboro, Kentucky.



hole is only drilled through one side of the barrel — don't go all the way through.) Drill and tap for aileron shaft set screws now as per drawing. Set screws used were 4/40 by ⅛".

( ) Now let's go to the front of the rudder barrel, or the end with the ¼" hole. From the center of the ¼" hole towards top of the rudder barrel, measure ¼" and center punch. Drill a ⅛" hole approximately 3/16" deep. This hole is for the aileron centering post. Now let's scribe a line down the rounded portion of the rudder barrel, being careful to keep this line in center of ¼" hole at one end and ⅜" hole at the other. Down this center line from the front (¼" hole end) come down 5/32" and center punch, now drill a 1/16" diameter hole 3/32" deep. Don't drill into hole through center of barrel.

( ) This completes the basic rudder barrel, so lay it aside for now and let's make the other goodies. Construct the rudder spring retaining collar (this is best made on a lathe and the bottom filed flat), rudder centering post and the aileron centering post as directed in the drawing. The way we made the original aileron centering post was to take a piece of ⅛" brass welding rod, put it in the vise and heat it so we could get a good sharp bend (90 degrees). Then we filed a nice flat edge as noted so we could retain as much as possible inside the rudder centering collar. Silver braze the rudder spring retaining collar, the rudder centering post and aileron centering post on to the rudder barrel being careful to keep these in line. (Note drawings.)

( ) Next let's make the combination rudder centering collar and shaft extension as per drawing and silver braze the other rudder centering post into the collar as shown. (NOTE: Just a word of caution. The location of all the various components on the rudder barrel need to be centered for correct movement right and left.) Silver braze the ¼" diameter rudder shaft extension to the collar — its length is up to you — 1⅜" was used on prototype. Drill and tap the collar for the two 4-40 set screws.

( ) Lay the rudder assembly aside and pour another cup of coffee. Now let's make the main U frame. Take a piece of 3/64" sheet brass, 1" x 4⅞", and lay out the main U frame as per drawing. (NOTE: All holes are centered ¼" up from bottom of sheet and center of aileron hole extends through center of elevator centering tab.) Now drill two ¼" holes and one ⅜" hole as noted on the drawing. These holes should be located and drilled as accurately as possible (this is important). Bevel the collars as shown in drawing. Next silver braze the collars (NOTE: Collars are ½" x 3/16" with ¼" hole) to U frame as noted in drawing. Now fold main U frame as per drawing.

If you are starting from scratch, and do not have a Digitrio already built, drill holes in part A as per drawing — do not drill any holes in transmitter case at this time — fit the completed stick in its relative position in the transmitter case and drill the holes to correspond with holes in part A.

If you do own a Digitrio—and intend to use the original part A — you can elongate the holes in part A to allow proper positioning of the stick assembly. (It will be necessary to move part A to the right approximately ⅛".)

( ) Assemble stick as per exploded view drawing. The rudder pot is Ohmite part #CU1031 (the same as recommended in the original article). After installing this pot, cut the shaft off 9/32" from the rudder barrel. (Tech Editor's Note: Solder joints on the prototype stick were "sweated" with ordinary solder and have adequate strength.)

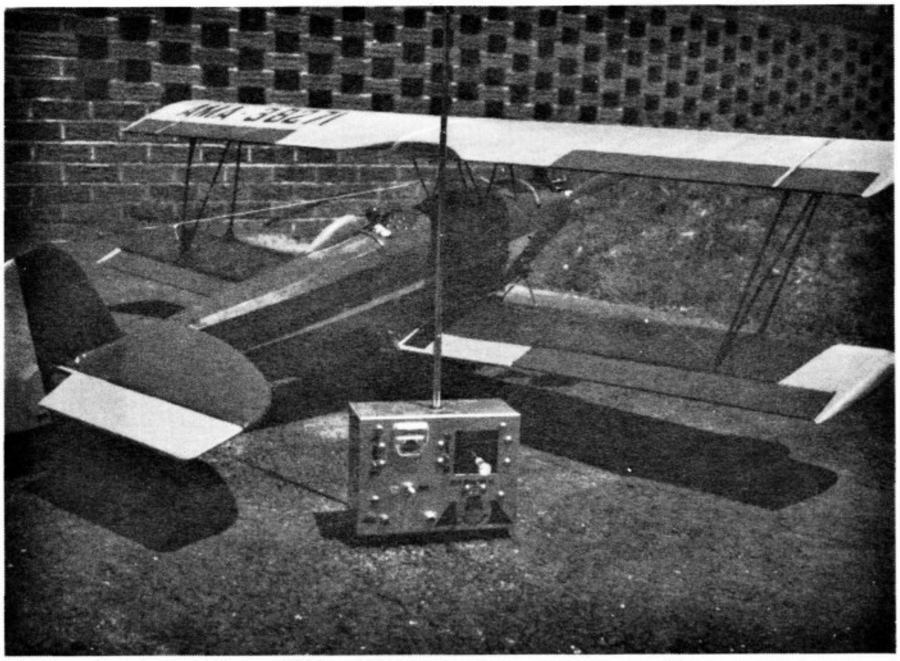
INSTALLING STICK ASSEMBLY

( ) Remove batteries completely to prevent damage and arrange transmitter for maximum accessibility. Remove old stick assembly completely and clip wires at pot terminals.

( ) Remove vertical (elevator), trim pot and clip wires at terminals.

( ) Install new 10K pot in elevator trim bracket with shaft cut to ¾". This shaft is used as pivot for stick assembly and "burrs," etc., should be removed. (Tech Editor Note: The bushing on main U frame can be soldered on side facing trim pot to prevent buying a new pot if your present shaft is too short.)

( ) Install stick assembly. This will be a cut and try job depending on the original stick configuration. If your original stick was as per Digitrio articles only minor adjustments will be necessary. If properly made and installed this new stick will give smooth trouble-free service. So take your time.



Warren Thomas, Jonesboro, Arkansas, claims his bipe is a real performer with Digitrio.

( ) Make necessary adjustments for smoothness, etc., if elevator trim pot moves while manipulating the stick. Center punch the threaded portion of the pot to stiffen it up.

( ) Rewire pots so that elevator wires go to vertical pot and rudder wires go to horizontal pot. If necessary, install new wires and tie off these wires to convenient places on the stick assembly to prevent strain and possible breakage.

You can continue to fly the Digitrio in this manner until you complete the modification to four channels. At which time you will wire the rudder pot.

Check your stick for proper throw by "eyeballing" the servos in operation. If you need more throw get out the file and remove excess material. This may require removal and reinstallation of the stick a couple of times until it is right. Take your time here and do a good job. You can also, at this time, temporarily wire the rudder pot for adjustment purposes

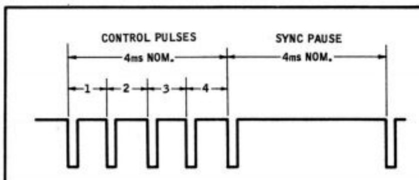
THEORY OF OPERATION (TRANSMITTER-4 MODIFICATION)

The transmitter modification for four channel operation is simply the addition of two more one-shots. The theory of operation of the one-shot circuit was covered previously so I'll just explain their use as applied to the modification.

To start with, two more one-shots are used to obtain five pulses for the four channels. This allows the unijunction to be used solely as a pulse train initiating circuit and sync pause generator. The unijunction has no direct control function. Rather than depend on a timing circuit in the decoder to compare with the timing of the unijunction, at relatively long timing periods, an additional one-shot is used to complete the pulse train action. This takes the demand for precise timing from the unijunction circuit and its operation becomes noncritical, within reason. It also relieves the decoder of precise timing and places it under the direct command of the transmitter for all channels. In other words, it becomes a passive receiver of pulses with noncritical timing circuits used throughout. During the sync pause the decoder resets itself without regard to precise timing.

The only electrical difference between the two additional one-shots is the use of 4.7K resistors as collector loads instead of 1K's used in the original Digitrio. These were used to keep current consumption down so the voltage regulator circuit would not have to be changed. The only significant component type change is the use of disc type .1's for the timing capacitors. These are discs with a good dielectric characteristic for this type circuit and should not be confused with inferior transistor general purpose discs. Also, you will note that no trim pot circuits are shown. Since these two one-shots are assigned duty as motor and rudder control circuits I didn't feel the extra expense and complication is warranted. However, if you wish trim on one or both of these controls, trim pots can be added the same as on the original Digitrio.

When the last one-shot of the original Digitrio (Q8 and Q9) completes its timing cycle, it triggers the first one-shot of the modification (Q1 and Q2). When this one shot completes its timing it triggers the remaining one shot of the modification (Q3 and Q4). This completes all control information. Approximately 4 MS later (during which the decoder resets) the unijunction circuit starts the chain reaction again. A transmitter pulse occurs when the unijunction initiates the action and one occurs for each of the one-shots. We now have five pulses controlling four variable channels. (See pulse train waveforms.)



DIGITRIO-4 PULSE TRAIN

The total unijunction recurrent timing period (frame rate) is approximately 8 MS — 4 MS nominal during the five control pulses plus 4 MS nominal for the sync pause. The sync pause is not critical and can vary from 4 MS upwards, but it's best to stay close to 4 or 5 MS unless you know the extent of the total action. Actually, the sync pause width varies constantly with control stick movement and its length is equal to the remainder of time left in the frame rate after the control pulses are sent.

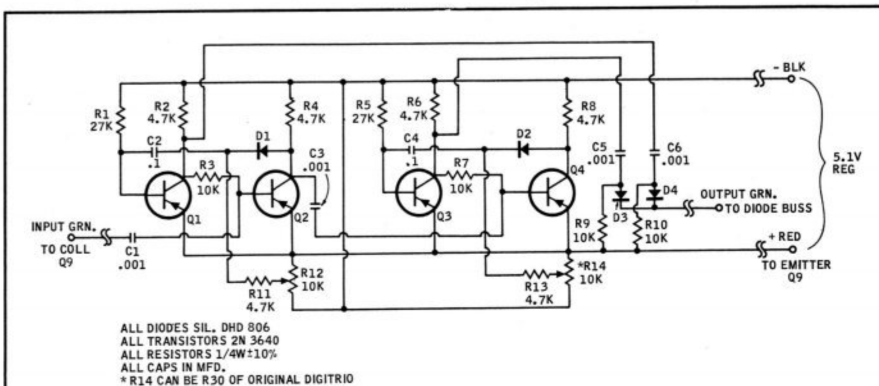
WIRING TRANSMITTER AUXILIARY P.C. BOARD

( ) Mount all 4.7K's. (6 ea)

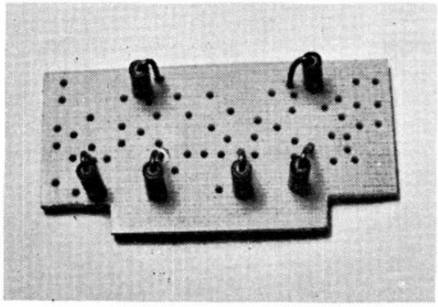
( ) Mount all 10K's. (4 ea)

( ) Mount all 27K's. (2 ea)

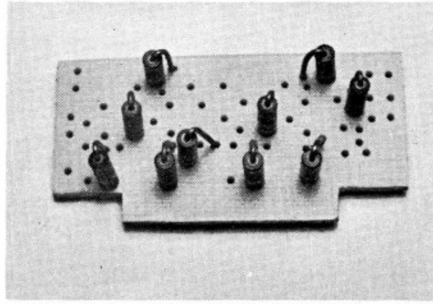
( ) Mount all diodes (4 ea.) Observe overlay for proper polarity. Bar is up on all diodes.



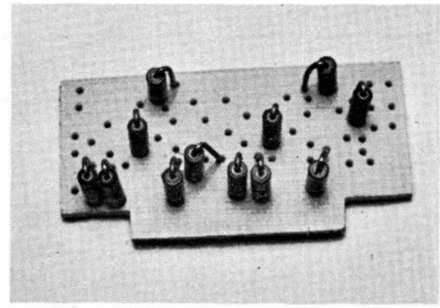
DIGITRIO 4 XMTR. MOD.



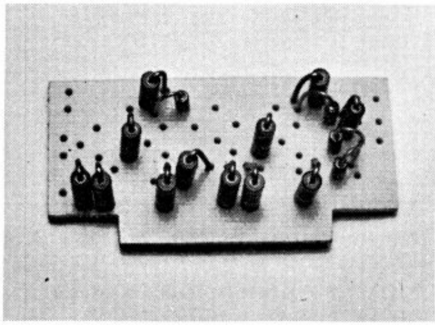
Six 4.7K resistors in place.



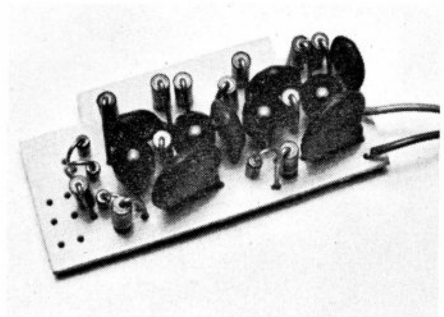
Four 10K resistors added.



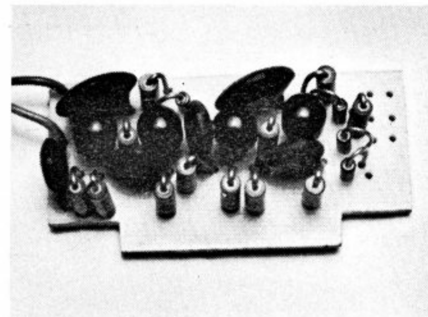
Two 27K's added to board.



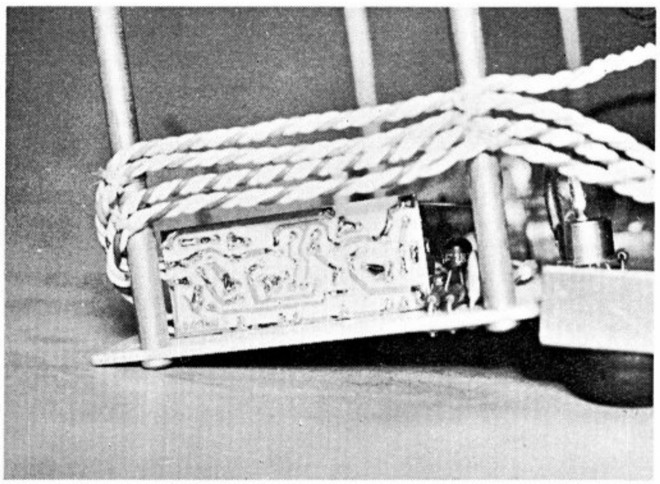
Diodes soldered in place.



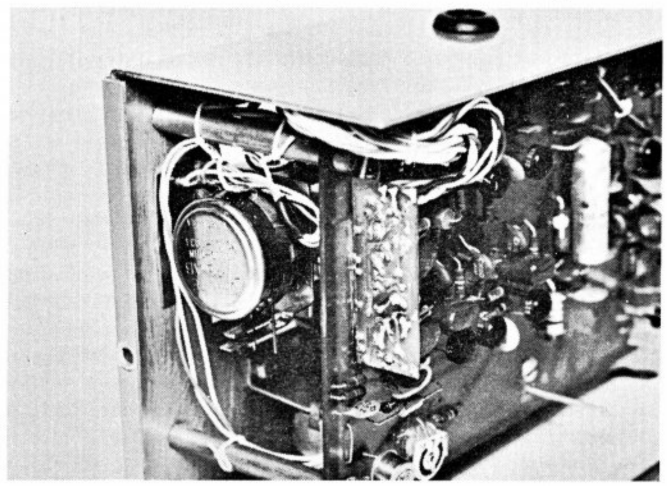
.1 and .001 mfd caps added.



Completed board, less control pot wires.

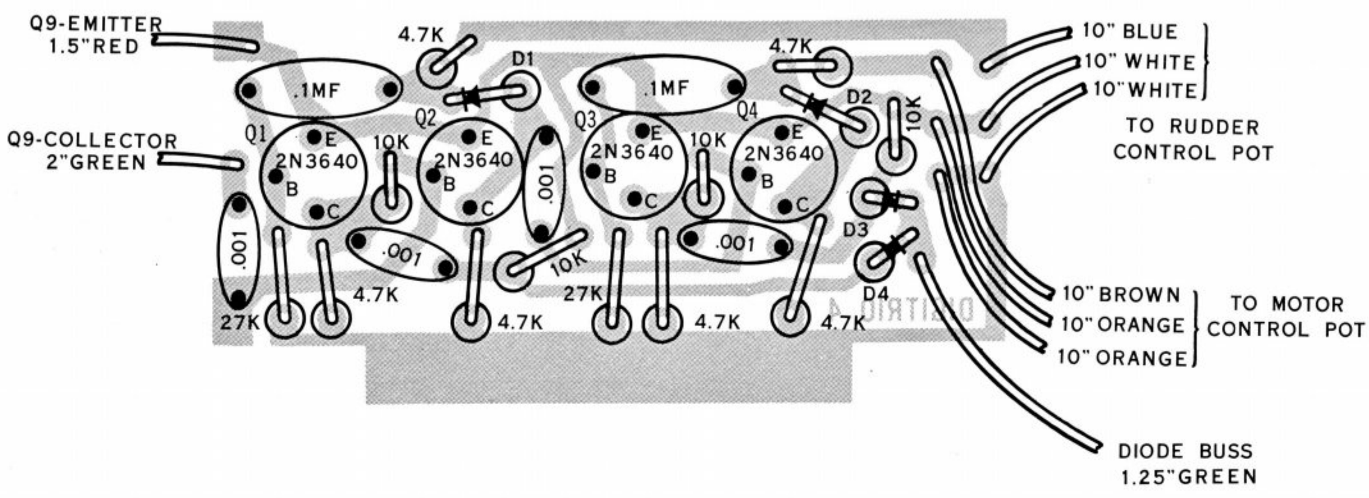


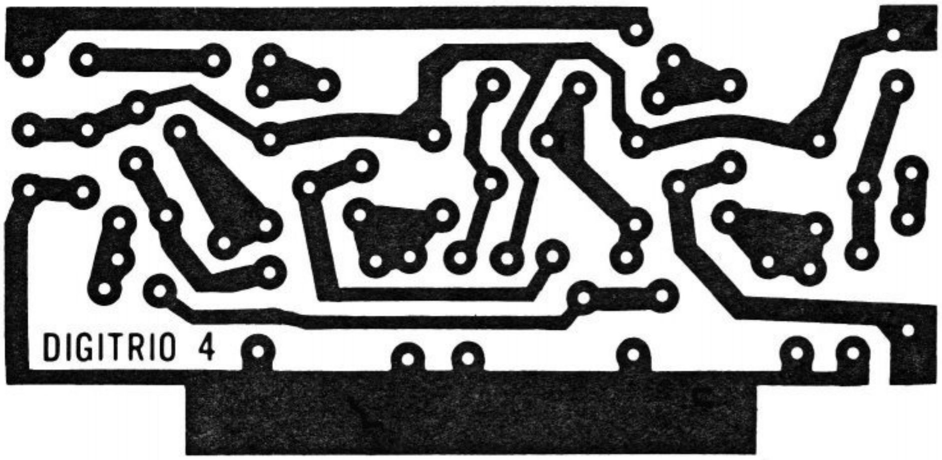
Auxiliary PC board installed on main transmitter board. Note neat, cabled control wire installation.

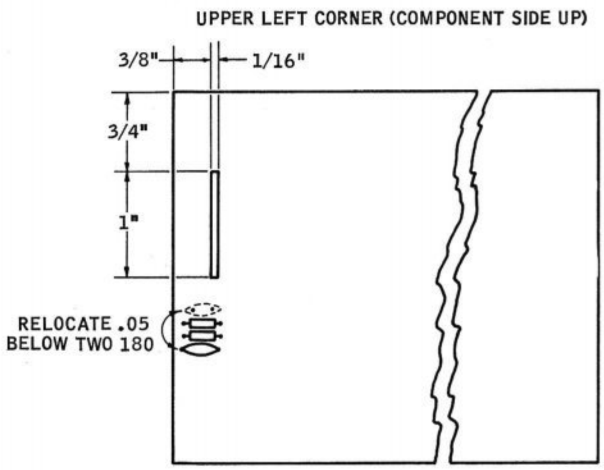


Main transmitter board in place and showing location of fourth channel auxiliary board.

DIGITRIO 4 COMPONENT LAYOUT







1. SLOT IN MAIN P.C. BOARD TO ACCEPT AUX. P.C. BOARD
2. AUX. BOARD IS MOUNTED WITH COMPONENT SIDE FACING CENTER OF MAIN P.C. BOARD
3. NEG. BUSS OF AUX. BOARD IS SOLDERED TO NEG. 5.1V BUSS OF XMTR.
4. SLOT SHOULD BI-SECT 5.1V BUSS OF XMTR.

DIGITRIO-4 XMTR MOD.

PARTS LIST

REFERENCE NUMBER	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURER'S NUMBER
C1	.001	Erie	831-000-Z5U-102P
C2	.1	Erie	5655-000-Z5EO-1042
C3	.001	Erie	831-000-Z5U-102P
C4	.1	Erie	5655-000-Z5EO-1042
C5	.001	Erie	831-000-Z5U-102P
C6	.001	Erie	831-000-Z5U-102P
D1	Silicon Diode	G.E.	DHD 806
D2	Silicon Diode	G.E.	DHD 806
D3	Silicon Diode	G.E.	DHD 806
D4	Silicon Diode	G.E.	DHD 806
Q1	2N3640	Fairchild	2N3640
Q2	2N3640	Fairchild	2N3640
Q3	2N3640	Fairchild	2N3640
Q4	2N3640	Fairchild	2N3640
R1	27K ¼W 10% Res.	Ohmite	LIDSM
R2	4.7K ¼W 10% Res.	Ohmite	LIDSM
R3	10K " " "	"	"
R4	4.7K " " "	"	"
R5	27K " " "	"	"
R6	4.7K " " "	"	"
R7	10K " " "	"	"
R8	4.7K " " "	"	"
R9	10K " " "	"	"
R10	10K " " "	"	"
R11	4.7K " " "	"	"
R12	10K Pot	"	CU 1031
R13	4.7K ¼W 10% Res.	"	LIDSM
R14*	10K Pot	"	CU 1031

*R14 can be R30 of original Digitrio.

MISCELLANEOUS

P.C. Board			World Engines
Hookup Wire	(2 10" white) (1 10" blue) (3 ¼" green) (1 ½" red)		Controlaire, Bonner, etc.

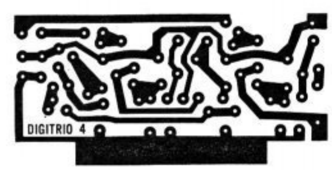
( ) Mount all .1 MFD caps. (2 ea)
( ) Mount all .001 MFD caps. (4 ea)
( ) Mount the 2N3640's. (4 ea)
( ) Add 10" white-blue-white control pot wires.
( ) Add 2" green input and 1¼" green output wires.
( ) Add 1½" length of red wire (positive).
( ) Clean and inspect board for "solder-bridged" lands.

PRELIMINARY CHECKOUT

( ) Check component installation for improperly installed parts.
( ) Check clearance between all component leads for "shorts."
( ) Flat the solder mounds with a fine file and clean with acetone or dope thinner.
( ) Measure the resistance between the positive (red) wire and the negative land (running across bottom of board). You should read approximately 2,000 ohms. Observe meter polarity.

PREPARING TRANSMITTER MAIN P.C. BOARD

( ) Cut slot in board as shown in drawing and photo (Don, take photo of slot). You should have split the land approximately in center and remove the inside half. This allows part of the land to be used to solder the two boards together. After you have made the measurements to cut this slot "eyeball" the task as you go to make up for slight differences between the two boards. This can be done by drilling a series of small holes and cutting them into a slot with an Xacto knife. If you accidently cut through this land, repair the break with a resistor lead.



Three times full size printed circuit board for auxiliary transmitter shown at left. Above: Actual size auxiliary board.

( ) Drill three #60 holes as follows for connecting wires:
(See original overlay)
1. Between top ends of D4 and D5 for the green output wire.
2. At the junction of Q9's emitter and the bar end of Z1 for red positive lead.
3. At the junction of the 1K, D2 and Q9's collector for the green input wire.

( ) Drill two new holes and relocate the .05 cap from above the two 180 ohm resistors to below it.

WIRING THE TWO BOARDS TOGETHER

( ) Insert the auxiliary board and solder it in place. Check for clearance between components of both boards.

( ) Solder the green output wire between the top ends of D4 and D5.

( ) Solder the red positive wire at the junction of Q9's emitter and bar end of Z1. The negative connection was made when you soldered the auxiliary board in place.

( ) Solder the green input wire in the hole you drilled at junction of 1K, D2 and Q9's collector.

FINAL TRANSMITTER WIRING

( ) Remove the orange-brown-orange wires at the P.C. board previously used for motor control.

( ) Remove and relocate R29 (10K) down to where the two orange wires used to be.

( ) Shorten orange-brown-orange wires by approximately 2½" and solder them to the auxiliary board as shown on the overlay.

( ) Wire the control pots as follows:

1. Select the left-hand set of stick and trim-pot wires from the main board and wire them to the elevator controls. White-blue-white to stick pot and yellow-green-yellow to the trim pot wire.
2. Wire the other set of stick and trim-pot wires from the main board to the aileron controls.
3. Wire the white-blue-white wires from the auxiliary board to the rudder control pot.
4. Wire the orange-brown-orange wires to the motor control pot (if not already wired).

NOTE: When connecting the wires to the two moveable control stick pots — it is important to provide some sort of strain relief to prevent wire breakage. Tie the wiring off and take as much time as necessary.

( ) Adjust R13 to midrange. Adjacent to Q5. (This sets frame rate to approximately 8 MS).

( ) Center all control pots electrically using the ohmmeter method.

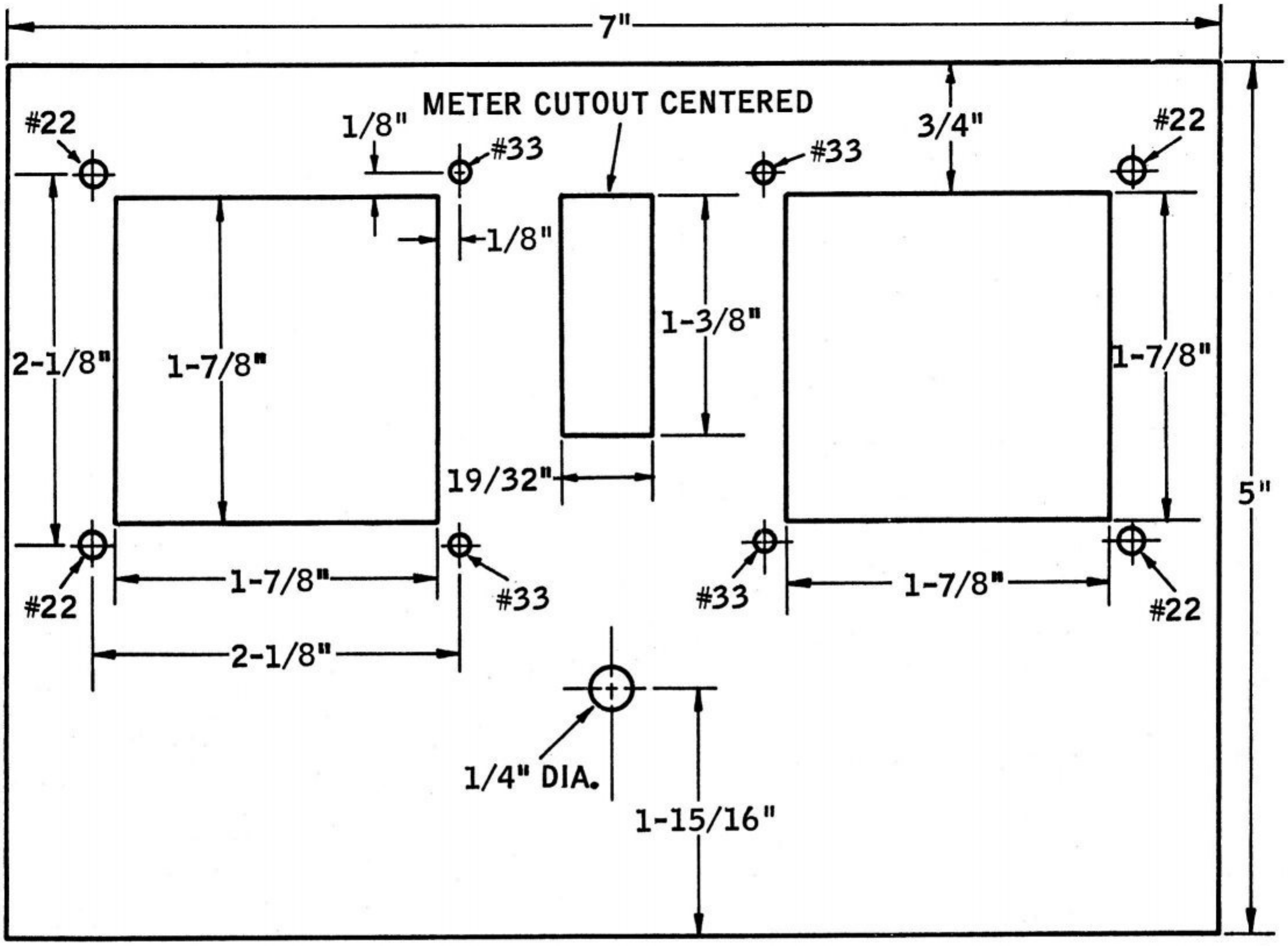
DELUXE TRANSMITTER

For those of you who want a more professional look to your radio gear — here is a deluxe version of the Digitrio-4. The only difference between this version and the three control stick version is the mechanical differences to provide the "face lifting." Most of the construction details are shown in the pictures. A little more care should be taken during case preparation as minor "goofs" will appear exaggerated due to the overall effect of the commercial sticks.

My unit was built around the World Engine's kit using an unpunched transmitter case. The LMB #145 case can also be used. By inverting the P.C. board the standoffs delivered with the Bonner sticks can be used as is without shortening them. When you invert the P.C. board you will have to move the antenna mount support to the component side of the board. Also, it will be necessary to cut the top of the oscillator tuning coil form off slightly to clear one of the pot shaft locking screws on the Bonner stick beneath it. Drill a ⅛" hole beneath the coil form (L2) for tuning access. 4-40 blind nuts epoxied to the inside mounting holes of the Bonner sticks allow easy removal or installation of the P.C. board and stick assemblies as a unit. The P.C. board mounting posts are not "peened" at the stick assembly so that the sticks can be lifted off the posts for P.C. board access. This requires that the four outside mounting holes on the case front be large enough for the posts to be inserted into them. The meter was mounted with "Silastic," a silicon rubber adhesive. This was done strictly for appearance sake and mounting screws can be used. Silastic is a product of the Dow Corning Corp. and is one of the most useful adhesives I've found for the type of work I do. It has a myriad uses in RC modeling and must be used to be appreciated. A meter face print is shown for those of you who want the meter to read vertically. This can be exchanged for the present meter scale by removing the tape holding the two halves of the meter together.

I installed a "McKnight" charger, which appeared in an earlier issue of RCM, using a "TV" type AC connector and a chassis mount socket for the receiver. Two holes in the back of the transmitter allow you to monitor the charger in operation. The handle and battery pack came from World Engines.

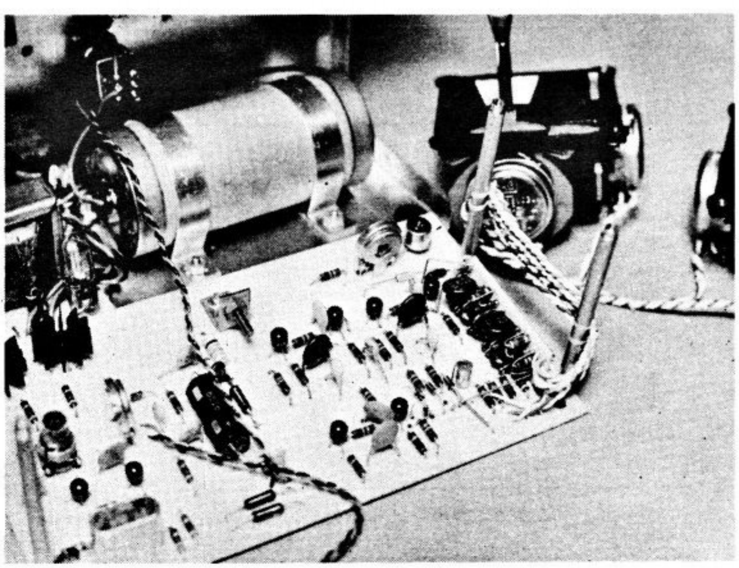
As you can also see in the pictures I used 2N3640's in place of the 2N3638's and 2N3646's in place of the 2N706's. I recommended these changes a couple of issues back but no longer recommend the 2N3646's be used in the final amplifier due to a "burn out" believed to have been caused by base emitter junction failure due to transient voltage when the switch is turned on. I have also tested some Motorola transistors which I recommend as substitutes for the 2N3638's and 2N3640's — they are types MMPS3638 and MMPS3640.

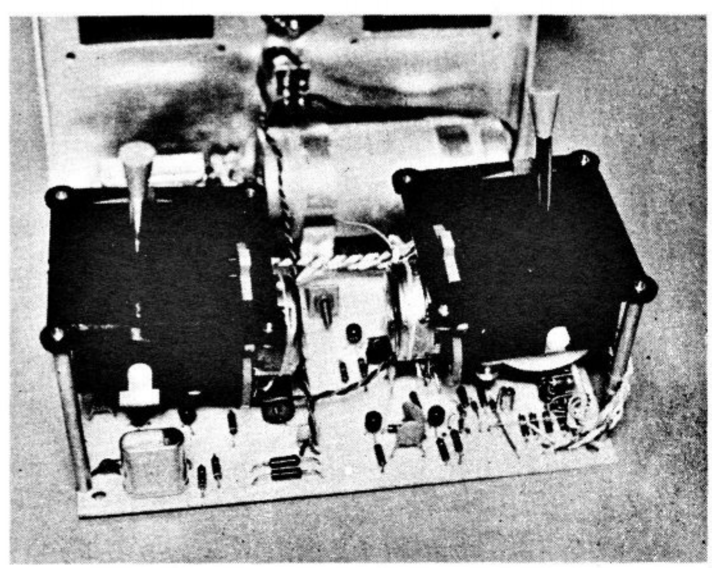


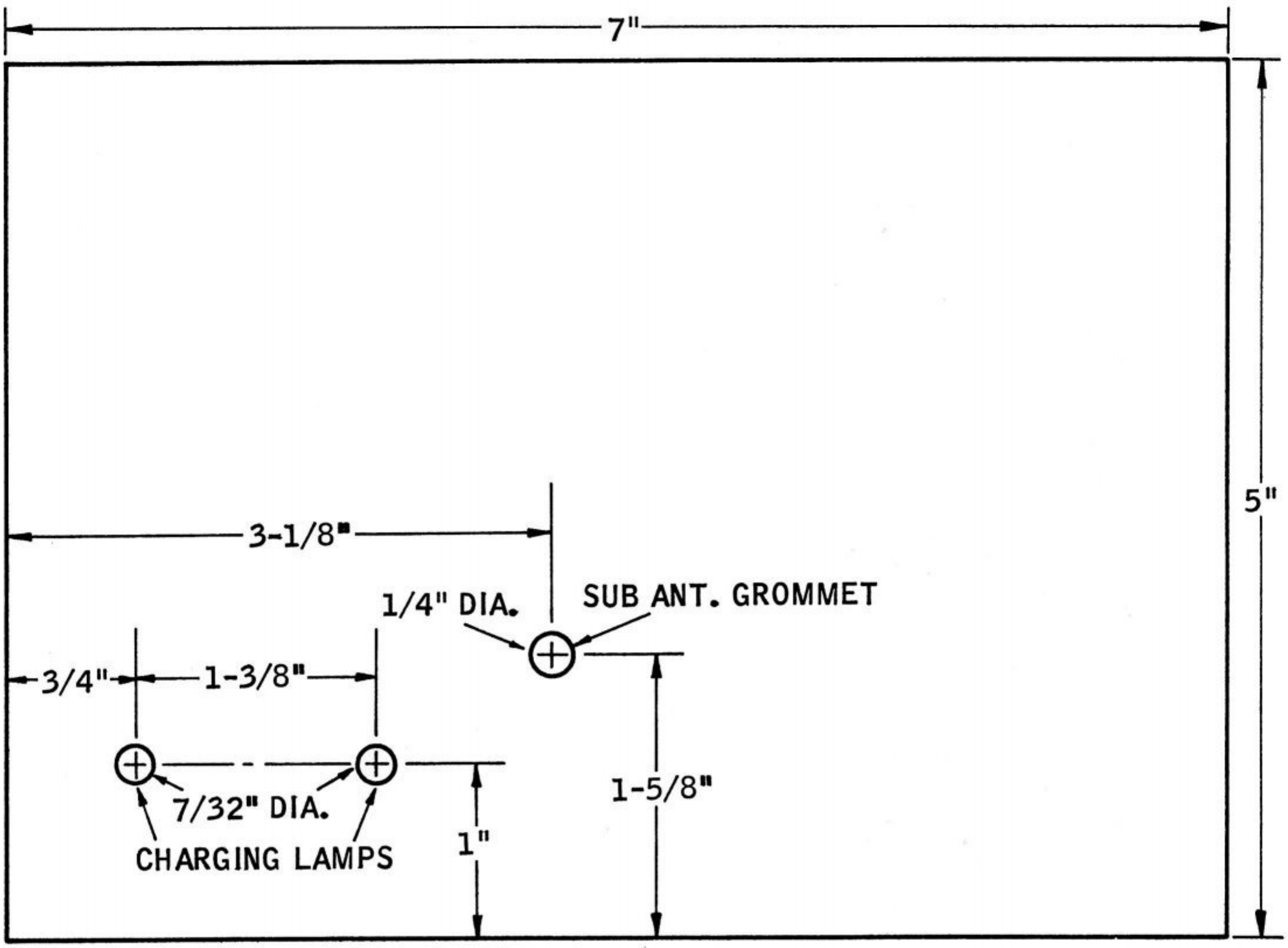
DELUXE DIGITRIO-4 CASE FRONT (FULL SIZE)

PC board removed from mounting posts shows McKnight dual charger in center left of photo and Controlaire nickel cadmium pack in upper center. Note neat cabling and tie-down of wires. Bonner sticks in background.

Bonner sticks mounted in place and entire assembly ready for mounting to case front. Note antenna mount support relocated on component side of board.

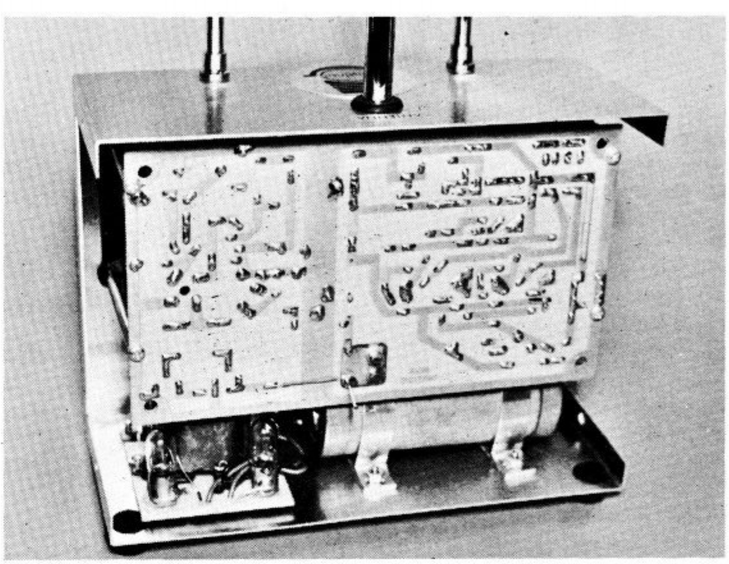


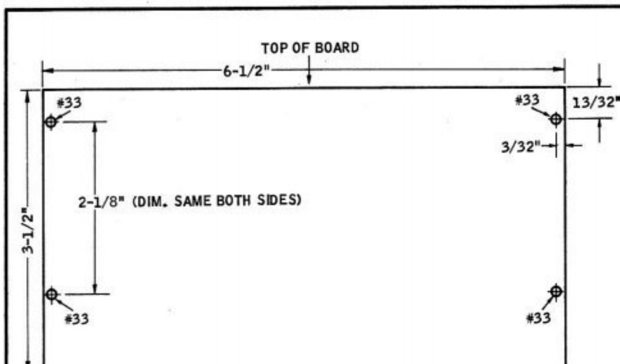




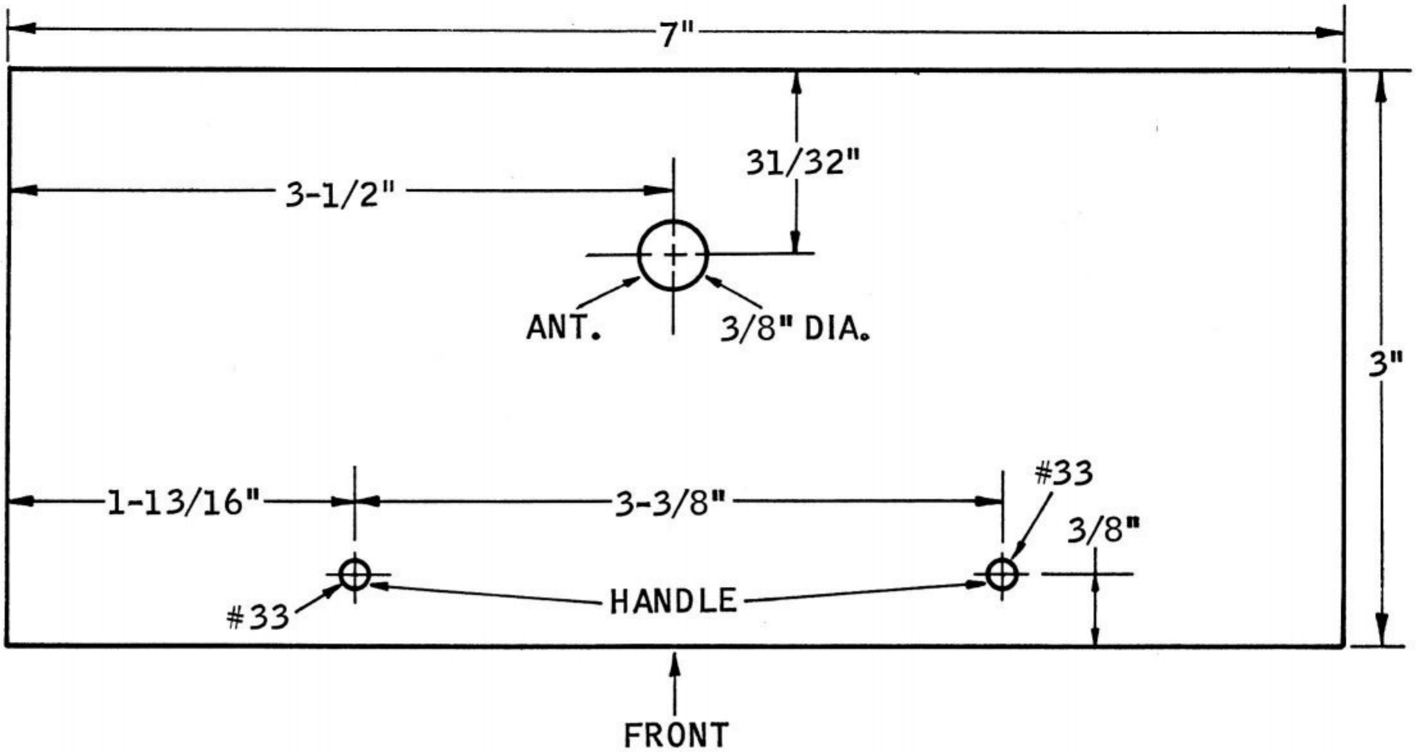
DELUXE DIGITRIO-4 CASE BACK (FULL SIZE)

Charger, power pack, Bonner stick assemblies, and printed circuit board mounted in place. Note antenna location. Chrome carrying handle shows partially on top front of case.



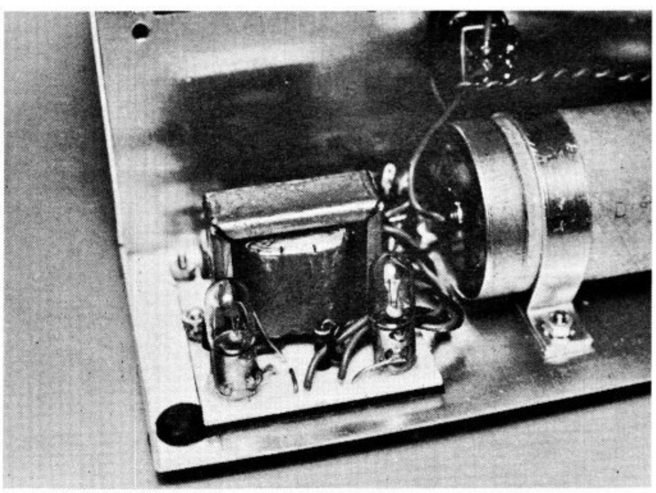


DELUXE DIGITRIO-4 PC BOARD MOUNTING HOLES

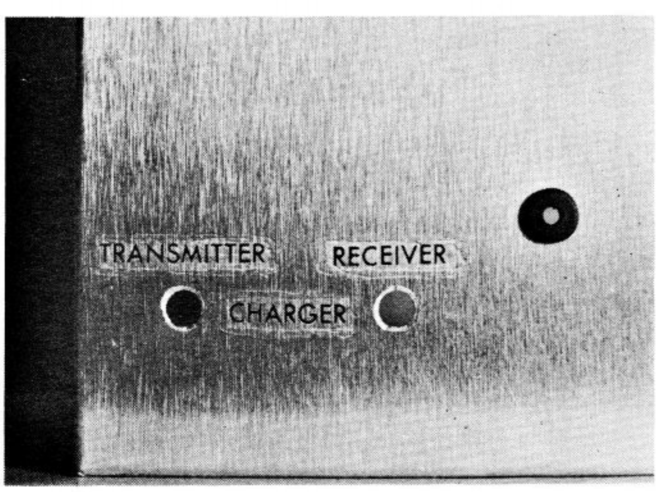


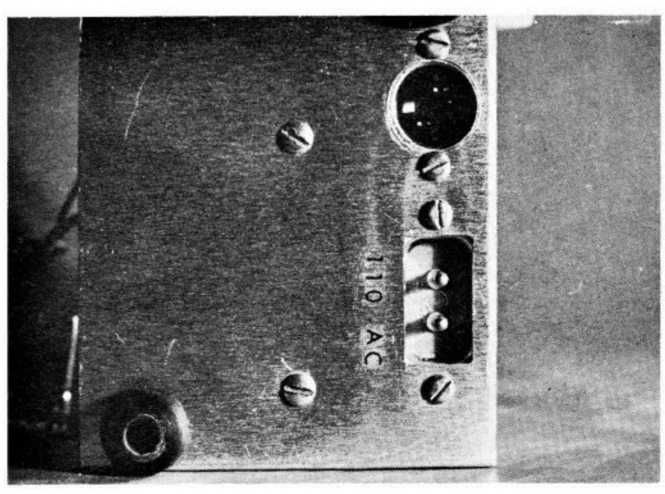
NOTE: CHECK ANT. ALIGNMENT BEFORE DRILLING HOLE.

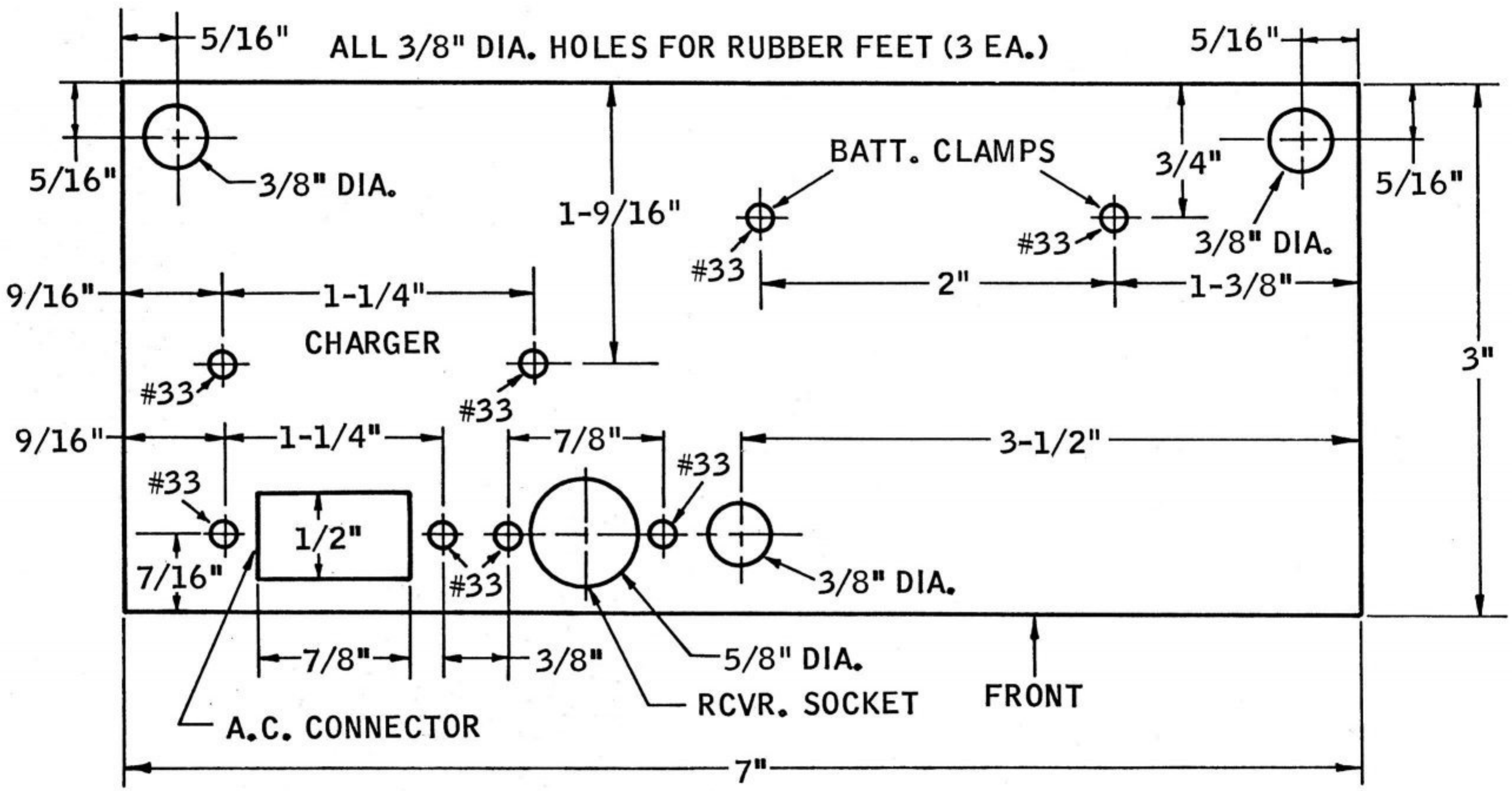
DELUXE DIGITRIO-4 CASE TOP (FULL SIZE)



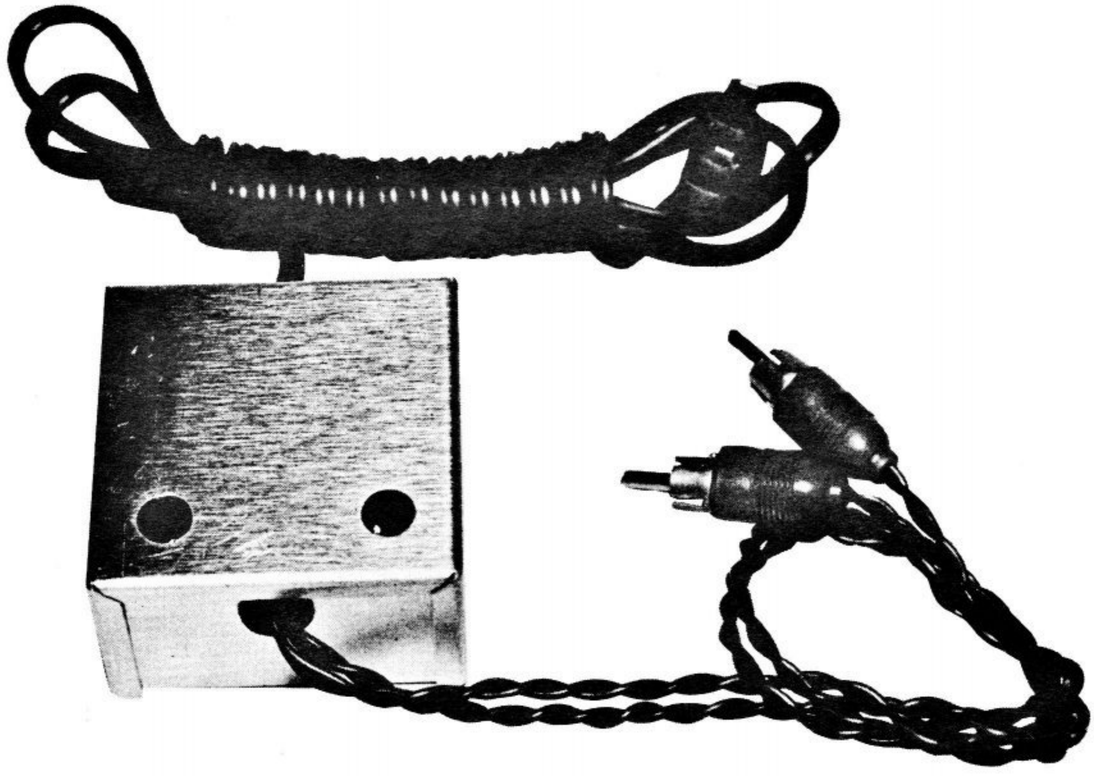
YOU CAN GIVE YOUR DIGITRIO THAT 'CUSTOM COMMERCIAL' LOOK . . .







DELUXE DIGITRIO-4 CASE BOTTOM (FULL SIZE)



DUAL DIGITRIO CHARGER

BY BOB MC KNIGHT

THIS charger was designed for use with the Digitrio system, and has the following features: The use of an isolation transformer to eliminate shock hazard, a series connected charge indicator light for each output that tells when batteries are charging; duel output that allows you to charge both the transmitter and receiver batteries simultaneously.

The aluminum case for the charger measures 2¼" x 2¼" x 1⅜". These dimensions are not critical, and a larger box may be used if desired. The PC board is shown full size and may be made by the standard photo process, or due to the simplicity of the board, may be mechanically constructed by scribing the outline of the rectangular lands with an X-Acto knife and then carefully peeling away all excess copper. Before starting, check fit of the circuit board in the case bottom. Trim to fit if necessary.

( ) 1. Cut 12V transformer leads to ½" length. Strip ¼" insulation from each lead. Insert black leads into holes 21 and 22. Insert Green leads into holes 19 and 20. Temporarily mount the transformer to the PC board with 4-40 x ⅜ bolts and locknuts. Solder the Green and Black leads to their corresponding lands.

( ) 2. Insert line cord through one of the 3⁄16" grommets. Split the line cord back 2" and tie a knot for strain relief. Strip ¼" insulation from both leads and pre-tin. Insert leads into holes 23 and 24 and solder.

( ) 3. Insert one diode into hole 12 with red end up and solder. Insert other lead (red end) into hole 13 and solder.

( ) 4. Insert other diode into hole 11 with red end up and solder. Insert other lead (red end) into hole 10 and solder.

( ) 5. Insert 100 ohm resistor into holes 14 and 15 and solder. Resistor should stand up over hole 14.

( ) 6. Insert 47 ohm resistor into holes 5 and 6 and solder. Resistor should stand up over hole 6.

( ) 7. Mount one #49 pilot lamp as follows: Solder a ½" piece of scrap diode lead to copper side of PC board crossing over the center of hole 16. See Fig. 1 and picture for correct location. Center #49 pilot lamp over hole 16. Pilot bulb should stand in a vertical position. While pressing bulb firmly against board quickly solder the center terminal of bulb to the wire lead previously installed. Avoid heating the bulb too much as heat can damage the filament. Insert a small piece of scrap resistor lead in hole 2 and solder. Bend this lead over against the base of the bulb and solder. See picture.

( ) 8. Mount the other #49 pilot lamp in the same manner. Solder a ½" piece of scrap diode lead on the copper side

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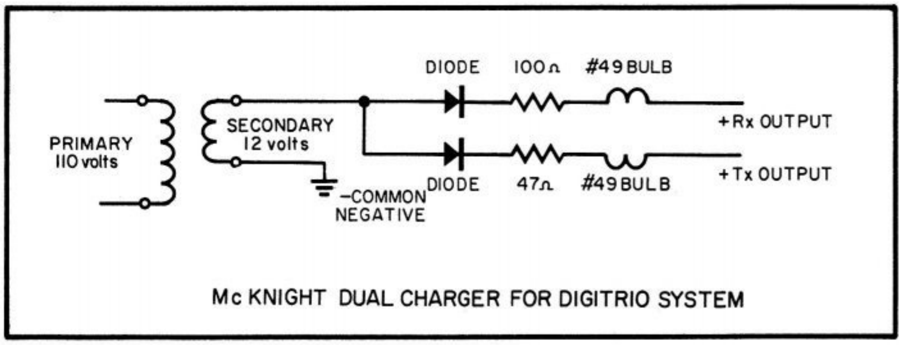
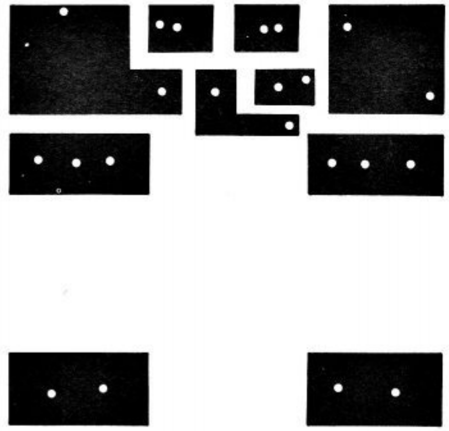
RCM Technical Editor's Note: *The charge rates for the McKnight charger were measured at 20-25 mah. This is adequate for extended charging, but a higher rate is recommended for the standard practice of overnight charging. I recommend 30-35 mah as the minimum charging rate. This can be obtained by reducing the 100 ohm receiver battery series limiting resistor to 47 ohms, and replacing the 47 ohm transmitter battery series limiting resistor with a length of resistor lead. This change will cost you nothing if you're building from the Controlaire kit since the necessary material is supplied.*





Charger schematic shown above. Full size printed circuit board at left.

of the PC board crossing over hole 9. Center the #49 pilot lamp over the hole and while pressing the bulb firmly against the board quickly solder the center terminal of the bulb to the wire lead. Insert a piece of scrap resistor lead in hole 7 and solder. Bend this lead over against the base of the bulb and solder. See picture.

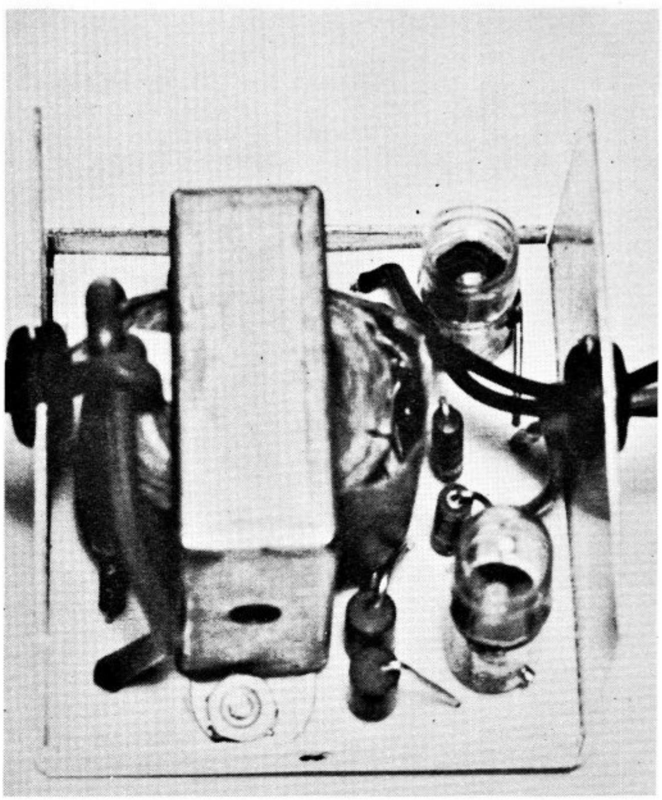
( ) 9. Cut two 18″ lengths of black insulated wire. Strip ¼″ insulation from one end of each wire. Insert these two black leads into holes 17 and 18 and solder.

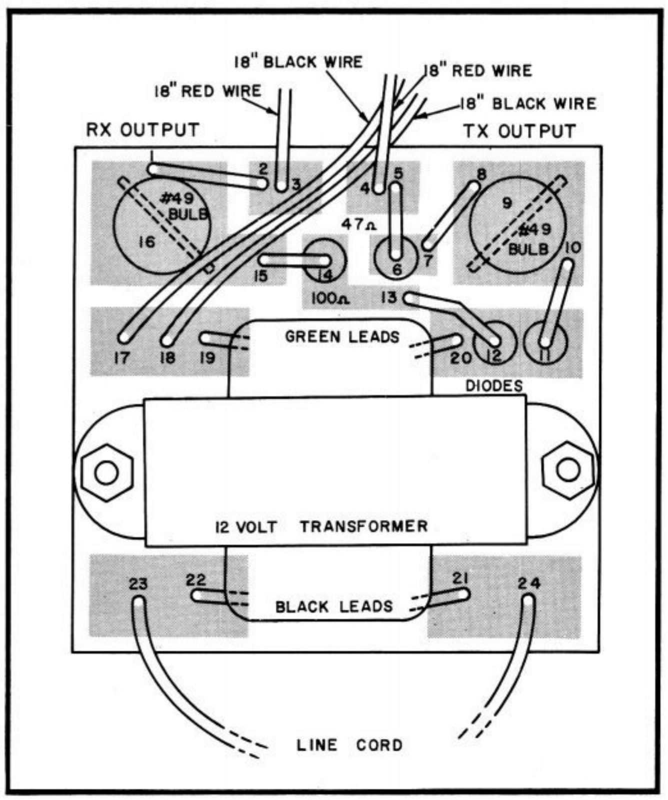
( ) 10. Cut two 18″ lengths of red insulated wire. Strip ¼″ insulation from one end of each wire. Insert these two red leads into holes 3 and 4 and solder.

( ) 11. MOUNTING CHARGER INTO CASE: Insert ¼″ grommet into hole in end of case bottom. Lay the insulator sheet in bottom of case. Remove the 4-40 x ⅜″ bolts and nuts holding the transformer to the PC board. Insert charger into case with the red and black leads threaded through the ¼″ grommet. The line cord and grommet should slide over the notch in the end of the case. Insert the 4-40 x ⅜″ bolts through the bottom of the case, through the insulator sheet, PC board and transformer mounting tabs. Bolt firmly together with 4-40 lock nuts.

( ) 12. RECEIVER OUTPUT: Take the black lead from hole 17 and the red lead from hole 3. Twist these two leads together to form a cable. Cut the leads so that the red lead is ¾″ longer than the black lead. Strip the Black lead back 3/16″ and the Red lead should be stripped back ⅝″. Pre-tin these leads. Insert the Red lead through the center pin of the phone plug and solder. Solder the Black lead to the outside terminal of the phone plug. Push rubber cap down over the phone plug. The phone jack should be connected to the battery pack. The center terminal (red lead) should be connected to the plus end of the battery pack. The side terminal (black lead) should be connected to the minus end of the battery pack.

( ) 13. Transmitter output: Take the black lead from hole 18 and the red lead from hole 4. Twist these two leads together to form the other output cable. Cut the leads so that the red lead is ¾″ longer than the





The Editors of R/C Modeler Magazine would greatly appreciate your assistance in completing the attached questionnaire. It will assist us to determine how we may improve future technical articles similar to the Digitrio series:

R/C MODELER MAGAZINE

P. O. Box 487

Sierra Madre, California

1) I built my Digitrio system from: kit ____ scratch____ both____.

2) My Digitrio: worked right off or with modifications____
   My Digitrio: worked with help of a technician____
   My Digitrio: doesn't work____.

3) How well does your Digitrio work compared to other proportional systems? Excellent____ Fair____ Poor or doesn't____.

4) Did you like the presentation of the Digitrio? Yes____ No____
   (If no, please say why in remarks.)

5) How much experience in electronics do you have? Years____
   In R/C? Years____.

6) How many Digitrios are flying or being built in your area?______.

7) How much (approximate) did it cost you to build the Digitrio?
   $__________.

8) If you had to do it over, would you still build the Digitrio?
   Yes____ No____ (If no, please say why in remarks.)

9) What single thing do you like the most about the Digitrio? ________
   ____.

10) What single thing do you dislike most about the Digitiro? ________
   ____.

11) What other gear do you own? reeds____ single channel____
   proportional____.

REMARKS: ____

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Name ______________________________ **Age** ____

Address ______________________________ **Zip** ________

City ______________________________ **State** ________

Please complete and mail to:

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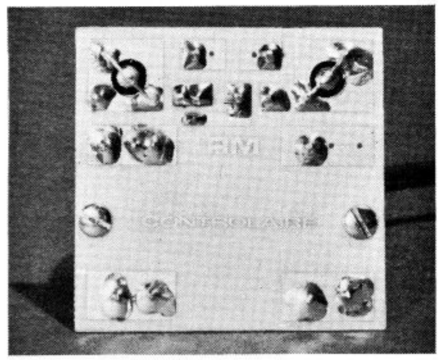


Bottom view of PC board showing center terminals of pilot lamps soldered to diagonal wires.

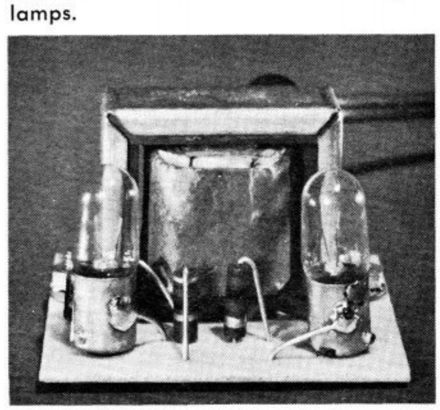
Black lead. Strip the black lead back 3/16" and the red lead should be stripped back 5/8". Pre-tin these leads. Insert the end of the cable through the remaining rubber cap. Insert the red lead through the center pin of the phone plug and solder. Solder the black lead to the outside terminal of the phone plug and push the rubber cap down over the phone plug. Wire the phone jack in your transmitter so that the center terminal is plus and the outside terminal, or case, is negative.

( ) 14. Install top lid and secure with two #6 x 1/4" sheetmetal screws. Charger is now ready for use. NOTE: The receiver and transmitter charging plugs should be marked so that you will be able to identify them.

Operation

Connect charger plugs to both transmitter and receiver batteries before 110 volt AC plug is installed into wall socket. 500 MAH cells should be charged 24 to 30 hours when new. After this and before each day's use, a recharge of 20 hours will keep them in top condition. Recharge time depends upon previous use. If you are in doubt, charge for 24 hours.

Top view of PC board showing installation of wires soldered to base of pilot lamps.

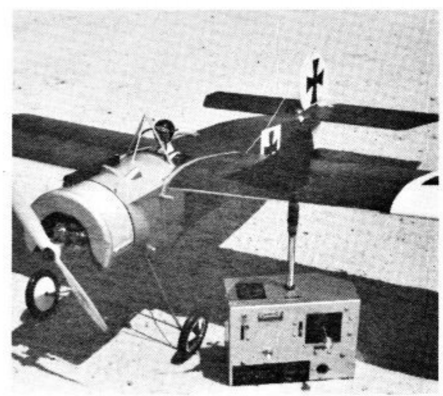


General

Since silicon-controlled switches (SCS) are not found at every corner drugstore, and have just recently found application in the R/C field, I'll attempt to give a basic rundown of how they work. First off, here's a few things of interest.

1. They are not silicon-controlled rectifiers (SCR).
2. They are not new devices.
3. They do not possess magical powers. They have design characteristics that must be considered for proper operation.
4. They are not integrated circuits. They are simply four-layer devices — essentially a diffused base transistor with a third junction.
5. They are versatile devices that can perform a myriad of functions such as a sensitive voltage level detector, bistable memory element, ring counter stage, time-delay generator, pulse and tone generator, relay or motor driver — they can also be used as an SCR.

Since SCR's haven't been given more than cursory attention in the model press I'll start with them and work up to the SCS's (besides, it's easier that way). The SCR is a four-layer device that has the ability to block applied voltage in either direction. In other words, with the device connected in a circuit, such as figure 1a, and with voltage applied it will, in its "off" condition, block current flow and not allow the relay to operate. This is an important characteristic of an SCR but hardly makes it a useful device as



RCM Art Editor Bob Dance's Eindecker and Digitrio. WW I craft is actually a highly modified Falcon. Rig works, despite the fact that Fearless Leader built it!

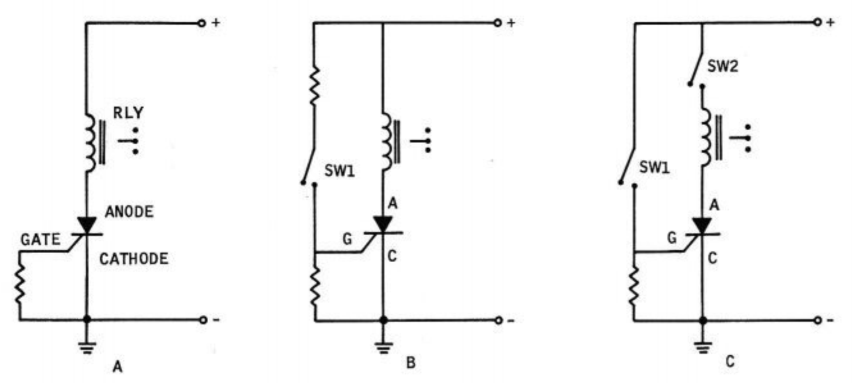


FIG. 1

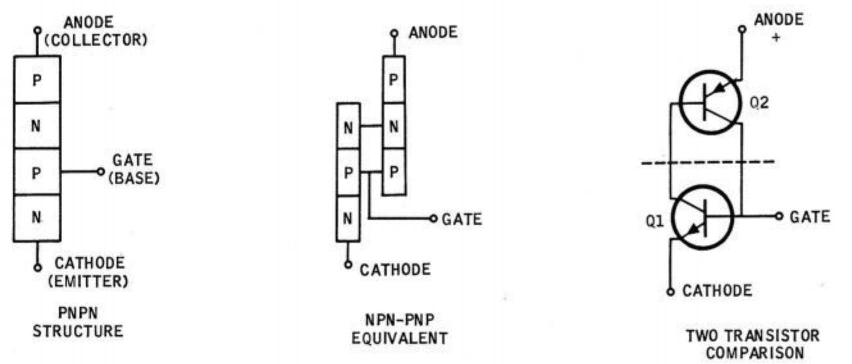


FIG. 2

yet. In order to make it useful we must be able to cause it to draw current through the relay and close the contacts. Figure 1b shows how this can be accomplished. When the switch is closed the SCR will conduct and current will flow through the relay. Here's the selling point to the SCR's existence; when the switch is opened and voltage is removed from the gate it will not cease to conduct. In fact, it will continue to conduct forever if we don't disturb the circuit. It won't do any good to apply a negative voltage to the gate as it has lost control of the device. The only way we can turn the SCR off is to remove the applied voltage. Figure 1c shows a switch in series with the anode voltage that will accomplish this. Let's recap: Once an SCR is "off" or "blocked" it will remain in that state until we apply a forward-biasing voltage to its gate. When we cause an SCR to conduct it will continue to conduct without necessity to maintain forward bias on the gate. In fact, the gate looses all control of the device and we cannot turn it off with reverse bias applied to the gate. The only way the SCR can be turned off is by removing the applied voltage to the circuit. What I have said so far applies to the circuit of figure 1 and should satisfy the average person. To explain a little further for the experimenter it will be necessary to "dig" a little deeper. The SCR is like a rectifier except we can control the "turn-on" by external circuitry. Conduction will continue until the current flowing through the device falls below the "holding current" (I_H). When this happens the device reverts to its "off" state and the gate is again ready to exercise control. This makes the SCR a solid state equivalent to a vacuum tube thyratron.

In order to grasp the turn-on mechanism the SCR can be compared as an NPN and PNP transistor interconnected to provide positive feedback. Figure 2 shows this comparison. Note that the anode, gate and cathode are analogous to collector, base, and emitter respectfully. When the anode is positive, with respect to the cathode, the center junction (corresponding to the two collectors and shown by the dotted line) will be reverse biased as long as neither transistor is conducting and the loop gain is below unity. In this condition the anode to cathode current (I_A) is, for all practical purposes, nil and the device is in its blocking state. It will remain in this state until we cause the loop gain to equal or exceed unity, whereupon it will become regenerative and conduct. Since the conducting state is regenerative the device will turn on at a speed determined by the effective frequency response of the two transistors and current will be limited by the effective saturation resistance of the two devices and the external circuitry. To clarify the regenerative action of the transistor pair assume that the device is in its blocked state and we have just applied a small positive voltage to the gate. This will cause conduction of Q1 which will create a small current flow from the anode through the emitter base junction of Q2 down through collector of Q1 to the cathode. The current flow we caused at Q2's emitter base junction forward biases Q2 and causes it to conduct heavily. This heavy conduction provides a path for Q2 to cause current flow between the emitter base junction of Q1 forward biasing Q1. We no longer need the gate voltage we previously applied to start things off as the collector current flow will sustain conduction.

Let's try again and see if we can condense the operation down to a few sentences. The collector of the NPN transistor drives the base of the PNP transistor and the collector of the PNP transistor drives the base of the NPN transistor. This forms the positive feedback loop and it will have a gain equal to the product of the two transistor gains. The circuit will remain blocked as long as this gain is less than unity and becomes self-regenerative when the loop gain reaches unity. When a positive current is introduced to the gate the NPN transistor conducts. The gain rises with increased current flow and a point will be reached where the loop gain becomes unity and the device will become regenerative. The transistors will drive each other into saturation and the device conduction becomes independent of trigger current. It will remain in conduction until the loop gain is reduced to less than unity. That's the third time I've explained how it works and you're probably growing weary of details. Why don't you read through it again (this time with feeling) and stop at the explanation that fills your needs. If you're the type that needs math for a super-detailed analysis, I recommend Book B-7954 entitled "Silicon-Controlled Rectifier Designer's Handbook" by Westinghouse. The address is Westinghouse Electric Corp., Semiconductor Division, Youngwood, Pa. The cost is $2.00.

Well, now that you understand all about SCR's, and are saying to yourself how you knew it all the time, let's go on to SCS's and see what the difference is between the two devices. To start with, the basic difference is that an SCS cannot only be turned on by a positive current at the gate it can also be turned off with a negative current applied to the gate. Figure 3 shows two circuits with some waveforms.

A is an SCR and B is an SCS. As you can see, the SCR turns on at the leading edge of the first positive going pulse and continues conducting even though the input alternately goes positive and negative. This was explained before and is due to the fact that the gate lost control of the SCR. The only way to turn it off is to remove the voltage to the circuit.

The SCS, on the other hand, turns on at the leading edge of the first positive going input pulse and turns off at the trailing edge when it goes negative. It turns on when the input goes positive and turns off when the input goes negative. The output therefore follows the input with a 180 degree phase difference. To achieve turn-off without removing circuit voltages we must adhere to the "holding current" characteristics of the four-layer device. Holding current (I_H) is described as the minimum anode current at which the device will **not** turn off under specified circuit conditions and temperature. Assume that (I_H) for our circuit is 1 MA and in its "on" state the SCS is drawing 5 MA. It's obvious that we could disconnect the anode lead and the current would drop to 0 MA. This would drop the anode current (I_A) below the (I_H) and the device would "turn off." Remembering that we can control the "on" and "off" state of the SCS, it is also obvious that we will be lowering the (I_A) below the (I_H) by the application of reverse bias to the gate. That is the selling point for the existence of the SCS. We can control both the "on" and "off" state of the SCS by application of either forward or reverse bias to its gate without the necessity to sustain the bias for operation in either state.

The foregoing discussion concerning the inability of the SCR to "turn off" with reverse gate bias is theoretical in nature and based on manufacturer's literature. The gain may be reduced below the regenerative point if enough reverse current can be applied. At high anode currents this would not be practical, and even at low anode currents special circuitry would probably be required for consistency. On the other hand the SCS was deliberately designed to be "turned off" with the application of reverse gate bias. The reason for the difference in operating characteristics of the two devices is in their inherent design and they are controlled during manufacture to operate in the different manners I have described. It is beyond the scope of this article to go into all the different parameters of either device or to include typical circuits which could give a better understanding of how they work. If you are interested in digging further into theory or application I suggest you start with the General Electric Transistor Manual. The manual is available at most all electronic, radio, and TV parts outlets.

Before I go on with the decoder, I would like to mention that the particular SCS used is a General Electric 3N84. This SCS has two gates which are designated as (G_C) and (G_A). (G_C) is the gate closest to the cathode and the one used in the foregoing discussion. (G_A) is a gate connected to the collector of Q1 (figure 2). It provides an additional control of the device in basically the same manner as the one we discussed. However, it requires more power and opposite polarity to accomplish the job we will require from the device. The gate we will be using is effective at the current levels used in the decoder and during constructions we will clip the (G_A) lead off. The (G_A) lead is not shown on the schematic for clarity.

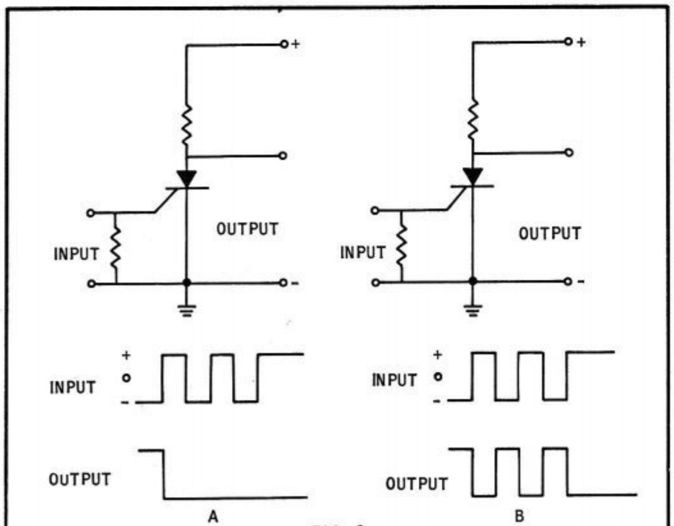
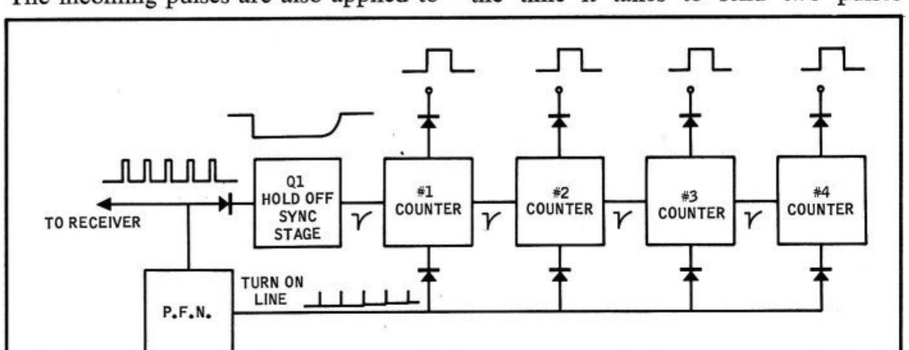


FIG. 3

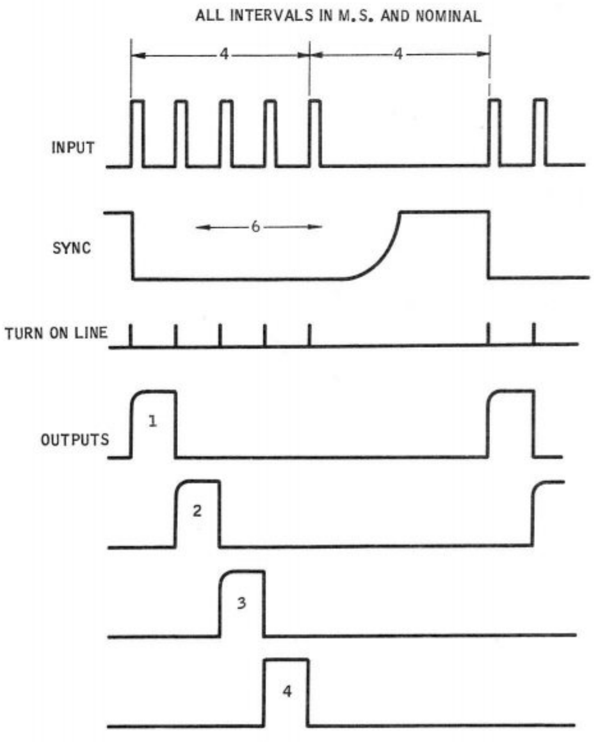
Theory of Decoder

The operation of the decoder is not complicated and even the nontechnical modeler can grasp the basics involved. If the foregoing discussion of silicon-controlled switches left you a little confused I would suggest you re-read it again. The main thing to remember is that positive pulses at the gate will turn one on and negative pulses will turn one off. Your local Einstein type will clear up any remaining questions you may have. The block diagram shows the various stages involved (figure 4). I'll run through the operation quickly for those of you who don't want to get too involved.

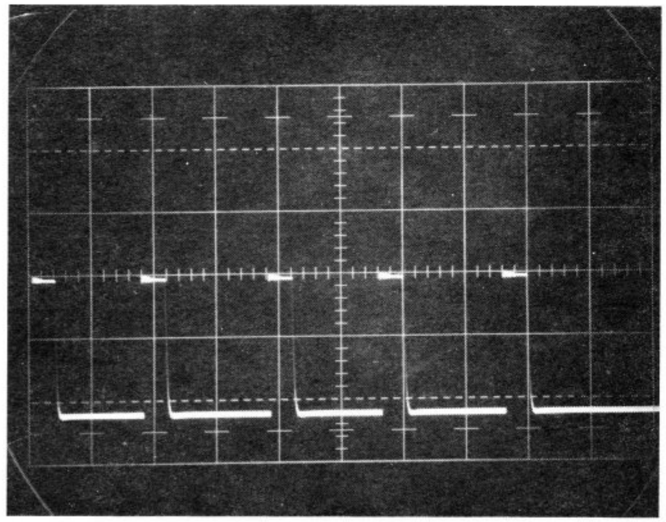
The Digitrio-4 transmitter sends five relatively wide pulses which are processed by and through the receiver. These pulses are applied to the decoder at the pulse-forming network (PFN). The pulse-forming network changes these pulses into very short pulses to be used as trigger pulses to turn on the SCS's. The incoming pulses are also applied to the "hold off" sync stage which senses the first pulse of the pulse train and "holds off" until after the pulse train is completed. Once the sync stage is in its hold-off state it does not "see" any further pulses. The first incoming pulse does two things: It causes the sync stage to "hold off" and applies a positive pulse through the PFN to the "turn on" line turning on any SCR that was previously "off." When the sync stage "held off" at the first pulse it also applied a negative pulse to the #1 counter turning it off. This initiated output pulse #1. When the next incoming pulse arrives it will create another turn-on pulse which will turn counter #1 back "on" and complete the #1 output pulse. When the #1 counter stage turns on again it turns off the #2 counter, initiating output pulse #2. The next incoming pulse then applies another turn-on pulse through the PFN and turns on counter #2, completing pulse #2. This action continues until the five incoming pulses have created the four output pulses which command the servos. Remember that the sync stage held off after the first pulse and was blind to the other four. This prevented the #1 counter from turning off on any pulse but the first. However, the sync stage knows when the incoming pulses are no longer present and after waiting for approximately the time it takes to send two pulses

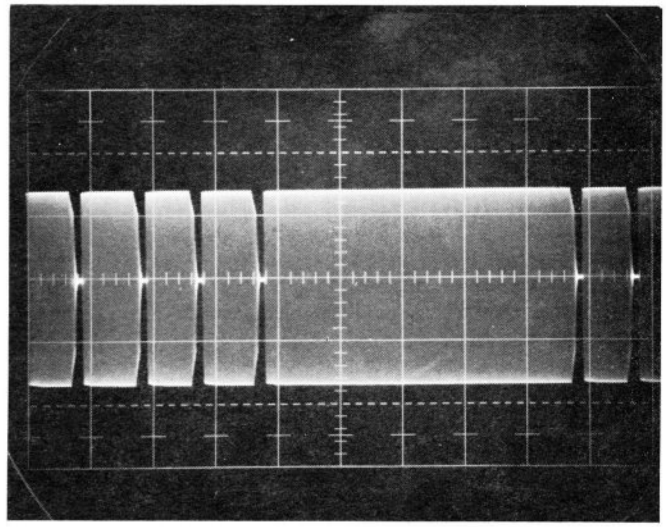


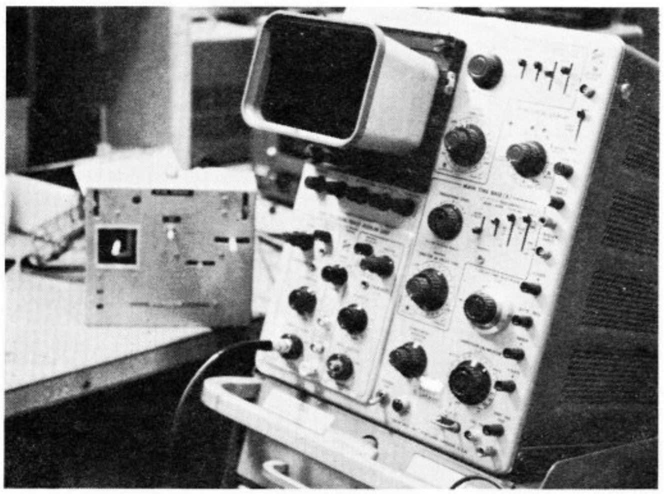
BLOCK DIAGRAM OF DIGITRIO - 4 DECODER
FIG. 4

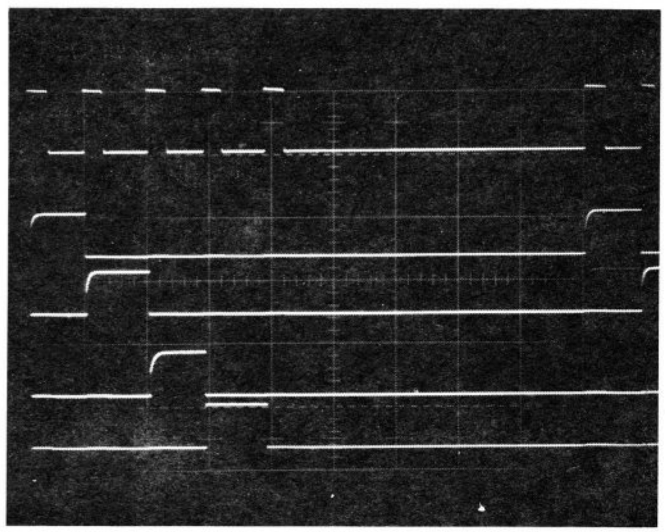


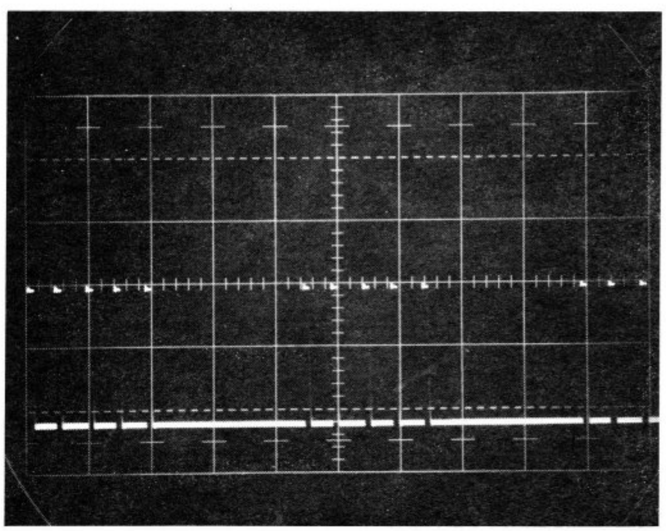
WAVE FORMS FOR DIGITRIO - 4 DECODER
FIG. 5



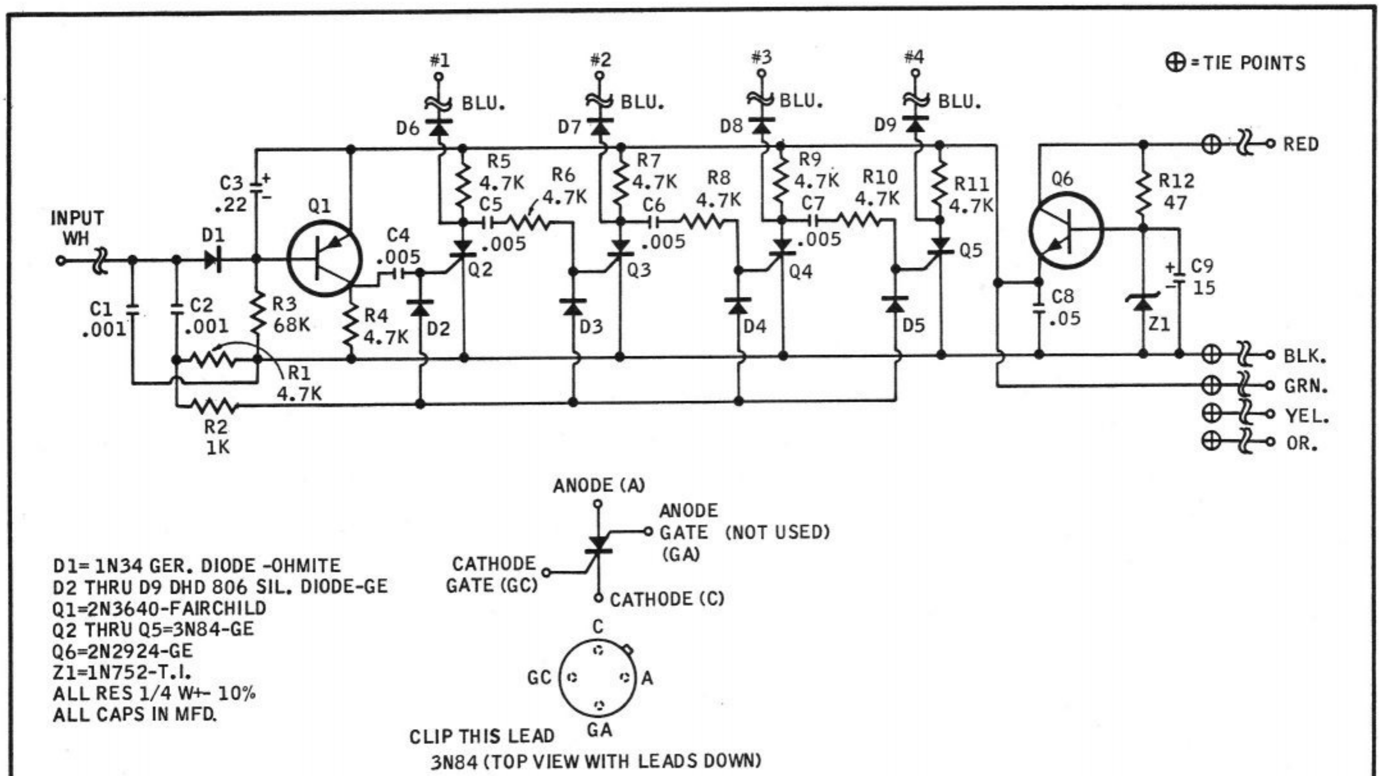








Left, middle: A portion of Dick Carman's workshop in Mountain View, Calif., and the equipment on which Dick made the accompanying scope traces. Left: 2V/CM 2 MS/CM; Collector Q11 transmitter. Frame rate 9MS. Above, top: 2V/CM, .5 MS/CM, collector Q11 transmitter. Above, middle: RF out 1 MS/CM using pick-up coil. Above: Top equals input to decoder. Channel 1 through 4 1 MS/CM 5V/CM.



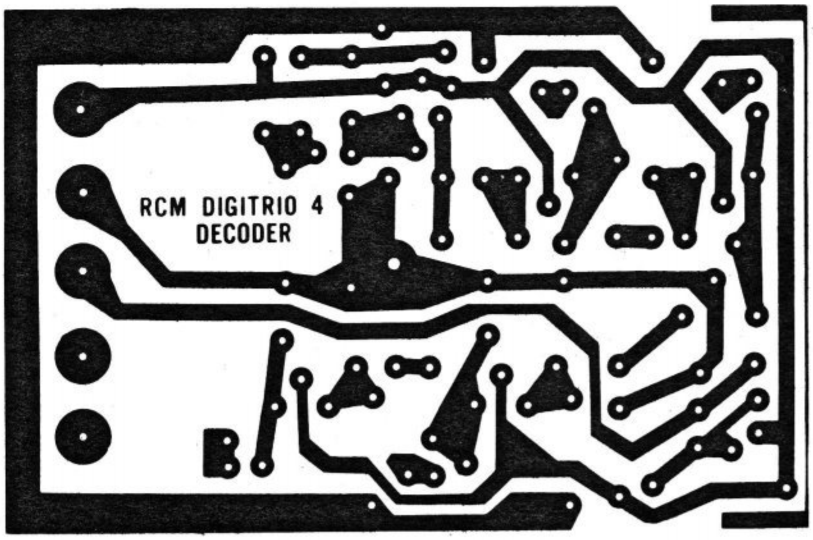
DIGITRIO - 4 DECODER

comes "on" again. This occurs during the sync pause between pulse trains and the decoder is ready to process the next pulse train that arrives. This action continues at approximately an 8 MS repetition rate. For the nontechnical that is basically how it works and I would advise you to read it over a couple of times to help you in case you have to troubleshoot the system after a prang. If the rest of you Einsteins will follow the schematic and waveforms we'll have another go at it. (One more time with apathy.)

The five incoming pulses are differentiated by C2 and R1 which make up the pulse-forming network. The pulses are then applied to the turn-on line through R2 which limits the positive gate current to the SCS's. Diodes D2 through D5 pass the positive pulses on to the individual SCS's and isolates the stages from each other. While we're at this corner of the schematic let's get rid of C1. Its only function is to ground the decoder end of the input wire for RF so that it doesn't radiate the sharp wavefronts of the pulses back into the receiver. The input pulses are also applied to Q1 (sync stage) through D1. Normally this stage will be conducting being forward biased by R3. C3 is charged by R3 also. The inverted appearance of Q1 is due to the schematic drawing and a close look will reveal that polarities are correct. The first incoming pulse causes D1 to conduct discharging C3 — this causes Q1 to cutoff. The time constant of R3 and C3 will keep this stage cutoff for the duration of approximately two input pulses. Therefore as long as pulses are present this stage will "hold off." As soon as the pulses are removed R3 will charge C3 and Q1 will conduct. At the end of each pulse train it does just that and prepares the decoder to accept the next pulse train. When the pulse train arrives and Q1 turns off its collector going negative allows C4 to discharge through R4. (Its left side was charged positive while Q1 was conducting.) This transfers a negative pulse via C4 to Q2's gate turning it

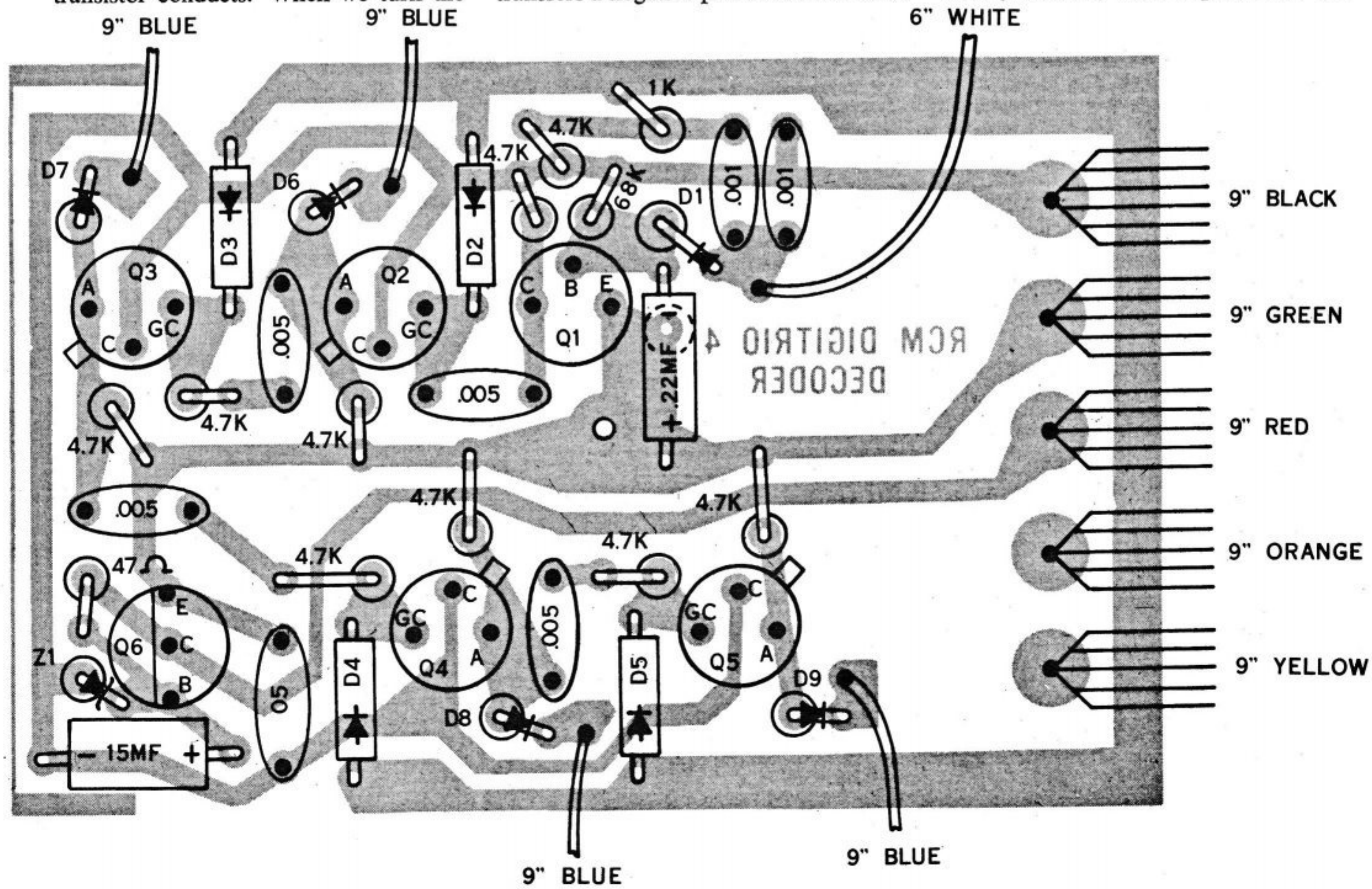
PARTS LIST

QUANTITY	DESCRIPTION	MANUFACTURER OR SOURCE	MANUFACTURERS NUMBER
2	.001 Disc. Capacitor	Erie	831-000-Z50-102P
4	.005 Disc. Capacitor	Erie	851-006-Z5UO-502P
1	.22 MFD Tantalytic Condenser 25 VDC	World Engines	CT-224
1	.05 MFD Disc. Capacitor	Erie	5635-000-Z5E-5032
1	15 MFD Tantalytic Condenser 15 VDC	World Engines	CL-156
1	1N 752 Zener Diode	Texas Inst.	1N 752
1	1N34 Germanium Diode	Sylvania	1N 34
8	DHD 806 Silicon Diode	General Elec.	DHD 806
1	2N 3640	Fairchild	2N 3640
1	2N 2924	General Elec.	2N 2924
4	3N84 SCS	General Elec.	3N 84
1	1K ¼ watt 10% resistor	Ohmite	
9	4.7K ¼ watt 10% resistor	Ohmite	
1	68K ¼ watt 10% resistor	Ohmite	
1	47 ohm ¼ watt 10% resistor	Ohmite	
4	Servo Connector Set	World Engines	
1	Battery Connector Set	World Engines	
1	4PDT Switch	R/C Craft	
5	¼" Rubber Grommet	World Engines	
1	#2 x ¼ Self-Tapping Screw — Type A		
1	9" length Heat-Shring Tubing (Large)	⅛" Alpha	FIT-105
1	16" length Heat-Shrink Tubing (Small)	Alpha	FIT-105
1	Insulation Sheet 2 — ⅛" x ⅜"	World Engines	
1	Prefabricated Circuit Board	World Engines	
7	9" Black Wires	#26 Hookup Wire — World Engines, Bonner, Ace, etc.	
5	9" Green Wires		
6	9" Red Wires		
6	9" Orange Wires		
6	9" Yellow Wires		
4	9" Blue Wires		
1	6" White Wire		



Actual size decoder board shown above. A 2X enlargement at left for your convenience in having a negative made.

off. For those sharpies who caught it, the fact that both a positive pulse from the PFN and a negative pulse via C4 are present at Q2's gate at the same time has already been allowed for. The pulse duration of the positive pulse is made considerably shorter and the negative pulse wins every time. The next incoming pulse (#2) doesn't affect Q1, which is still "holding," but it does turn Q2 back on. Let's pause here and discuss the output pulses to the servos. Q2 through Q5 are normally conducting and their anodes are at their cathodes potential. Since the input transistors in the servos are NPN's they are cutoff. When we turn off one of the SCS's its anode goes positive and the servo input transistor conducts. When we turn the SCS back on the servo input transistor cuts off again and we have produced a decoder output pulse (or servo input pulse). Since Q1 "holds" throughout the pulse train Q2 cannot be turned off again (Thank God!) until the sync pause. So it stays conducting until turned off again by Q1 conducting on the first incoming pulse and repeats the action just described. When the first output pulse is completed and Q2 conducts, it transfers a negative pulse via C5 and R6 to Q3's base turning it off. Although we again have two pulses of opposite polarity present at the gate the negative pulse wins due to its longer duration. The next incoming pulse (#3) after being differentiated, turns Q3 back on and it transfers a negative pulse via C6 and R8 to Q4's gate turning it off, etc., etc., etc. As each output pulse is completed the associated SCS remains on. Each SCS stage can only be turned off by the preceding stage turning on (except in the case of Q2 which turns off when Q1 cuts off) so the circuit counts the pulses down. As you can see the duration of each decoder output pulse is dependent upon the time between the leading edges of the adjacent pulses in the incoming pulse train which control it. R5, R7, R9 and R11 are the SCS anode load resistors. C5, C6, C7, R6, R8 and R10 are for interstage coupling. Their values were selected for both the proper time constant and gate current to allow optimum results. D6 through D9 are silicon diodes (DHD806) used to provide a volt-



age drop and are necessary for proper operation. The SCS has a slightly higher saturation voltage than the threshold voltage necessary to cause the servo input transistors to conduct. Without them the servos could conduct continuously even though the decoder was working properly otherwise. I might mention here also that D1 is a germanium diode (1N34). Don't substitute silicon for germanium or vice versa or you will be in trouble. I hope you read that advice the first time around and are not just now finding it after tearing your hair out looking for your trouble. If so it serves you right for not following instructions. Q6 and associated parts make up the voltage regulator and is a duplicate of the original Digitrio regulator. I know some of you are getting sick of my standard warning not to substitute parts — if so, get out the "belch bag" because here it comes again. **DON'T SUBSTITUTE PARTS.** You will notice that I didn't use my familiar Mickey Mouse phrase. Bernie Murphy didn't mention the Digitrio so why should I mention him? I need a new phrase anyway. Anyone have a suggestion except the obvious, "why don't you just shut up"? I wouldn't do it anyway!

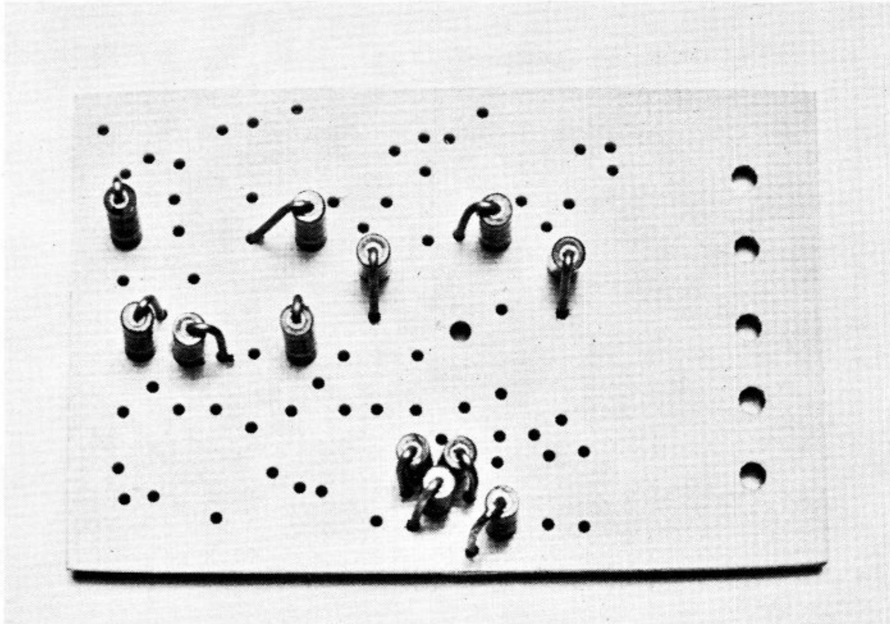
CONFIDENTIAL TO B.M.

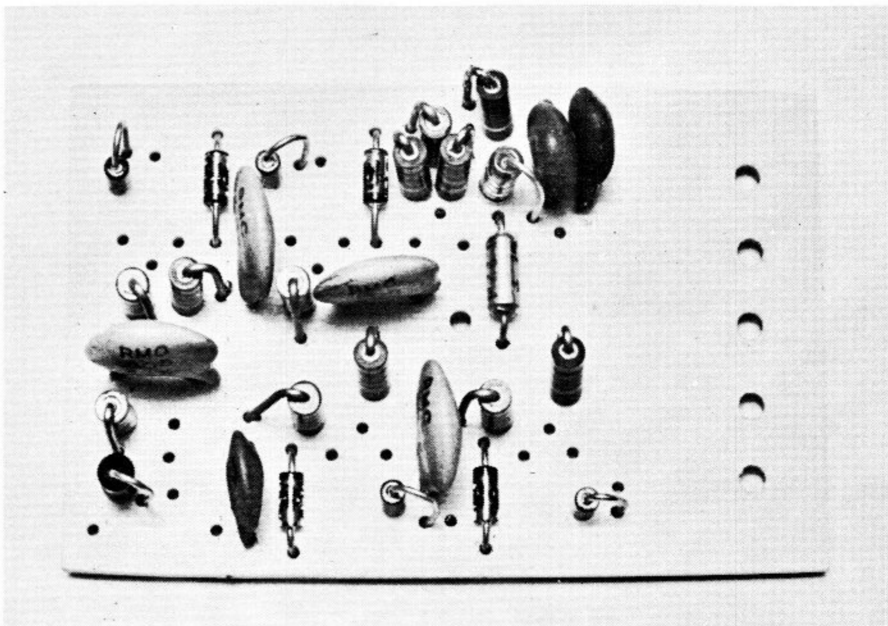
I'll meet **you** at the field, in the street, or on the "green" anytime you're ready.

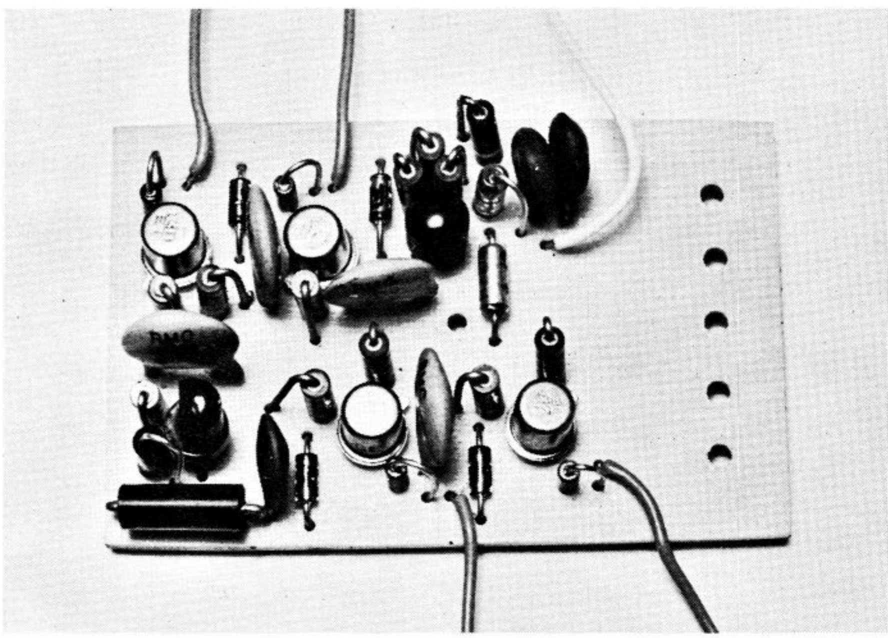
WIRING DECODER BOARD

Make sure your board fits the case properly and the mounting hole lines up with hole in case. Drill all holes with #65 drill.

( ) Clip off GA lead of 3N84's (see drawing and overlay). Be careful! Bend GA lead out and check by placing SCS over drawing before cutting. Use tab for alignment **not** writing on case.
( ) Mount all 4.7K's (9 ea.) as shown on overlay.
( ) Mount the 68K as shown on overlay.
( ) Mount the 47 ohm as shown on overlay.
( ) Mount the 1K as shown on overlay.
( ) Install Z1. The bar will be up on this zener diode.
( ) Install 1N34 **germanium** diode (D1). The bar will be down on this diode.
( ) Mount all DHD806 **silicon** diodes (8 ea.) observing polarity. It would be a good idea to check these individually with an ohmmeter to insure that they are good and properly marked. The bar end of all diodes standing up will be up. The bar end of all diodes laying down will be toward the center of the board.
( ) Mount the 15MFD capacitor. Observe polarity. Bend Z1 lead so it doesn't touch this capacitor's case.
( ) Mount the .22 capacitor. If you are using the old one mount it vertically as shown by dotted lines — observe polarity.







( ) Mount the two .001 capacitors.
( ) Mount the four .005 capacitors.
( ) Mount .05 capacitor.
( ) Mount the 2N3640 transistor as shown on overlay.
( ) Mount the 2N2924 transistor as shown on overlay.
( ) Mount the 3M84 SCS's as shown on overlay (4 ea.). See note #1.
( ) Add wires as shown on overlay: Twist ⅜" bare end of the groups together, insert into proper hole and solder. Solder the four blue wires as shown. Solder white wire as shown.
( ) FLAT solder mounds with fine file and clean board with acetone or dope thinner.
( ) Bevel edges of board to prevent shorting to case.

PRELIMINARY CHECKOUT

( ) Inspect copper side of board carefully for BRIDGED solder lands.
( ) Inspect component side of board for proper parts mounting and insure that component leads don't touch. Also insure that 3N84 cases don't touch adjacent leads or components.
( ) Measure resistance between black (negative) land and green (positive reg. 5.1V) land. You should read approximately 3K with proper polarity and on the X100 scale — this reading depends on the meter you use and can vary. (I used a 20K/V multi-meter.)

PREPARING RECEIVER/DECODER

These steps apply only if you have a three-channel decoder already built:

( ) Remove receiver and decoder from case.
( ) Unsolder white/green/black wires from receiver. Set the receiver board aside as it will not require any changes.
( ) Completely dismantle decoder removing all components and wires. If you are going to use all new parts, of course this step doesn't apply.

NOTE: Your best bet on servo/power wiring is to salvage the old plugs and completely rewire. You can use your old wiring harness but it gets pretty exasperating.

( ) Prepare decoder case for five grommets as per original Digitrio article and drill antenna and mounting hole.

NOTE: A shield is not required on the decoder. To obtain a good ground, melt a solder mound around decoder mounting hole, drill it with an undersize drill and let sheet-metal screw tap into it.

( ) Mount decoder, with the insulating sheet, in its case half with mounting screw and install grommets.
( ) Route one each blue, yellow, orange, red, green and black wire through grommet for each servo.
( ) Route one each red, orange, yellow and black through grommet for power wiring to switch.
( ) Twist all servo groups together and clip to length desired.
( ) Slip a 1" piece of large heat-shrink tubing over each of the servo wire groups.
( ) Twist the remaining white/black/green and cut to 3".
( ) Untwist 1" and tin each wire 3/16" in the servo groups and slip a ½" piece of small heat-shrink tubing over each lead.
( ) Solder each servo plug as shown in original wiring diagram.
( ) Slip a 1" piece of large heat-shrink tubing over the four power wires.
( ) Tin each power lead 3/16", slip a ½" piece of small heat-shrink tubing over each lead and solder to switch connections.
( ) Solder the battery plug and wires to switch in the same manner.
( ) Solder the receiver leads to the receiver board as per original overlay.
( ) Mount receiver in its case half and slide the two case halves together while checking for pinched wires.

NOTES:

1. When soldering in the SCS's it would be advisable to use a heat sink on the leads (a pair of long nose pliers will do). Also unplug the soldering iron to prevent capacitive voltage coupling which could damage or change the characteristics of the SCS's.
2. The motor control servo must be returned to original circuitry if it was modified.

GENERAL

Later in the article I'll cover final testing of the Digitrio-4 modification. From the phone calls I have received so far, many of these systems have been built from the articles and are flying with excellent results. All of these systems were operating properly before they were modified. If you were having difficulty before the mod, you may carry over your problems to the four channel. Remember, all we have changed is the decoder. If your trouble was in your decoder the new decoder may solve your problems. On the other hand if your problems were elsewhere, the -4 mod will not clear them up. When you troubleshoot the system keep in mind that we have only changed the decoding method and added two more pulses at the transmitter.

I have received many letters inquiring about repair service on the Digitrio. There are many places around the country that can repair your Digitrio. I have received several letters from different firms and individuals asking if they have my permission to service the Digitrio. Although it is impossible for me to vouch for the quality of the service rendered by all these people, I encourage them to perform repair service. My feeling is that I would like to see as many Digitrios flying as possible, and since the system is basically simple in concept to a qualified technician, careful selection of your repairman should yield satisfactory results. If you are having trouble beyond your capabilities, or just want to know that your rig is performing properly, I would suggest, first of all, that you get with your technician friend. He can probably tell you whether your problems are serious or minor in nature. If he can't, try your dealer, he should know the **really** sharp technicians in the area. If your problems were minor they should have been cleared up by that route. If you can't get satisfaction locally, your problems may be of a complex nature and require expensive test equipment for a solution. Even simple troubles often defy detection. I have repaired many Digitrios for my friends that had improperly installed components. Some of these sets required many hours to correct. When told that their trouble was one of parts installation their reply was essentially the same, "I checked it over at least a dozen times and would swear it was right!" The problem here is evident — when checking back they simply repeated the same mistake they made originally. This could be due to reading the instructions improperly or having a "mental block." I have made this mistake many, many times myself. One improperly installed component can usually be found by observing symptoms and applying circuit knowledge along with common sense. However, two or more improperly installed components can lead to many hours on the test bench and involve expensive test equipment, as well as the best efforts of the technician for a cure. By the same token, one or more defective parts could be present in the system giving approximately the same symptoms and troubleshooting problems. On several occasions I have been subjected to a Digitrio builder displaying a temper tantrum because this system didn't work properly. This type person usually possessed occult powers because he had applied his mystic powers of electronic's knowledge to his built-in, "brain-powered" computer and came up with the revelation that the "Digitrio could never work properly! In a few cases a simple "tweak" of the alignment tool caused replacement of his crystal ball with a book on electronic theory. You'd be surprised how many people fail to peak their receiver and end up with a P.C. board full of useless parts.

Then, there's the type that starts changing parts values at the first sign of trouble. This type is doomed from the start unless he truly understands what he is doing. An example of this was a fellow to whom I loaned my original decoder so that he could get his system in the air. My decoder had been through well over 200 flights and performed flawlessly. At the first sign of difficulty a modification was made to my decoder, followed by some passable and some impassable flights. Of course, all the problems experienced were blamed on my decoder. As it turned out, my friend forgot to install the zener diode in his transmitter. The moral here, is: If you can't pin-point your trouble don't experiment with the circuitry!

One quick way to determine where your problem lies would be to swap your defective sub-systems with a friend whose rig is working properly. This is an often overlooked, but highly accurate, way to pinpoint your trouble. Say, for instance, you suffer from lack of range. It's easy to swap transmitter crystals with your buddy in order to check your transmitter against his airborne equipment. It's a little more involved to swap receiver crystals, but can quickly tell you whether your airborne equipment is at fault. This same reasoning applies to the decoder and servos. All parts of the system were designed to be built separately and can be interchanged — just remember to go through alignment of the transmitter and receiver if you swap crystals. Also, if you have to resort to the parcel post route, send the entire system to your repairman — including antenna, batteries, battery charger, etc. A lot of troubles are quite minor such as failure to resonate the antenna as described in the articles, bad batteries, improper polarity of battery charger, etc. Performing the modifications I recommend may clear up a problem for you, also. If there are any doubts about system performance, perform the recommended mods. These were worked out from actual case histories and won't degrade the performance so you have nothing to lose.

Another often overlooked item is interwiring errors, especially at the servo plugs. I know of several cases where the switch was improperly wired so that there was current drain on one or more batteries with the switch turned off. Check all wiring carefully and look for loose strands of hook-up wire that may be causing shorts, especially at the switch. One other place to check is where stranded wires are inserted in the P.C. boards. It is possible for one or two strands to "push" away from the hole and "short" to an adjacent component lead. This has happened on two known occasions with the white wire at the receiver causing failure of Q7.

Whatever your problems and regardless of how complex they may seem to you, systematic checking by a good technician should be routine, so seek help if you get over your head. World Engines prints on each kit they sell that they will repair systems built from their kits. By the time this is in print or because of this article others should offer repair service so check the ads in RCM and check with your dealer. I'll try to compile a list of those offering this service for later publication. Now that the -4 mod is completed I'm undecided where to go next. Frankly, I'm glad it's over and I can assure you that the letters I received kept me going. I received more letters of encouragement than I could count and only a few critical ones. To you who wrote letters of encouragement I would like to say thanks again and urge you to let the other model editors know when you enjoy or are interested in an article. I am sure you don't realize what a profound impact you make on a writer's morale and incentive to do his best. To the critical writers, I'd like to say thanks also — you taught me a valuable lesson and expanded my knowledge of human nature.

A long overdue acknowledgment of patience and well wishing is due to our friends "down under." The Australian chaps have many Digitrios flying in spite of difficulty in obtaining parts and extra delay of magazine delivery.

From the letters received there seems to be a need for comprehensive Digitrio troubleshooting instructions which I am considering. Also the mail indicates a desire for a simple pulse system with which I am experimenting. I also have been working on some 72 MC gear which works well. Perhaps some of this will be published later on. The problems I encountered so far with these new frequencies are small and I foresee no problems except the type approval tests required. While the type approval will require a little more effort on the part of the designer the largest hurdle lies in compiling the information required by the F.C.C. It also appears that this new band of frequencies could develop into an "appliance operator's band" with the restrictions of type approval which is/was apparently overlooked and/or endorsed by the AMA. Since most of what has been written about this new "blessing" is either premature or in the form of publicity, I have no significant comments except that the "high desirability of these new frequencies" remains to be proven. Further, the restrictions placed on equipment at these frequencies will, in all probability, severly hinder state of the art advancement in the future.

TROUBLESHOOTING THE -4 MODIFICATION — TRANSMITTER

The transmitter mod only added two one-shots which are identical to those previously covered. I therefore don't have any troubleshooting advice here except to recheck your modification installation. If possible look at the sync pause duration (adjustable by R13) on a scope. This can be viewed between the collector and emitter of Q11. Adjust R13 to 8-9 MS between the leading edges of the #1 pulses in the pulse train. This will provide a nominal 4 MS sync pause. To calibrate your scope, display one or two cycles of 60 cycles AC. Each cycle will have a time period of 16⅔ MS. Eyeball a half cycle (either a positive or negative alternation) and you will have 8⅓ MS. With your horizontal gain and horizontal centering control adjust this half cycle to occupy four divisions on the scope. Your scope is now adjusted to approximately 2 MS/DIV. Display the pulse train at Q11 and adjust R13 so that the leading edges of the #1 pulses are separated by four divisions on the scope face without adjusting either the horizontal sweep frequency or horizontal gain. The above procedure, while not super-accurate, will get you within design limits. The same procedure can be used by European and other countries that use 50 cycles for household voltage. The only difference is the period of one cycle being 20 MS. In that case, adjust ½ cycle for five divisions so that each division still represents approximately 2 MS and set up the #1 pulses between four divisions. For those of you who don't have a scope or easy access to one simply set R13 to midrange.

DECODER

It would be advisable to check the decoder for upper temperature limits before flying in hot weather. This can be as simple as exposing it to direct sunlight on one of the hottest days you anticipate flying or placing it in the oven. Since winter is coming on and the hotter days won't be with us for a while the oven is your best best. CAUTION: Don't depend on the oven temperature dial for this test. Buy or borrow a centigrade thermometer if you want to go above 120° F. The normal household type only goes to 120° F. Decide what would be the hottest day on which you anticipate flying and add 30° F (20° F for direct sunlight effect and 10° F for insurance). By experimenting with the heat control and opening the oven door to varying degrees adjust the heat to your predetermined upper limit temperature. Insert the complete airborne system along with the thermometer and let it soak up the heat for at least 15 minutes after the thermometer stops rising or total of 30 minutes whichever is longest. Keep the bulb of the thermometer close to the decoder and use a piece of wood or cardboard (a small cutting board is fine) to support the equipment. Operate the equipment as it soaks up the heat and if it stops you can estimate what the upper temperature was when it failed. Also you can check servo drift with heat by marking the output arms with a pencil. The drift should be no more than the width of a pencil line to about 140° F. If you are satisfied with the test, place your transmitter in the oven and check it also. Since you have gone this far you might as well go the deepfreeze route too. You can either let the equipment cool to room temperature first or give it the shock treatment and go directly to the deepfreeze. If you don't anticipate flying with the eskimos, use the refrigerator. It will take awhile to get it down to temperature due to previous heating, so be prepared to wait awhile. Your equipment should work between 20° F to 140° F. I checked five systems and one worked to 170° F, three to 160° F and one to 110° F which was corrected to 160° F. The lower limits were below 20° F (limit of my deepfreeze) on four and 30° F on the one I corrected. Before I get into correcting for temperature I'll explain what factors influence temperature range.

As explained earlier in the theory of operation the turn-on line provides a positive pulse through a diode to each SCS gage. The circuit constants were chosen to provide a 200 ua positive pulse of approximately 2 us duration for this purpose. The turn-off pulse for each stage is provided by the preceding stage and circuit constants provide a 300 ua negative pulse with a 10 us duration. The difference in pulse duration and strength account for proper commutation by allowing the negative pulse to overcome the positive pulse when they arrive simultaneously at a gate and the selected stage is turned off.

Enter HEAT—the turn-on sensitivity rises with heat and the turn-off sensitivity decreases with heat. As heat is raised a point will be reached where the device will not turn-off with the presence of the turn-on pulse. A further increase in temperature will not allow turn-off even without the presence of the turn-on pulse and eventually the temperature will rise where the gate loses all control and the device is held conducting by minority carrier current flow. As temperature is lowered the trigger requirements will react in an opposite manner as far as circuit operation is concerned. This circuit was designed for proper operation between conservative limits of 20-140 F by selection of circuit constants. Some of the causes for premature failure could be that one of the SCS's trigger parameters has changed either by excessive heat or capacitive voltage coupling during P.C. board assembly. Or, possibly that one of the SCS's was on the parameter border line when you received it. If temperature effects cause failure before the upper temperature limit is reached a solution can be affected in one of two ways. Either replace the SCS that is failing or increase the turn-off/turn-on pulse ratio. Replacement of the SCS is the most expensive of the two methods and in most cases is unnecessary if you don't mind an increased lower temperature limit. If we increase the amplitude of the turn-off pulse the total temperature spread will shift upwards although the rise of the extremes won't be directly proportional. In other words, say our temperature spread was 20°-110° F. We may cause an increase of our upper limit by 50° up to 160° F and our lower limit may only rise 8° up to 28° F. As you can see this can get complicated since the discussion so far pertains to only one stage and we will be working with four. Actually the temperature checking procedure is rather simple if done in a systematic manner and I'll outline it for you as follows:

1. Select your minimum upper temperature limit as described previously.
2. Adjust your oven or place the equipment, with the receiver case open, in the direct sunlight on an extremely hot day. If your servos were not marked as to which output they are controlled by, mark them before you go any further. Mark them from #1 to #4.
3. With all the equipment hooked up (all servos) operate the equipment and look for a servo failure as the temperature rises. If the failure occurs in the oven, estimate as best you can the equipment temperature when the failure occurred. If you believe the failure occurred at an acceptable temperature (say within 5°-10° F of your target temperature) run further tests to insure that the failure temperature is not within your specifications. NOTE: Your first tests will probably be on the hot side until you are used to the procedure. Also there may be hot spots in the oven. If the failure occurs in direct sunlight of course the results will be unacceptable.
4. The next step is to decide which stage is failing. If more than one stage failed during the test concern yourself with only the first to fail. The failure of one stage will cause the following higher-numbered stages to fail also. For instance, if #3 stage failed, both stages #3 and #4 would be inoperative, but if #4 failed it wouldn't affect the other three. However. if #3 failed at a higher temperature then #4 would be the second one to go out. The objective here is to fix them one at a time systematically and prevent confusion. Keep notes of failures for further reference.
5. Fix the stage that failed. Here you have your choice of methods. Either replace the SCS or increase the value of the .005 coupling capacitor from the preceding stage to a .01. This can be done by paralleling the existing .005 with another .005 at the copper side of the P.C. board until the tests are completed. The coupling capacitors are C4, 5, 6 and 7. If #4 output failed (Q5) you would increase C7, #3 C6, #2 C5 and #1 C4.
6. Run another test to determine if any other stages will fail within your upper limit specifications and correct them as above.
7. When you are satisfied with the upper limit tests, run the lower limit tests in the refrigerator or deepfreeze. Here again you can use one of your coldest days and set the equipment outside but don't set it in the direct sunlight. If a failure occurs higher than your lower temperature specification check your notes to see if you added a capacitor to correct the upper limit of that stage. If so you will have to replace the SCS to maintain both high and low temperature extremes.
8. Replace the SCS's or the .005's with 0.1's and recheck the temperature range for insurance.

Here's another way to make a quick check. Although it won't tell you the temperature extremes accurately it will let you know whether you're in the ball park or not:

1. Heat the oven to what you feel is about twice as hot as you expect the equipment to operate.
2. Place the equipment in the oven and operate the servos until the cases get hot to the touch (not warm). At about 140° F the cases will be uncomfortable to hold but not hot enough to burn the skin. Or, you can wait until you have a failure and remove the equipment noting the case temperatures when the equipment starts operating again. A WORD OF CAUTION HERE: Your equipment could go beyond 160° F without failure and chances for heat damage to component parts will increase, so stay within reason on the touch test.
3. Run the deepfreeze test. Here the lower test limit will be determined by the temperature setting and the freezer's ability to recover from the added heat of the equipment. At about 20° F the servo wires will get stiff and servo response may slow down slightly due to the cold. It should be easy to obtain a household thermometer for this test.

The above "quick" check will depend a lot on your ability to determine temperature by symptoms.

Troubleshooting follows the same logic as the heat checks to pin-point a defective stage. Determine which stage is defective by observing servo action and repair as necessary. Don't run the heat checks until you are sure the system is functioning properly as it will be a waste of time. From the letters received and personal observations I know there will be many cases of germanium and silicon diode swapping. Also diodes installed backwards or marked improperly. If you don't know for sure what type diode you have (hunches are sure to get you into trouble) don't use it. Also a check of each diode before installing them may prevent later problems. If you use a scope and want to look at the outputs you will either have to connect the servos or simulate them. They can be simulated by placing a 22 K resistor and a silicon diode in series across the decoder output with the diode arrow pointing to ground (SCS cathode). Don't check the SCS's with an ohmmeter unless you've got a lot of money for replacements. All the components used have been identified for you and if you make substitutions you know my favorite saying. I'll spare you the nausea this time and just say "good luck!"

One thing should be obvious at this point. Since each SCS stage is identical it would be an easy matter to increase the number of channels. I have gone to six without any circuit changes other than SCS stage addition. Beyond this R2 may have to be decreased to maintain on/off pulse ratio. 500 ohms should be about right for 8 channels. If I get enough letters I may publish a board for additional channels. How many depends on the requests. The same goes for a new transmitter board. If you write in please state your desires and spare me the lectures on why I should have done it in the first place. Also fellows, no more lectures on the number or content of articles it's taken to complete the system. When you write articles on the system you design I promise not to tell you how to do it. O.K.! Fair enough.

Here are a couple of notes on the Digitrio that may answer a few letters. Ed Means and Jack Albrecht of Colorado Springs were up last Saturday. Ed brought along a Digitrio-4 that he is building, for a look-see on the scope. The equipment worked well as checked with a FSM and multimeter. The transmitter scoped out perfectly and the power output was measured as higher than average. When we scoped the receiver, however, it also appeared a little "hotter than average." However something didn't seem quite right. At certain signal levels we would get double output pulses. Also the diode load output had a "rabbit" running through the pulse trains. This "rabbit" had no direct relationship to either the individual pulses or the sync pause. It just drifted through the pulse train at a very slow rate. This led to several hours of trouble shooting, and finding nothing wrong, it seemed obvious that our problem was in the scope connections. But, regardless of how we isolated the scope leads the problem persisted. By this time all the desire to "play" with this "damned Digitrio" was dissipated. Ed and Jack left for Colorado Springs mumbling something about sticking something somewhere!

The next couple of days I would turn the receiver on occasionally and check to see if the trouble had cured itself. My prayers to the "Electronic Fairy" were

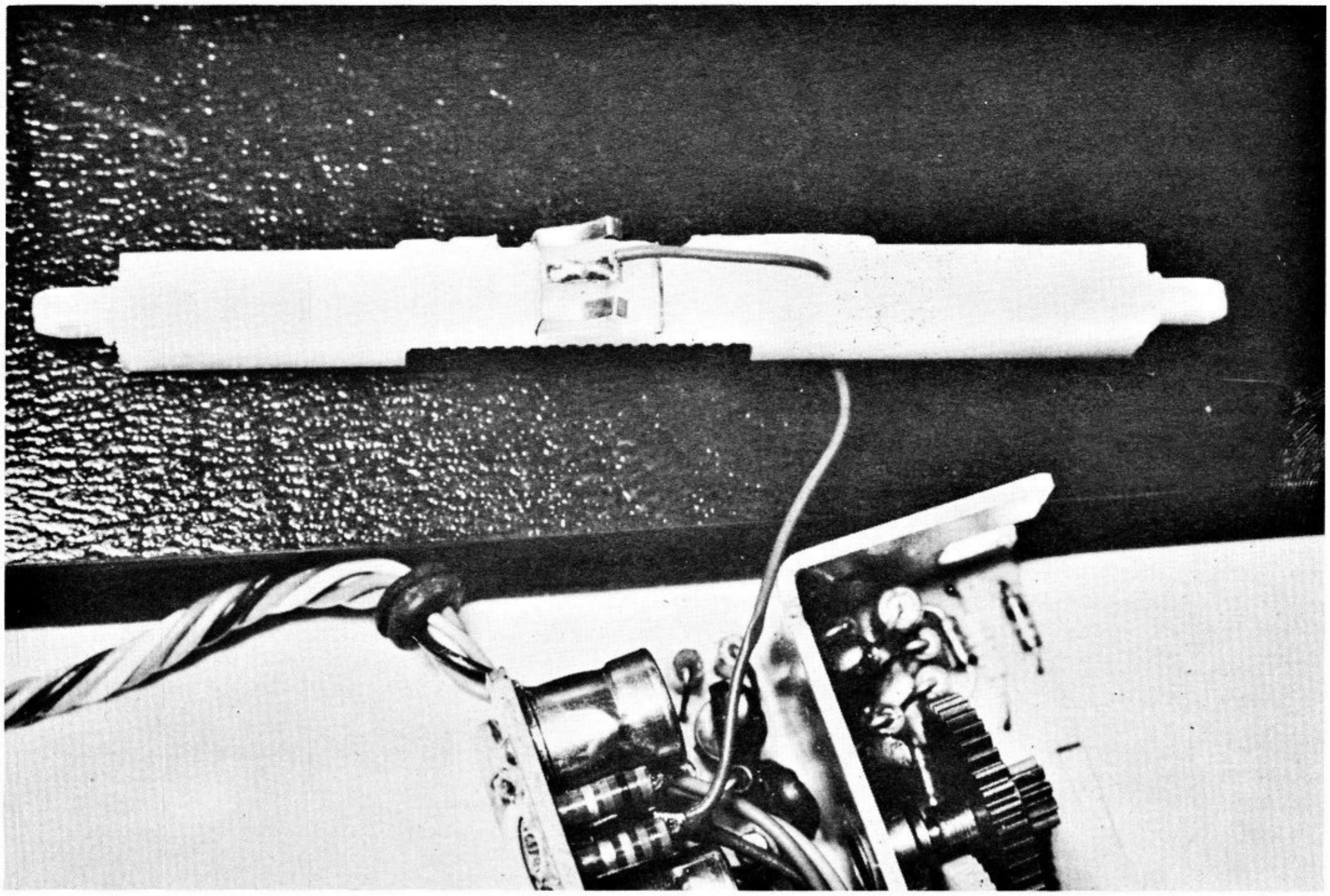
Russ Johnson, Palmerston North Aeroneers MAC, New Zealand, with his OS .19 powered Falcon and Digitrio.

not working and the "radio rabbit" was still running. I tried ignoring it for a couple more days by "de-mothballing" the Digifli and installing a new ringed Max 40. After a successful day of flying the Digifli (bringing it home in one piece), a thought struck me — "Thompson, when was the last time you brought a plane home in one piece?" I thought for awhile and said to myself, "I don't remember, it's been so long!" I checked with my neighbor, Tom Wyatt, and he said, "It must have been when you were still in Phoenix." After a few calls to Phoenix Bob Burand reminded me that one time last February I had forgotten to take my transmitter to the field.

What I'm getting at is this. With what I had just accomplished I knew that a simple receiver problem would be "duck soup." First of all I pulled the receiver out of the Digifli and looked at it with the scope. I saw the "rabbit" but it was insignificant. I took it out of the case to look at the IF stages and the "rabbit" came on strong. There was my answer, the receiver should be in the case for testing. But then I remembered that this hadn't happened before so I got out my old scope and ran similar checks. The "rabbit" was gone, whether it was in the case or not. I then tried to figure out what was causing the problem when I used the new scope. I never really came to a concrete conclusion although several things were contributing:

1. A local broadcast station was entering my new scope — apparently through the A.C. line and modulating the scope trace.

2. A power line leak was emitting a pulse-type electrical noise with a 20 DB over S9 signal on my communication's receiver. I later verified that it was showing up in the Digitrio receiver output. I did find a way to eliminate the problem though. With the receiver in the case and grounded to the case no trace of the "rabbit" is evident on either scope. The receiver case is grounded when the case halves are together because the decoder board is grounded to its case half. However with the case halves separated there is no ground between the receiver board and its case half. The easiest way to supply a ground is to notch the mounting hole in the receiver board case half. Solder a bare piece of wire to the +5.1V land at the junction of the two 40 mfd electrolytics and let it stick through the notch in the mounting hole. Insert the mounting screw and wrap the wire around it one turn and tighten it down. The "rabbit" appeared to be causing the double-pulse output and was cured before the grounding process by replacing R15 (10K) with a 47K. Whether this was necessary or not I don't know as Ed has his receiver back now and I didn't change it back. A check of my receiver indicates no change in resistors is necessary but I am passing it on as something to try in case you have similar trouble. Based on the fact that the trouble I experienced is possible, whether real or induced, I recommend that the receiver board be grounded as described to preclude troubleshooting confusion.



DIGITRIO SERVO MODIFICATIONS

The addition of a single wire eliminates the most troublesome point in any servo — the sliding contact between the contact finger and wiper shim. **By Ray Pisar.**

Here is a reliable modification for the Digitrio servo by Ray Pisar of Phoenix, Arizona. The minor effort required will reap huge benefits. I recommend this modification be performed on all Digitrio servos.

WHEN I first met Ed Thompson two years ago, he impressed me as being a person not easily satisfied; fortunately for us, he has not changed. His constant experimentation and testing with his Digitrio and the coming four channel version have resulted in probably the most sought after characteristic in R/C systems — **reliability.**

It is my purpose here to present a modification which will enhance this already superbly reliable system.

The addition of one wire in each servo results in the elimination of the most troublesome point in any servo — the sliding contact between the moving contact finger on the output arm and the wiper shim on the PC board.

Most Digitrio flyers will want to update their present servos since this simple modification can be added to existing Digitrio servos as easily as it can to new servos being built from kits.

Proceed with the modification as follows:

1. Drill a #60 hole down through — and at 90° to — the output arm at a point ⅛" to the left of the right edge of the raised portion of the output arm. The wiper fingers point toward the right edge.

2. File and deburr a 1/16" notch ⅛" from the upper right edge of the "C" frame.

3. Cut a 2¾" piece of stranded #24 wire and strip ⅛" insulation from one end and 1/16" from the other. Tin both ends. I used some super flexible wire which I bought from Kraft.

4. Clean and tin the middle wiper finger on the output arm (it isn't used anyhow) and solder the ⅛" stripped end of the wire to it. Work quickly and avoid excessive heat here.

5. Feed the wire up through the #60 hole (a dab of R.T.V. may be applied to the wire where it enters the arm to relieve strain) and bend the middle finger so it is parallel to the output arm and flat. Don't forget to readjust the feedback pot wiper finger(s).

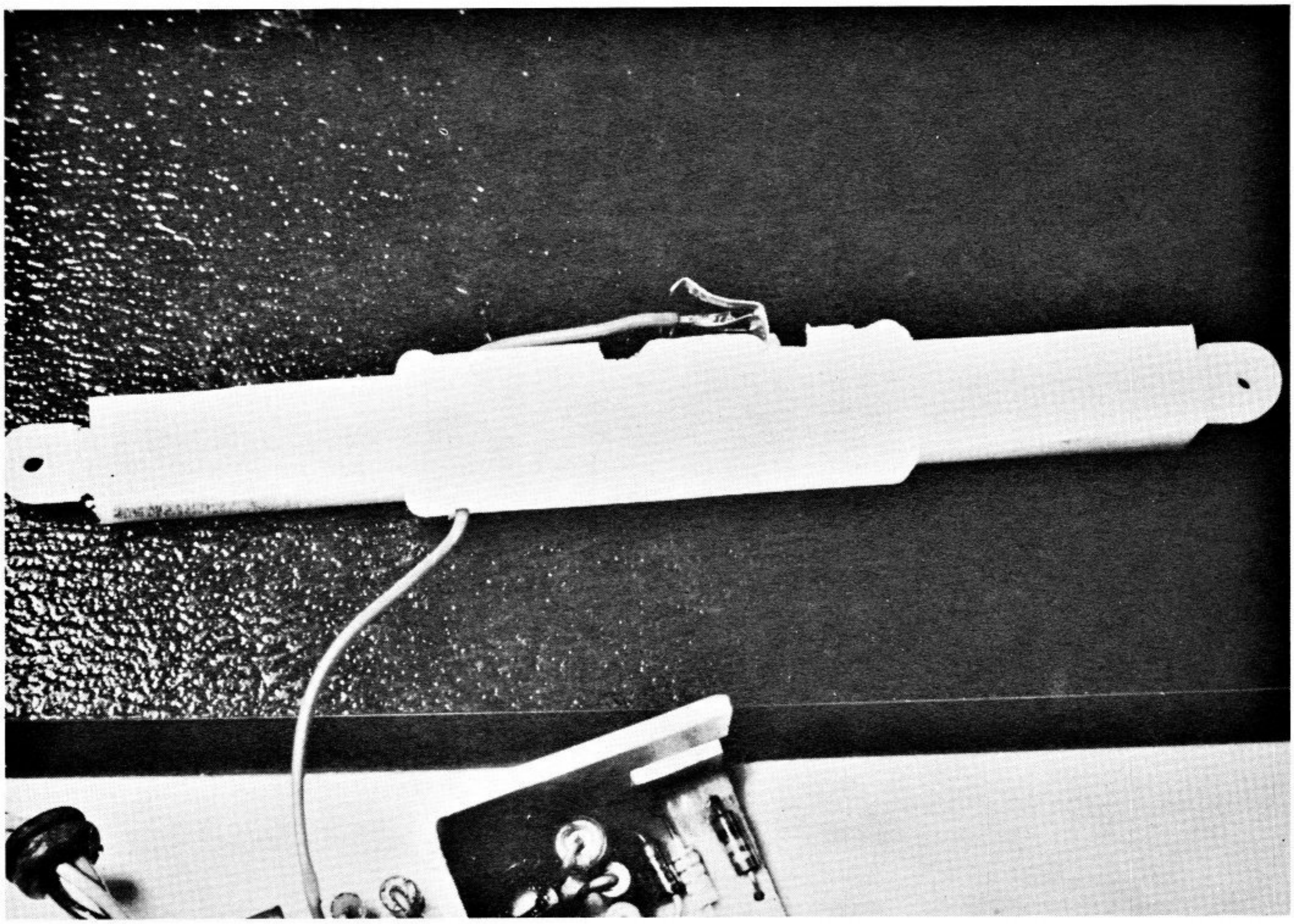
6. Solder the remaining end of the wire to the exposed lead of the 68.K ohm resistor (R-12) located on the auxiliary board and the modification is complete. (See original servo overlay.)

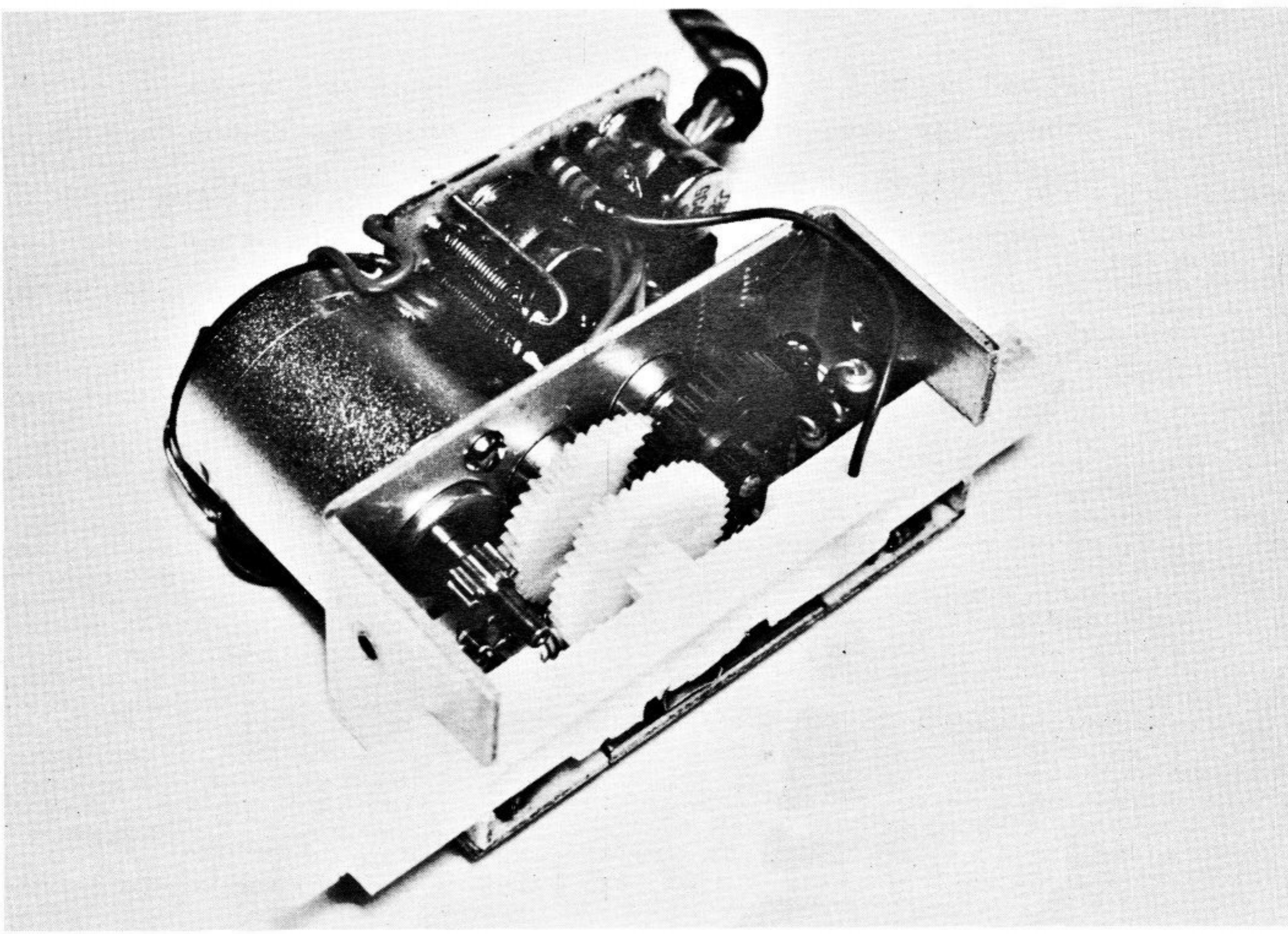
Carefully route the new wire into the 1/16" notch in the "C" frame while reassembling the servo per Ed's article.

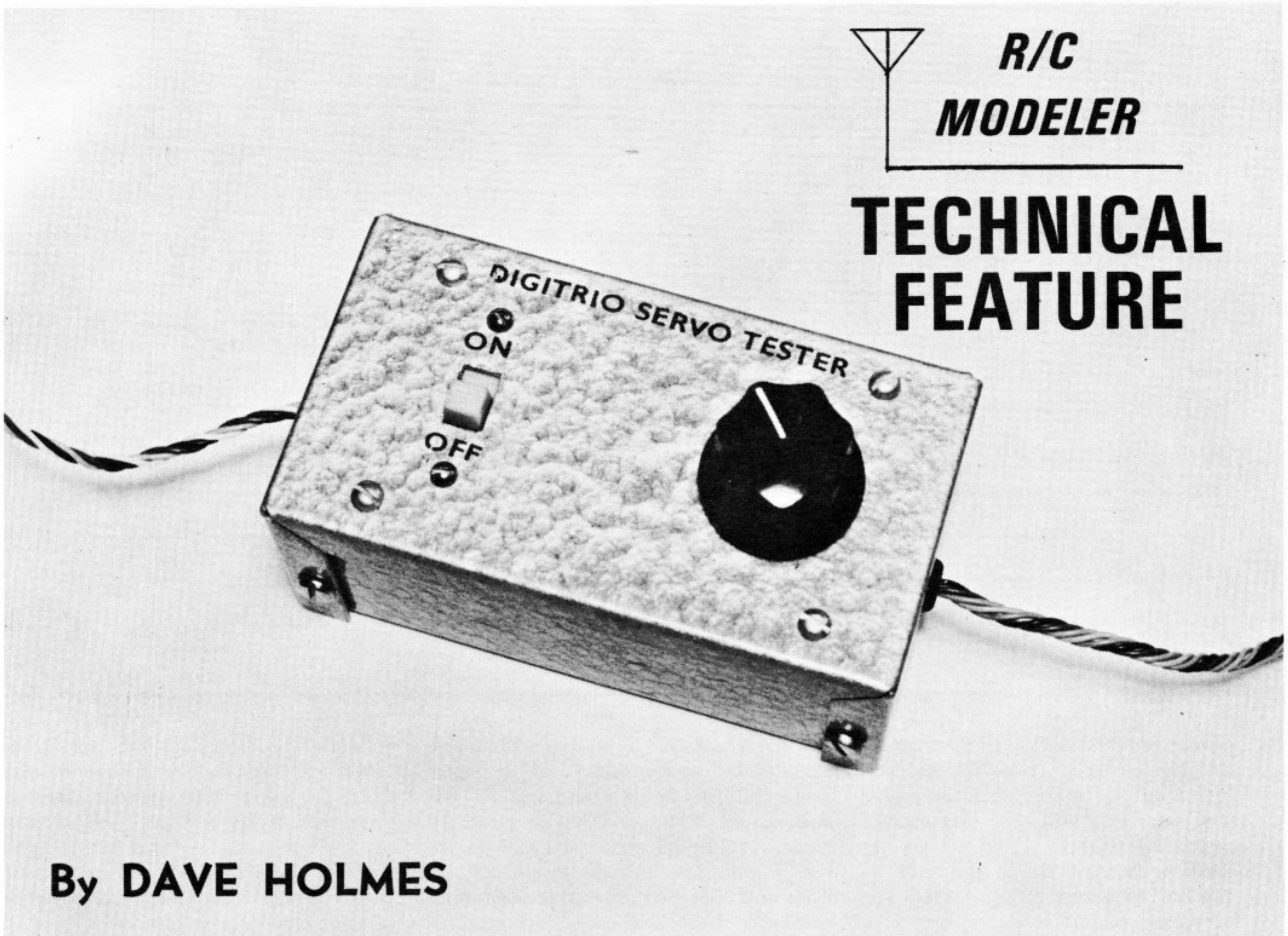
This modification does not change any wiring of the original servo. The servo must be built as per the original article. This additional wire is a form of insurance in case of wiper failure.

By the way, in case you're interested — there are 160 solder connections in a Digitrio servo, 300 in a four channel transmitter, 139 in a 4 channel decoder, 148 in the receiver, 18 in the harness, and 16 in the receiver pack, for a grand total of 1261 solder connections in a Digitrio-4.

File **that** under miscellaneous information.







DIGITRIO SERVO TESTER

Designed for the Digitrio, this servo tester can be modified for use with any digital system. Excellent for setting up linkages or operating servos without using the transmitter.

Tech Editor's Findings

RCM has checked Dave's servo checker and finds it to be an extremely useful device for testing Digitrio servos. As the author says, the basic design can be modified for use with other type digital servos. Some servos will require a negative going pulse for proper operation and a pulse inverter could be added.

THIS is the first in a possible series of articles on test equipment for proportional equipment. While this tester is designed particularly for the Digitrio equipment, it can be modified to work with other systems such as Micro-Avionics, Kraft, PCS, etc.

This little device will allow you to work on servos without having to use the transmitter and receiver and also comes in handy for setting up linkages in a new airplane. Since I often fly in contests, I have also felt the need for some way to operate the throttle servo when my engines are acting up (normal conditions) and my transmitter is impounded. Contest pilots can appreciate this point.

The cost of this tester is in the vicinity of $12.00 or less and it is well worth the time and expense involved.

Construction

Construction is quite simple and proceeds as follows:

( ) Drill all holes in board with #67 drill.

( ) Enlarge mounting holes with #44 drill and tap for 4/40 bolt.

( ) Install all resistors.

( ) Install all capacitors. Observe polarity of C1, C2 and C4.

( ) Install diodes. (Check polarity.)

( ) Install transistors.

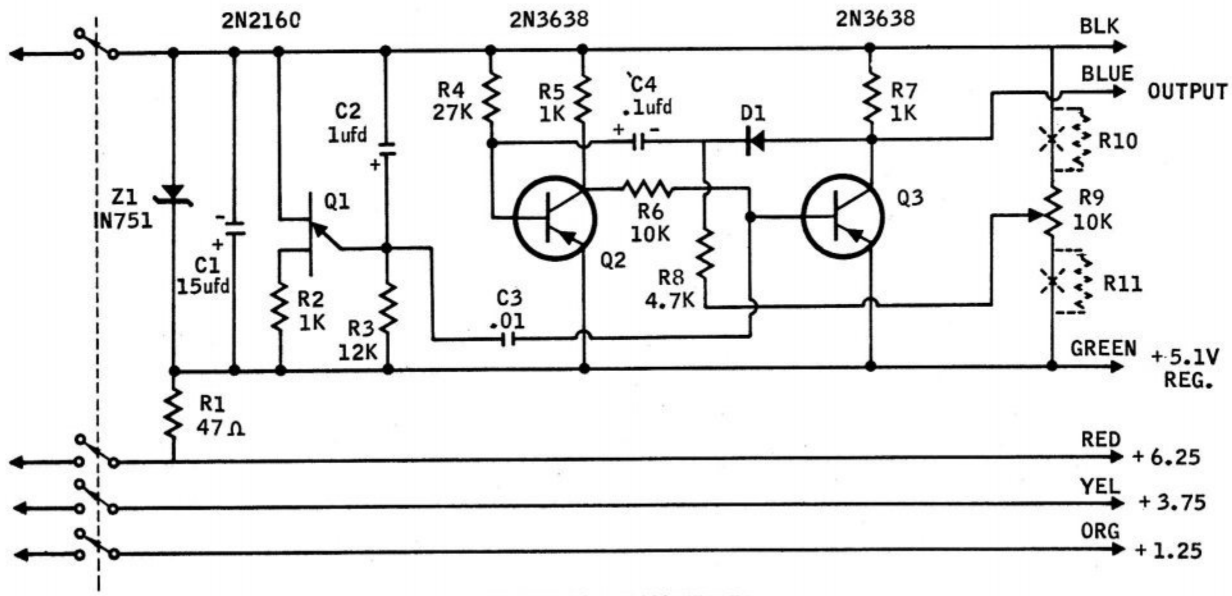
( ) Install 4″ lengths of red, black, yellow, orange hookup wire in proper holes. (Zener end of board.)

( ) Install 6″ lengths of red, green, blue, black, yellow, orange hookup wire.

( ) This completes the wiring of the board. Clean all joints with thinner or alcohol.

( ) Lay full-size template over top of box and mark holes and switch cutout.

( ) Drill all holes as indicated. On the



DIGITRIO SERVO TESTER

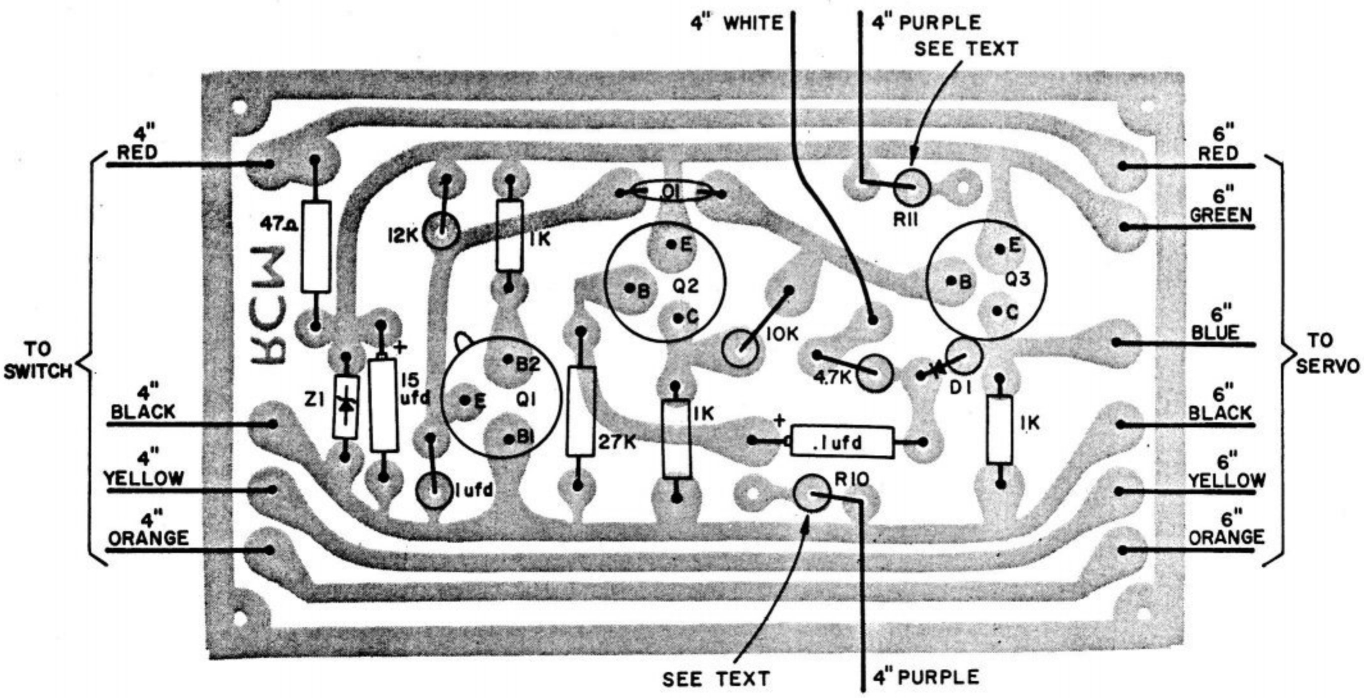
cutout for the switch, a little care in drilling a row of holes around the inside of the marks and filing out the remaining will give you a neat appearing cutout.

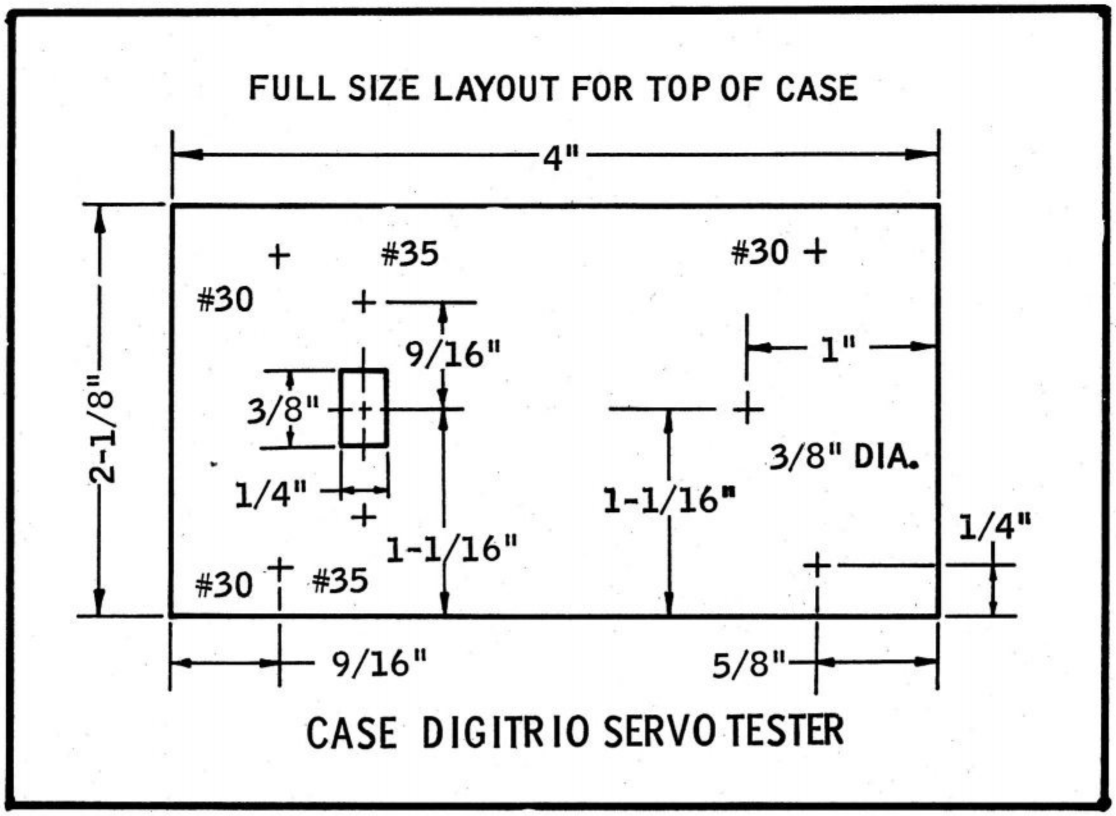
( ) Drill holes centered in the ends of the box to accept ¼″ grommets for servo and battery leads.

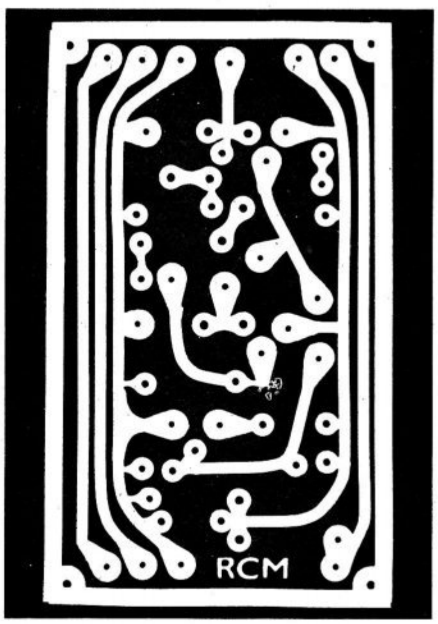
( ) Cut 4 ea. 15⁄16″ lengths of 5⁄32″ brass tubing for spacers.

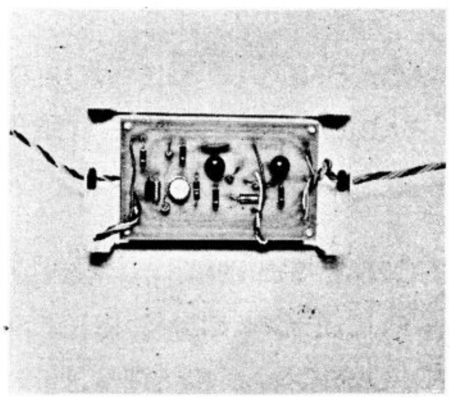
Assembly of the tester is best done by first mounting pot and switch in the case. Wire the battery leads to the center arms of the switch. Lay complete P.C. board component-side down beside box and route 4″ leads to switch. Trim and solder. Route 4″ purple and white leads to pot with white going to center arm. Fold board over and install bolts and spacers. Route servo and battery leads out through grommets and assembly is complete. Recheck all connections and check battery cable with ohmmeter for shorts and proper connections to board. If you are sure of the connections then a smoke check is in order. Plug in battery (no servo) and turn on switch. Check voltages at servo cable with a volt meter. Measure voltages with minus lead of voltmeter to black lead of servo cable. All voltages should check as indicated on schematic. If all voltages are right, set the pot in the center of its rotation and plug in servo. Turn on power. Servo should seek approximate center and stop. Adjust knob to position servo in exact center of its rotation and reset knob on pot to a reference mark. That completes alignment of your servo checker.

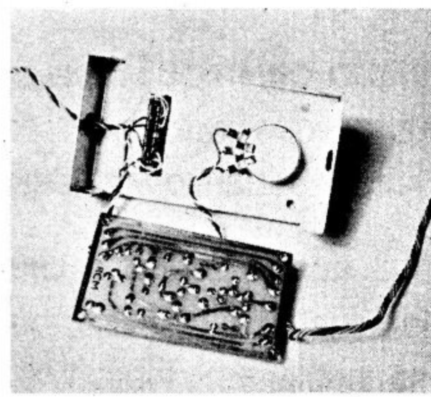
The tester with the parts values as shown yields the same servo movement for pot rotation as your transmitter gives you. If vernier action is desired, two 4.7K resistors may be inserted, one in each arm of the pot as shown in dotted lines on the schematic (R10 and R11). Pads are provided on the board for these











resistors if you wish to use them.

If it is desired to use this tester with other than the Digitrio, some wiring changes may be needed. The output from the unit is a one MS nominal positive-going pulse. If the servos you wish to use it with take a one MS positive pulse you are "in." Otherwise R4 may have to be varied. A larger value of R4 gives a longer nominal pulse and vice-versa. The pulse repetition rate can be varied by changing R3. Here a larger value gives you a lower repetition rate. These two resistors could also be replaced with trim pots if desired.

I hope you get as much pleasure from your servo checker as I have from mine. With this unit there should be no excuse for not giving your servos the periodic maintenance recommended by Ed.

Good luck and may you grow fewer grey hairs at the service bench.

PARTS LIST FOR DIGITRIO SERVO TESTER

R1	47 ohms	¼ W 10% Carbon
R2	1K	" " " "
R3	12K	" " " "
R5	1K	" " " "
R6	10K	" " " "
R7	1K	" " " "
R8	4.7K	" " " "
R9	10K	potentiometer CTS PQ 11-116
R10	4.7K	¼ W 10% Carbon
R11	4.7K	" " " "
D1	DHD806, 1N658 etc. Silicon Diode	
C1	15 ufd 6 volt tanalytic	
C2	1.0 ufd 6 volt tanalytic 10%	
C3	.01 ufd ceramic capacitor	
C4	.1 ufd 6 volt tanalytic 10%	
Q1	2N2160 G.E.	
Q2	2N3638 or 2N3640 Fairchild	
Q3	2N3638 or 2N3640 Fairchild	
Z1	1N751 Zener	
1	Aluminum case, Premier #PMC-1002, 4 x 2⅛ x 1⅝	
4	4/40 x 1⅛" bolts	
2	¼ grommets	
1	Pkg. hookup wire (8 colors)	
1	ea. female servo connector and male battery connector	
1	W.E. 9F switch 4PDT	
1	Knob	
1	4" 5/32 brass tubing	

As most of you undoubtedly know by now, World Engines is kitting the DIGITRIO package. DIGITRIO is a three channel digital proportional system which was designed by Ed Thompson and is currently appearing as a series of construction articles in Radio Control Modeler magazine. Ed Thompson and RCM have given World Engines the exclusive right to kit the DIGITRIO system. Several of these systems have been completed and are being flown; some very enthusiastic reports are already coming in. Those interested in this control system may purchase components separately from the published parts lists, however, a little investigation will reveal that the prices of the parts' kits as packaged by World Engines cannot be beat and represent a substantial savings.

Transmitter Kit

The photo shows a completed DIGITRIO Transmitter with the Bonner Stick option. The Tx kit price of $69.95 includes all parts, crystal and hardware except the control stick assembly and the power pack. The aluminum case (7" wide x 5" high x 3" deep) comes with only the major holes punched. Holes in the printed circuit board have been drilled and the antenna bracket mounted. With each kit we include any pertinent information, minor improvements, circuit corrections, last minute component changes or notes from Ed Thompson. For example, in the Tx a better shielding setup was worked out and we are including notes on this. We'll try to keep you up to date!

Bonner Stick Kit

We are making the Bonner Stick assembly available in kit form less the pots (they are included in the Tx kit). We do not have assembly instructions for these as such however, we must say that they are not too difficult to assemble and quite a number of them have been sold for the DIGITRIO system. There will be an article in RCM later concerning this assembly. Price of the stick kit is $10.95.

Charger Kit

Bob McKnight here at World Engines has worked up a dual output battery charger just for the DIGITRIO system. It will charge the Tx and Rx simultaneously. The charging rate is in the safe area of 30-32 MA to allow longer battery life. The circuit is transformer based for shock protection. All components are mounted on a printed circuit board. Two indicator lights show when the unit is in operation. Price of the complete kit, punched case and all parts is $7.98.

Receiver — Decoder Kit

The DIGITRIO Receiver and Decoder kits contain all parts that are needed including etched and drilled printed circuit boards, all components, crystal, battery and servo connectors. Both the Rx and the Decoder fit into the punched aluminum case ($1\frac{1}{2}$" x $1\frac{5}{8}$" x $2\frac{5}{16}$") that is provided. The DIGITRIO Receiver kit price is $29.95 and the Decoder kit is $27.95.

Servo Kit

The DIGITRIO Servo was designed around the Controlaire Servo mechanics: motor, case, gears and rack. The amplifier circuitry was developed by Ed Thompson. It uses a regulated voltage to eliminate neutral drift. No short cuts were taken and only top grade components used. The circuit has proven stable and trouble-free. As to the servo mechanics we can only say, "we use them ourselves." With the servo kit as the others everything is furnished. Price is $24.95 for a complete servo kit DTSC-1 (a total of three is needed for the system). For those interested in using parts bought separately we also sell a kit, DTSM-1, of the servo mechanics and miscellaneous items at a price of $13.95.

Complete parts lists with prices for each unit of the DIGITRIO System are available upon request and free of charge from World Engines, Inc.

DIGITRIO—4 MODS.

Tx - 4 Ch Mod Kit less stick	$ 7.98
Same Rx is used in both 3 Ch and 4 Ch.	
Decoder 4 Ch Kit same size as Channel	$29.98
Dual Charger Kit	$ 7.98

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