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Assembly and Operating Instructions

for the MODEL D528-E Servo (Orbit PS-4D Servo)



DESCRIPTION

This servo, one of the smallest available, is designed specifically for proportional control systems which provide a positive decoder output signal having approximately 1.5 milliseconds neutral timing and one millisecond total control swing. With its high input impedance characteristic, it is also compatible with most standard systems of other manufacture, such as Kraft, PCS, Heathkit, Orbit, Micro, etc.

SERVO FORMATS

This servo is available as a full kit, as a half-kit and in factory assembled form. All assembly instructions contained herein pertain to the full kit and the builder must perform each step. The half-kit contains assembled and soldered printed circuit boards, so assembly steps 1 through 34 can be omitted. All other information, except assembly steps, is applicable to assembled servos.

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SPECIFICATIONS

| | |
|-----------------------------------|-----------------------------------|
| Operating Voltage | 4.8 volts, C.T. |
| Current Drain (Nominal) | |
| Idle | 2-6 ma. nominal |
| Run | 110 ma. |
| Stall | 425 ma. |
| Output Type | Rotary |
| Travel | 90 degrees |
| Transit Time (Average) | .6 second |
| Thrust (Nominal) | 3.5 pounds |
| Operating Temperature Range | 0° to +140°F |
| Dimensions | 3/4" wide, 1-3/8" hi, 1-1/2" long |
| Weight (Complete) | 1.4 ounces |

BASIC THEORY (See Figure 1)

From the decoder a positive pulse of variable width (one to two milliseconds) is fed to the high impedance input of Q1. Its positive square wave output goes to the summing junction and also provides a trigger voltage for the reference generator. This circuit supplies a negative square wave of variable width to the summing junction. Width of the reference generator output pulse is determined and controlled by the setting of the variable feedback potentiometer. The potentiometer arm is mechanically gear driven by

the motor, so as the motor changes servo position it varies the potentiometer setting to change pulse width of the reference generator.

In the summing junction the incoming positive pulse width is compared with the reference generator negative pulse width. If the two pulse widths are different, an error voltage will be present at the summing junction, causing the servo motor to turn. Polarity of the error voltage depends upon which of the two pulses is wider, and also determines direction of motor travel. As the motor turns it varies the feedback pot setting until the reference generator pulse width agrees with that of the incoming pulse. When this occurs the error voltage at the summing junction "nulls" and the servo stops at this position.

From the transmitter a frame of information is transmitted approximately every 14.5 milliseconds. This means that only once each 14.5 ms is a pulse sent to the servo for comparison. In order to smooth out servo action and provide continuous drive voltage to the motor during the "off" periods, pulse stretcher amplifiers are used. These activate the following driver stages which control the related output transistors to drive the servo motor in a given direction.

CIRCUIT OPERATION (See Figure 2)

The positive signal from the decoder is fed to the base of servo input transistor Q1, which is connected as an emitter follower to provide a high impedance input circuit. Extremely light loading is placed on the decoder output circuits. The positive square wave output from Q1 goes to R4 in the summing junction for use as a comparison pulse, and, through C1, the leading edge provides a trigger pulse for reference generator IC-1.

Integrated circuit IC-1 functions as a reference generator. Transistor "W" of IC-1 is employed to trigger the "one-shot" multivibrator consisting of sections "X" and "Z". Transistor "Y" is not used.

In a steady state condition, transistors "W" and "X" in IC-1 are normally OFF, and "Z" is biased to be normally ON. The positive signal pulse from Q1 turns transistor "W" ON momentarily, driving the collector of "X" negative. When this occurs, timing capacitor C2 charges through diode CR1. The charge voltage in C2 holds "Z" in cutoff state until the

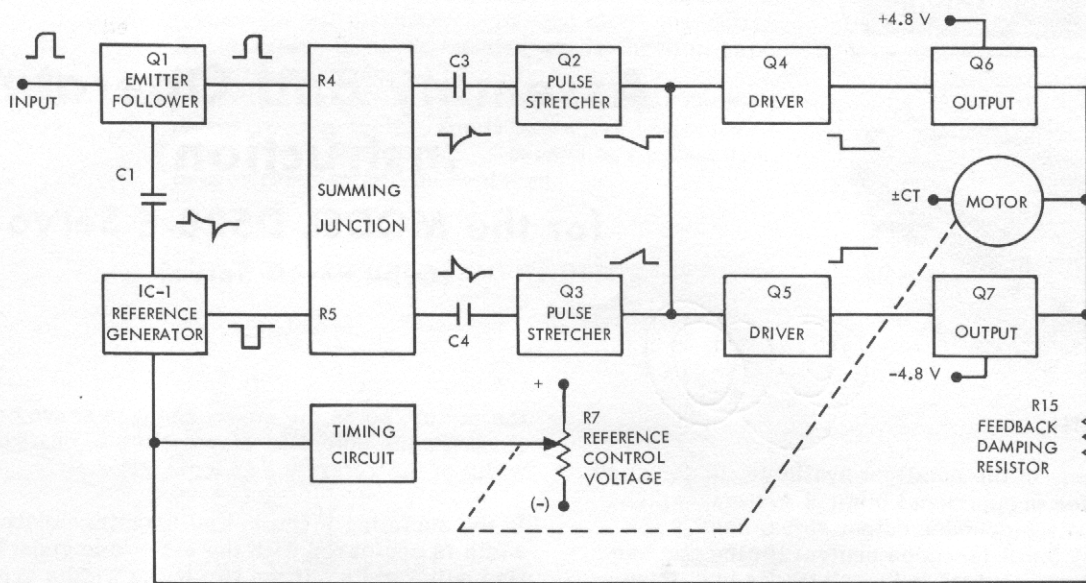


Figure 1. Block Diagram

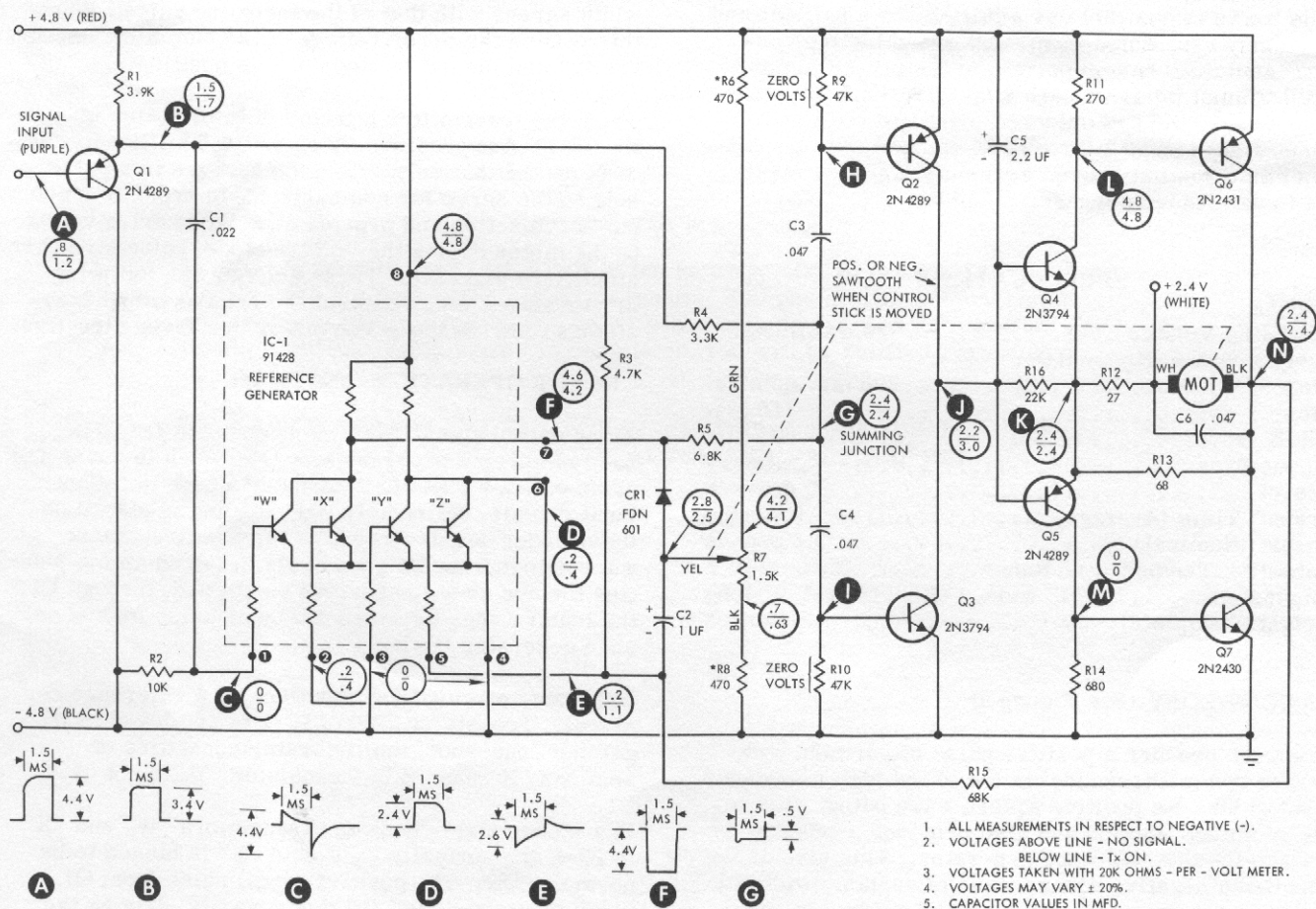


Figure 2. Schematic Diagram

charge bleeds off through timing resistor R3. "X" is held ON as long as "Z" is OFF.

The initial charge present on C2, and consequently the resulting pulse length, is dependent upon the setting of feedback potentiometer R7. Once the charge on C2 has reduced sufficiently, transistor "Z" returns to its steady state ON condition, biasing "X" OFF. The resulting output from pin 7 of IC-1 is a negative square wave, the leading edge of which coincides with that of the servo input signal and whose pulse duration is determined by the setting of the feedback pot.

Since the negative pulse from IC-1 is also fed to the summing junction through R5, the resultant error voltage pulses may be positive, zero or negative, depending on the time coincidence of the positive and negative pulses. If the positive pulse from Q1 is of longer duration than the one-shot output, the voltage at the summing junction will appear positive for a period of time equal to the difference of duration of the two pulses. Should the one-shot output be of longer duration, the summing voltage will be negative. Equal pulse lengths will provide a zero error voltage.

Let us assume a condition where the incoming command pulse is longer than the reference generator pulse. A positive differential will appear at the summing junction and be coupled through C3 and C4 to the bases of complementary transistors Q2 and Q3 respectively. This positive signal will tend to hold Q2 in an OFF condition, but will forward-bias Q3 so that Q5 and Q7 are turned ON. Junction N of the motor will go negative with respect to the +2.4 volt center tap connected to the opposite side of the motor. The motor will turn, changing servo position and mechanically varying the position of the feedback pot wiper to lengthen the pulse from the reference generator. When the generator pulse width equals that of the input signal, the summing error voltage will become zero, Q3, Q5 and Q7 will return to normal OFF condition, and the motor will stop. The servo will remain in this position until a new command in the form of a changed input signal is received.

Because of the very short duration of the differential command pulses, a pulse stretching circuit is required to provide smooth voltage flow to the motor. Capacitor C5 charges through Q3 when Q3 is activated by the positive pulse. Discharge of C5 takes place through the base-emitter junction of Q5 to provide a sufficiently long time constant to hold Q5 ON until the next pulse arrives at the base of Q3.

Reverse operation of the servo is obtained when a negative pulse is present at the summing junction. Transistors Q2, Q4 and Q6 are energized, causing application of opposite polarity voltage to the motor for opposite rotation. The reference generator pulse is shortened until a correct width match is obtained.

Feedback resistor R15 provides negative damping required to provide correct centering without over-

shoot. Increasing its value will effectively increase centering resolution and also overshoot.

Resistors R6 and R8 are selected to provide approximately 90 degrees of servo travel (without using trim controls). Increasing R6 and R8 to 680 ohms will increase servo travel to approximately 110 degrees. Smaller values will reduce servo travel.

Resistor R16 clamps transistors Q4 and Q5 to prevent undesired response to transient noise pulses. Capacitor C6 provides motor noise filtering.

KIT PARTS LIST

| QTY | ITEM | PRICE (ea) |
|-------|--|------------|
| 1 | P.C. board (type 1A) sold in pairs only | \$ 2.50 |
| 1 | P.C. board (type 2A) | |
| 1 | .022 UF disc capacitor | .20 |
| 3 | 47K (.047 UF) ceramic mini-disc cap | .65 |
| 1 | 1 UF tantalum capacitor | .75 |
| 1 | 2.2 UF tantalum capacitor | .75 |
| 1 ea | 1/8 watt resistors, values 27, 68, 270, 680, 3.3K, 3.9K, 4.7K, 6.8K, 10K, 22K and 68K ohms, ±10% | .25 |
| 2 ea | 1/8 watt resistors, values 470 and 47K ohms, ±10% | .25 |
| 1 | FDN601 silicon diode | .50 |
| 1 | 91428 integrated circuit | 1.50 |
| 1 | 2N2430 transistor | 1.25 |
| 1 | 2N2431 transistor | 1.25 |
| 2 | 2N3794 transistor (yellow dot) | 1.00 |
| 3 | 2N4289 transistor (blue dot) | 1.25 |
| 1 | 24" solder, .031 diameter | .15 |
| 1 set | P.C. board assemblies, types 1A and 2A, with all parts assembled and soldered in place | \$19.00 |

These P.C. assemblies are supplied in Half-Kits in place of above separate components.

Following parts are supplied in both Kits and Half-Kits.

| QTY | ITEM | PRICE (ea) |
|-------|---|------------|
| 1 ea | No. 26, 19 strand insulated wire in following lengths and colors: 2" yellow, 2" orange, 4" green, 10" purple, 12" red, 12" white, 16" black | .03 ft |
| 1 | 4 pin male plug | .75 |
| 1 | 3/32" x 3" shrink tubing | .50 ft |
| 1 | 3/16" rubber grommet | .03 ft |
| 1 | Cannon adhesive label | .20 |
| 1 | Operating and assembly instructions for servo | .50 |
| 1 set | Servo mechanics, including case, gears, motor, bottom cover, cover screws, output arms, mounting grommets | \$14.00 |

CIRCUIT BOARD ASSEMBLY

PREPARATION FOR ASSEMBLY

- a. Read these instructions and the General Assembly Instructions over thoroughly before starting servo assembly.
- b. Check kit parts against the parts list.
- c. Choose a smooth, clean work area so parts are not easily lost.
- d. The following tools are required:
 1. Needle nose pliers, 4" long.
 2. Diagonal cutters, 4" long, flush-cutting type preferred.
 3. Wire strippers for no. 26 wire.
 4. Soldering iron, 30 to 47-1/2 watts.
 5. Pencil tip for soldering iron.
 6. Damp cellulose sponge for cleaning soldering iron.
 7. Rosin core solder, 60-40 type, .031" diameter.
 8. Small metal screwdriver, 1/8" blade.
 9. Wet or dry sandpaper, 300 grit or finer.
 10. Fine-tooth metal file, 8" long.
 11. Small, stiff bristle brush.
 12. Lacquer thinner.
 13. Silicone rubber compound (RTV).

14. Xacto knife.

15. Eye loupe.

e. Check that outer trim edges of both P.C. boards are flush with outer edges of copper lands. If necessary, dress edges slightly with a file. Check fit of boards into recesses in sides of servo mechanics.

f. When soldering boards, use as little solder as possible to reduce bulk on back side of board. It is extremely important on this servo that leads be as flat as possible against lands, or bottom cover will not fit. Also, leads must not extend beyond edge of land to which they connect.

g. Use caution in handling subminiature 2N3794 and 2N4289 transistors. Their construction is delicate, and placing undue stress on the wire legs by spreading too far may fracture them internally.

BOARD ASSEMBLY

a. Position printed circuit board 1A, metal side down, so that hole arrangement corresponds with layout in figure 3. Proceed with steps 1 through 15, then repeat process with board 2A and steps 16 through 34, figure 4. Omit steps 1 through 34 on Half-Kits.

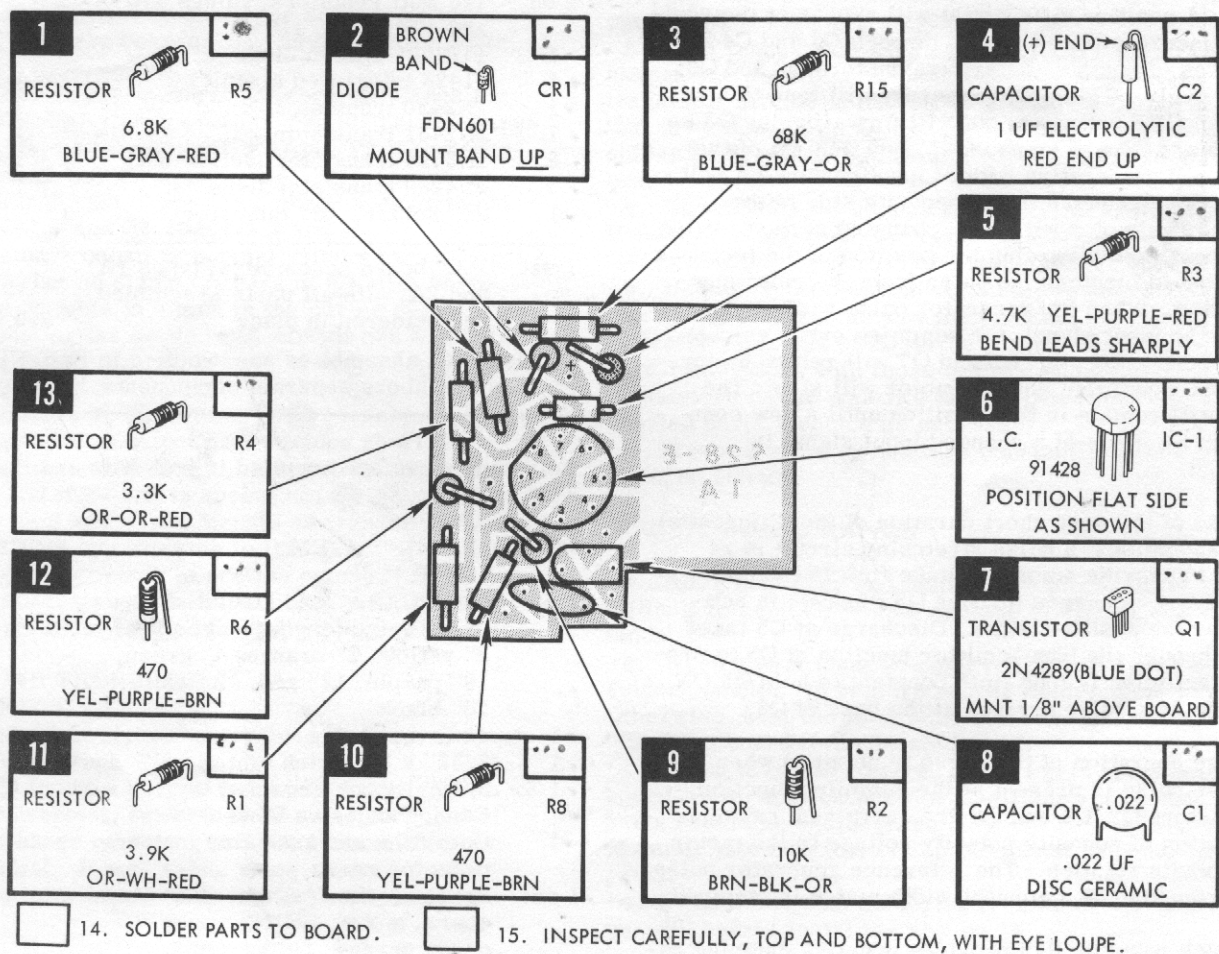


Figure 3. Assembly of Board 1A.

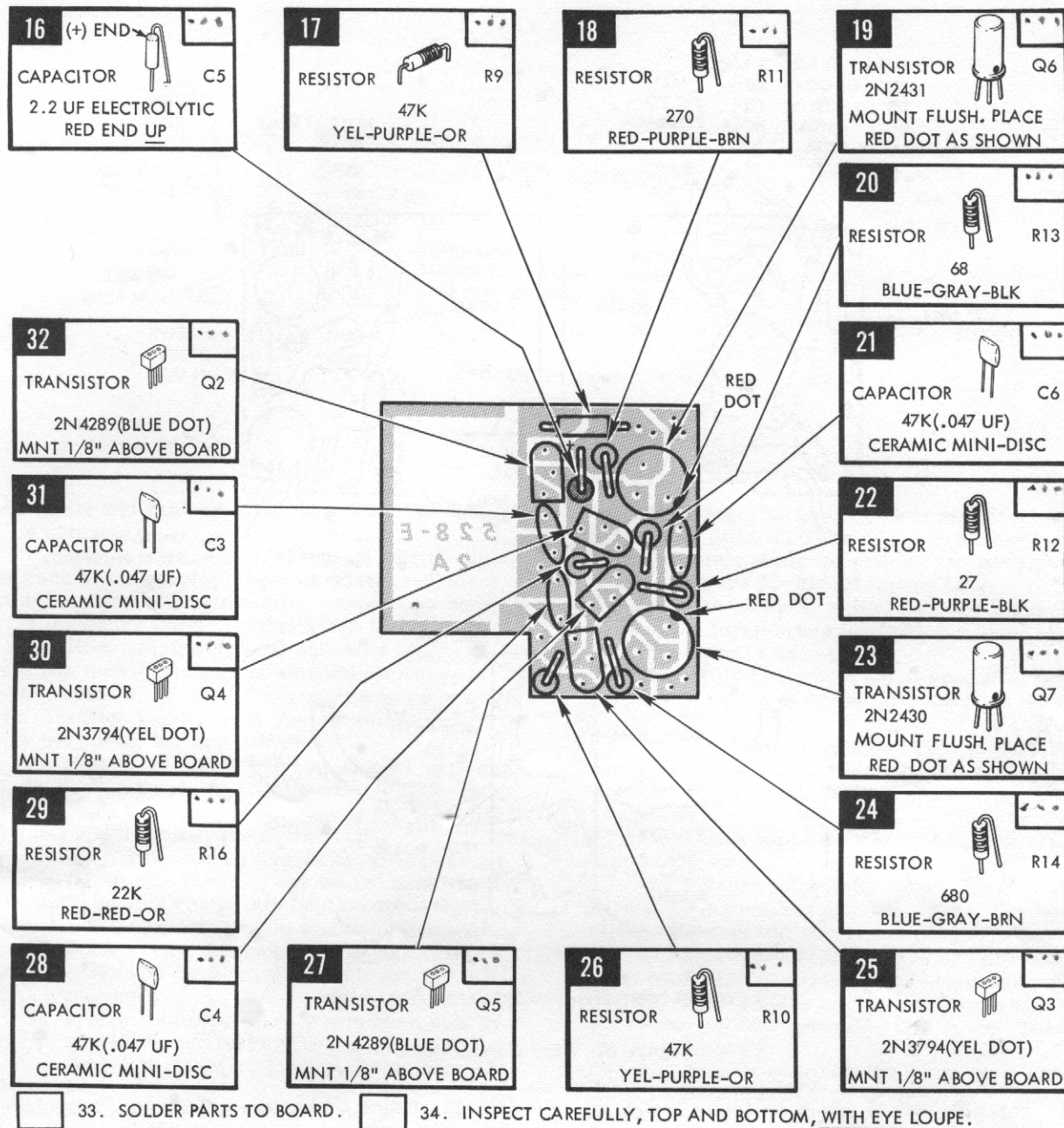


Figure 4. Assembly of Board 2A.

DETAIL ASSEMBLY

35. Cut following lengths of #26 wire. Keep in separate groups for later use.

Group "A" - Board-to-board wiring

| | | |
|---|-------------|-----------|
| 1 | red wire | 1-1/4" lg |
| 1 | orange wire | 1-3/8" lg |
| 1 | green wire | 1-1/4" lg |
| 1 | black wire | 1-1/2" lg |

Group "B" - Board-to-pot wiring

| | | |
|---|-------------|-----------|
| 1 | yellow wire | 1-1/2" lg |
| 1 | green wire | 1-1/2" lg |
| 1 | black wire | 1-1/2" lg |

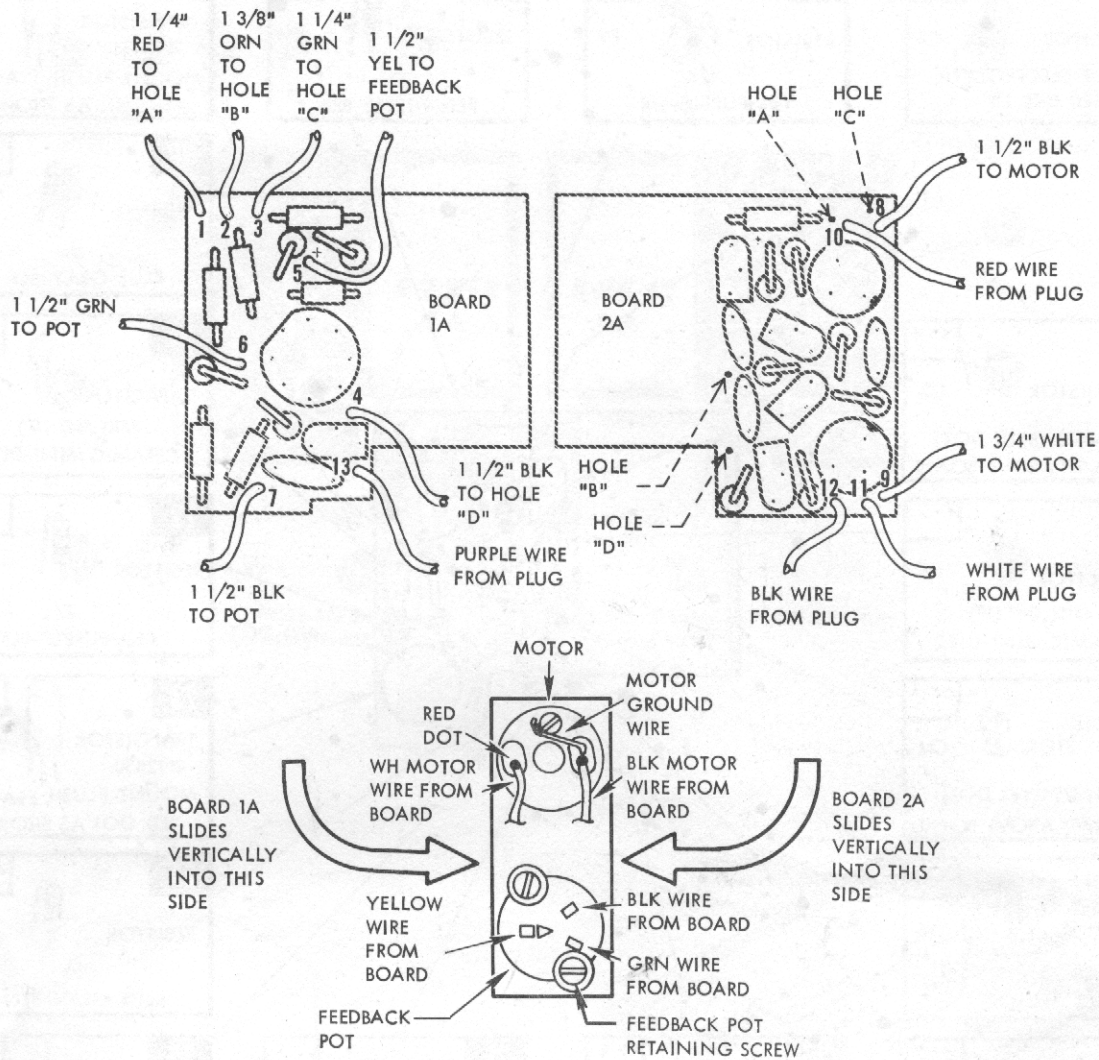
Group "C" - Board-to-motor wiring

| | | |
|---|------------|-----------|
| 1 | black wire | 1-1/2" lg |
| 1 | white wire | 1-3/4" lg |

Group "D" - Servo cable wires

| | | |
|---|-------------|--------|
| 1 | red wire | 10" lg |
| 1 | white wire | 10" lg |
| 1 | black wire | 10" lg |
| 1 | purple wire | 10" lg |

36. Using wire strippers, remove 3/32" insulation from both ends of each wire above, except remove 1/2" insulation from end of 1-1/2" black wire in Group "C".



NOTE CORRECT POSITIONS OF MOTOR AND FEEDBACK POT

Figure 5. Wire Connections

- 37. Twist strands of exposed wire ends tightly, then tin both ends of all wires cut. Use as little solder as possible to avoid solder lumps on wires.
- 38. Insert red wire from Group "A" through hole no. 1 in board 1A, and solder in place. (See figure 5.)
- 39. Likewise, solder orange, green and black wires of Group "A" into holes 2, 3 and 4 of board 1A.
- 40. Install and solder yellow, green and black wires from Group "B" into holes 5, 6 and 7 respectively of board 1A.
- 41. Clip soldered wires where they protrude through back side of board.
- 42. Twist the three pot wires from holes 5, 6 and 7 together and position them so they lie towards RH side of board which will be closest to feedback pot.
- 43. Connect red wire from hole 1 (board 1A) to hole A (board 2A). Solder in place.
- 44. Insert green wire from hole 3 (board 1A) into hole "C" (board 2A). Insert short end of black motor wire (Group "C") through hole 8 (board 2A). Solder both green and black wires in place.
- 45. Install and solder orange wire from hole 2 (board 1A) into hole "B" (board 2A).
- 46. Solder black wire from hole 4 (board 1A) into hole "D" (board 2A).
- 47. Solder one end of white motor wire (Group "C") into hole 9 of board 2A.
- 48. Clip all excess lead length from back side of board.
- 49. Clamp servo cable male plug in a small vise so that plug pins are held in the vise and plastic body sits flush on top of vise. Solder connections should be up.
- 50. Insert .031" solder into cavity of pin "A" of plug (see figure 6). Apply tip of soldering iron to upper side of pin until solder melts and fills cavity. No overflow, please.
- 51. Insert end of 10" purple wire into molten solder in cavity, then remove iron and allow to cool. Check that wire is securely soldered to pin. Caution: Do not overheat pin or plastic on plug may melt and pin may come out of seat.
- 52. Repeat above procedure and solder 10"

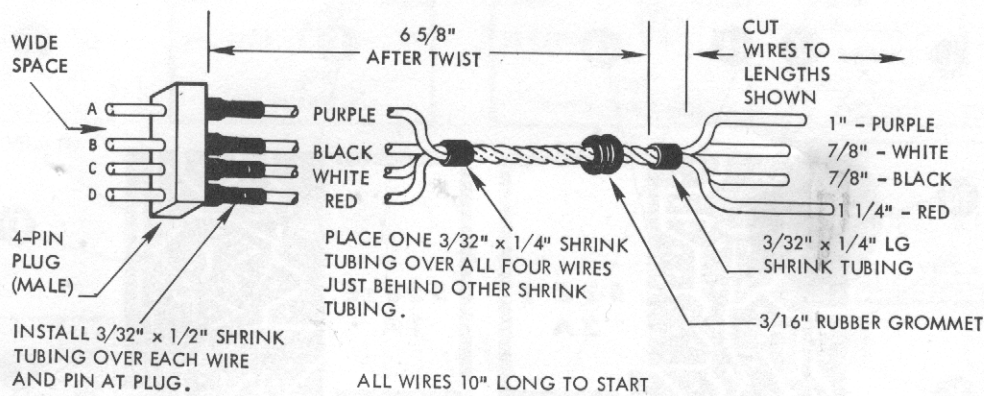


Figure 6. Servo Cable Assembly

black, white and red wires into pins "B", "C" and "D" of plug.

- 53. Slide a section of 3/32" x 1/2" shrink tubing over each of the purple, black, white and red wires until tubing covers plug pin fully. Apply heat and shrink the tubing tightly around wires and pins.
- 54. Hold plug in left hand and twist all four wires together until cable is smoothly formed.
- 55. Slide 3/32" x 1/4" shrink tubing over wire ends. Position 6-5/8" from plug as shown in figure 6. Apply heat to shrink in place.
- 56. Slide 3/16" rubber grommet over wire ends.
- 57. Untwist ends of wires beyond shrink tubing. Cut each wire to length shown (figure 6). Strip 3/32" from end of each wire, and tin the ends.
- 58. Spread boards 1A and 2A apart to permit cable installation. Figure 8 shows the position that cable must have in relation to both boards. Route cable wires to boards so cable will fit properly.
- 59. Solder red wire from plug to hole 10 of board 2A. Route wire alongside and below the two output transistors.
- 60. Solder white and black wires from plug to holes 11 and 12 respectively of board 2A.
- 61. Solder purple wire from plug into hole 13 of board 1A.
- 62. Clip excess wire leads from back side of board.
- 63. Using 8" metal file, remove excess solder from back side of each board to permit servo bottom cover to be installed when boards are in place. Check for proper cover fit as filing progresses. Do not file away too much material, loss of which will weaken solder joints.
- 64. Clean solder side of each board with lacquer thinner and a stiff bristle brush.
- 65. Using an eye loupe, carefully inspect boards top and bottom. Check for shorted leads, shorted lands, solder across lands, correct wire placement, etc. Sometimes solder shorts are hard to find. Compare back side of each board with land diagram in figure 7. Remove all defects found.
- 66. Position servo mechanics upside down as shown in figure 5 for final wiring connections. If necessary, rotate servo motor to position shown, red dot to left.
- 67. Loosen the two feedback pot retaining screws

one full turn each. Insert tips of needle nose pliers in opposite slots on outer edges of feedback pot and rotate element until connections are positioned as shown in figure 5. Leave screws loose.

- 68. Use an Xacto knife to scrape top surface of each of the three brass feedback pot tabs. Apply a drop of solder to each tab.
- 69. Apply heat and a small spot of solder to each connection on top of motor. Do not put solder on ground lug.
- 70. Position black motor wire so bare lead runs across right terminal and across to ground lug. Solder wire to terminal. Fold ground lug over bare lead and solder.
- 71. Solder white wire from board to red dot terminal on motor.
- 72. Untwist pot wires. Bend bare end of each wire at 90 degree angle to wire, using needle nose pliers. Clip off excess lead beyond 3/32".
- 73. Solder the yellow, black and green wires from board 1A to proper tabs on feedback pot.
- 74. Slide boards into servo case to check fit, with cover off and cover on. Dress wire leads as shown in figure 8.
- 75. Extract boards from servo case and spread apart to permit access to feedback pot. Inspect boards and wiring once more before test.

TEST AND ADJUSTMENT

- 76. Plug servo into desired channel in receiver plug. Leave transmitter OFF and turn receiver battery ON. Servo may jump momentarily, but should not run to an extreme position. If so, refer to Troubleshooting section, and repair servo.
- 77. Place transmitter controls in neutral, then turn transmitter ON. Servo should move to an approximate neutral position, then stop. Operate control stick and see if servo responds in both directions.
- 78. Using tips of needle nose pliers in notches on pot element, rotate element until servo arm rests at exact center position. Tighten pot screws until snug - too much pressure may crack pot.
- 79. Operate servo several times. Servo action should be snappy, with positive return to exact neutral each time. If action is not correct, refer to instructions on Feedback Adjustment.

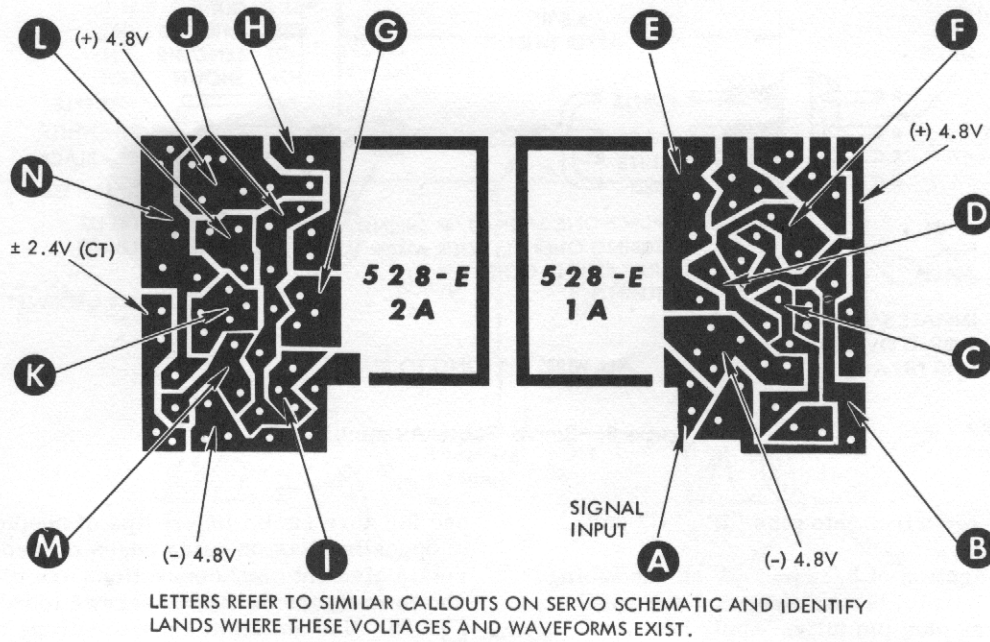


Figure 7. Test Point Locations

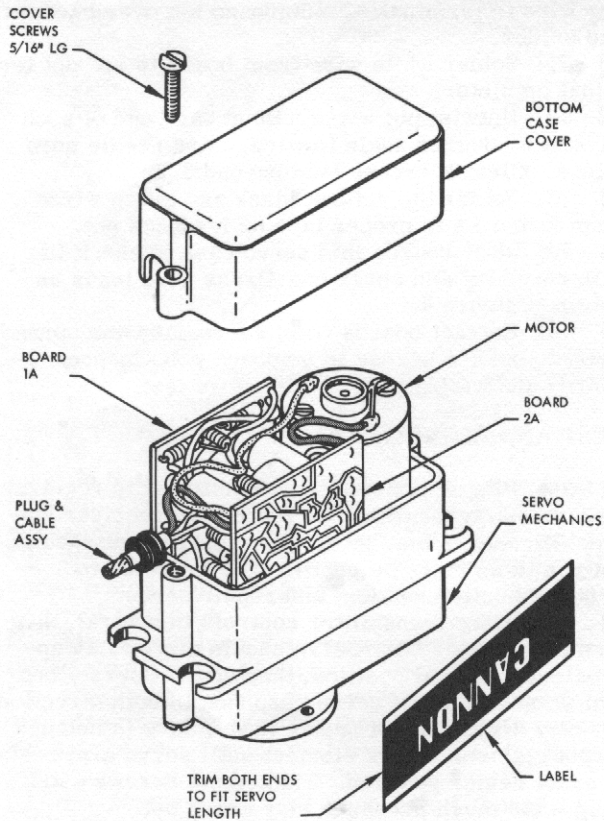


Figure 8. Servo Final Assembly

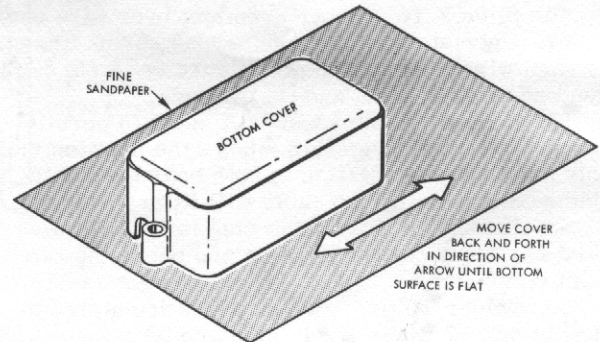


Figure 9. Sanding Bottom Cover

FINAL ASSEMBLY

- 80. Apply silicone rubber compound to ends of all wires where they solder to boards and motor.
- 81. Reinstall boards in servo. Dress wires as in figure 8.
- 82. Slip cover into position and see if gap appears between bottom and top sections. If so, remove cover and sand bottom surface until flat, as shown in figure 9.
- 83. Install cover, with grommet fitted into cover slot. Secure with two #2-72 x 5/16" screws.
- 84. Install Cannon adhesive label on top portion of servo so bottom cover can still be removed. Trim silver border from each end of label so it will fit on servo. Use razor blade to separate label from backing.
- 85. Add end mounting grommets to servo. Select output arm or wheel desired. Install servo in airframe, and it is ready for use.

MAINTENANCE AND ADJUSTMENT

GENERAL MAINTENANCE

- a. If servo gear lubrication is required, use fine powdered graphite or "Dry Lube". Never use grease or liquid lubricant of any type on servo.
- b. Should servo motor be removed from servo, do not attempt to reinstall it with gears in place or gear teeth will be nicked. Disassemble servo, take out gears, slide motor fully into position, then replace gears.
- c. Periodically clean pins on servo plug and matching receiver plug. Use end of an Xacto blade to bend pins of female plug together to restore friction fit.
- d. Disassemble feedback pot every 6 months or so, and clean wiper arms and pot element with an electronic lubricant and cleaning agent. Adjust tension on wipers.
- e. Always remove and check servo gears after a crash or extremely hard landing. Replace those with nicks, burrs and bent or broken teeth.

FEEDBACK POT WIPER ADJUSTMENT

- a. When servo feedback pot is cleaned or trouble is suspected in the pot, take out the two screws and lift out pot element.
- b. Using an electronic cleaning fluid and tissue, wipe away loose residue on contacts and pot element.
- c. With a small screwdriver, reach into pot cavity and spring the three contacts upward very slightly to insure good wiper contact. Replace pot element and recenter servo.

TROUBLESHOOTING AND REPAIR

GENERAL

Following are a number of tips and techniques describing methods of locating circuit faults, isolating troubles, basic repair procedures, etc. A troubleshooting chart is included as an aid in isolating and locating a defect.

SECTIONAL ANALYSIS

- a. For service, consider your servo as being electronically in three separate sections: Plug, cabling and individual wires; a front end consisting of the input circuit, reference generator and timing circuits; and a rear end consisting of the six transistors and associated circuitry which drive the motor. This includes everything from the summing junction (point **G** on schematic) through the motor.
- b. The front section further subdivides into the input transistor stage, the reference generator, and the timing circuit.

REVERSING SERVO DIRECTION

- a. To reverse operating direction of servo, interchange positions of black and white motor wires, and reverse positions of black and green wires to feedback pot. Do not change position of yellow wire to feedback pot. It is not necessary to change positions of ground wire when reversing motor wires. Re-centering of servo will be required.

CHANGING SERVO TRAVEL

- a. Servos are designed to provide nominal 90 degree total travel (± 45 degrees from neutral) without using trim controls.
- b. To decrease total travel, reduce values of resistors R6 and R8 until desired travel is obtained. For example 270 ohms in these two positions will provide approximately 80 degrees of travel.
- c. Increase values of R6 and R8 to increase travel.

FEEDBACK ADJUSTMENT

- a. Servo centering accuracy and "overshoot" action are controlled by negative feedback resistor R15.
- b. If servo does not return to exact center each time, negative feedback is excessive. Increase R15 to the next standard value to tighten centering accuracy.
- c. Insufficient feedback (R15 too large) will make a servo "jumpy" and overshoot will be noticeable when servo returns to neutral. Reduce value of R15 until servo centers properly without excessive "bounce-back". A small degree of overshoot is desirable to insure centering accuracy.

- c. Basically the rear end can be further considered in two parts: Transistors Q2, Q4, Q6 plus related parts which drive the motor in one direction; transistors Q3, Q5, Q7 and parts to drive the motor in the opposite direction.
- d. In case of servo trouble, your first job is to isolate the problem to one of the major areas listed above, then localize the fault to a specific component.
- e. Before any troubleshooting is attempted, inspect entire servo very carefully to make sure all components and wires are correctly installed.

INITIAL CHECK-OUT

- a. Plug servo into receiver. With transmitter OFF, servo should not move appreciably. If servo runs solidly to one extreme position, a defect exists in the rear end. This is usually caused by a solder short, an incorrect part installation, or a shorted transistor.
- b. If rear end appears O.K., turn transmitter ON. Servo should move to a specific point, then stop. If

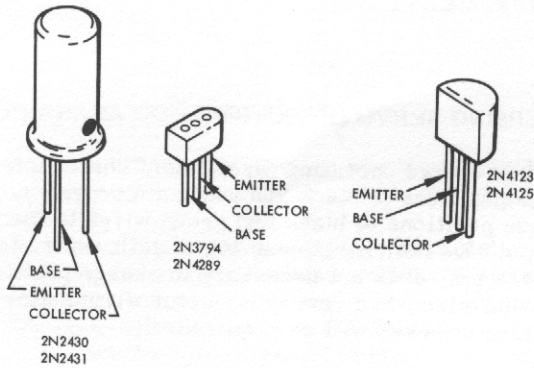


Figure 10. Transistor Identification

front end is O.K., servo should follow stick movement, and all that is required is to center servo and check operation. Front end may be inoperative if servo is dead, runs constantly in one direction or runs to an extreme.

c. If above check-out steps produce no results, refer to procedures under "Dead Servo" or "Defective Front End", as applicable.

DEAD SERVO

a. Use a voltmeter to check for correct voltages on back side of servo boards. See figure 7 for voltage test points.

b. If voltages are incorrect, inspect all wires for proper hook-up. Check continuity of all related wires from plug pins to the circuit boards. Voltage reversals may indicate wire reversals.

c. After voltages check O.K., check waveforms at test points **A** and **B** (figures 2 and 7).

d. If decoder output is normal without servo plugged in, but no signal appears at **A** with servo energized, trouble is either in the purple signal wire connections, or the servo input circuit has a short. Check for solder shorts on back of board 1A. If none, replace Q1.

e. If signal is at **A** but not at **B**, transistor Q1 is open or this circuit output has a solder short.

f. Check waveform at **G**. If servo is correctly centered and front end is operating, **G** should show alternate plus and minus signals as transmitter stick is moved from one extreme to the other. If so, front end is operating; refer to section entitled "Defective Rear End". If waveform at summing junction is incorrect, refer to "Defective Front End".

DEFECTIVE FRONT END.

a. Check input circuit as outlined in steps c, d and e of last paragraph.

b. If **G** shows a narrow pulse which varies with control movement, servo may be completely out of center. Change centering and see if waveforms become normal. If not, wrong value capacitor may have been installed in place of C2 to upset system timing.

c. If **G** waveform is similar to **B**, reference generator circuit is inoperative. Check feedback pot wipers for contact. Check back of board 1A for solder shorts. Observe waveforms at **C**, **D**, **E** and **F**. Replace IC-1 if these are not correct.

DEFECTIVE REAR END

a. Use a 470 ohm resistor to short from emitter to collector of output transistor Q6. If power is applied to servo (transmitter OFF), motor should run in one direction. Note direction of rotation. This verifies motor operation. Otherwise, recheck for correct voltage and/or replace motor.

b. Connect 470 ohm resistor from base to collector of Q6. Again, motor should run in same direction as before. If not, replace Q6.

c. Check motor run (same direction) by using 470 ohm resistor from base to collector of Q4. Replace Q4 if motor action is incorrect.

d. Repeat with 470 ohm resistor across base-collector junction of Q2. Replace Q2 if inoperative.

e. Repeat steps a through d above on transistors Q7, Q5 and Q3. Test results and corrections are the same except that motor should run in opposite direction. These five steps will locate an open or burned out transistor, evidenced primarily by an inclination of the servos to run in one direction only (Tx ON) and not returning to neutral (assuming correct front end operation).

f. With transmitter OFF, if motor persists in running in one direction, a short exists in the three-transistor circuit which controls motor rotation in that direction. With an eye loupe, check for possible solder bridges between lands or traces of copper on board.

g. Check voltages across resistors R9 and R10. If voltage is not zero, the related capacitor (C3 or C4) is shorted, or the related transistor is shorted.

h. Use an ohmmeter and voltmeter to check resistances and voltages across the emitter, base, and collector junctions of the three transistors. Compare resistances with those of the complementary transistors on the opposite side to determine the shorted part. Replace as necessary.

i. If servo hums or chatters constantly, check C5 for open circuit.

CIRCUIT BOARD REPAIR

a. After bent over and soldered in place, parts are difficult to remove without damage to circuit board lands.

b. When a part must be removed, if possible use a solder "sucker" to remove excess solder from joint. Otherwise, heat the joint until solder melts, then "flip" the board to throw solder off.

c. Using diagonal cutters, clip off part leads below board. With application of a small amount of heat, parts should be easily taken out. We recommend use of small size surgical clamps to assist in removing parts.

d. Open holes with soldering iron or small drill (no. 60) before installing new parts.

TROUBLESHOOTING CHART

| TROUBLE | POSSIBLE CAUSE | REMEDY |
|--|--|---|
| Servo dead | Solder short on board | Inspect, remove short |
| | Q1 defective | Replace Q1 |
| | Poor plug contact | Clean, adjust plugs |
| | Motor defective | Replace motor |
| | Q6, Q7 burned out | Replace |
| | White lead from battery open | Check and repair |
| Servo runs to extreme (Tx OFF) | Solder short in servo rear end | Inspect, remove short |
| | Q2 through Q7 shorted | Locate and replace bad transistor |
| | C3 or C4 shorted | Check and replace |
| | Broken red or black battery wire | Check, repair wire |
| | Incorrect part installation | Check all parts for value and placement |
| Servo O.K. with Tx OFF, but runs to extreme with Tx ON | Feedback pot wiper not making contact | Tighten wiper arms |
| | Incorrect part installation | Check all parts for correctness |
| | C1 open | Replace C1 |
| | C2 wrong value | Check, replace |
| | Reference generator not working | Check for shorts. Check components. Replace IC-1. |
| Servo follows control stick in one direction but will not return | Solder short in rear end | Remove short |
| | One transistor (Q2 through Q7) defective | Perform in-circuit test. Replace as necessary. |
| | C3 or C4 open | Check, replace |
| Servo works, speed and power below normal | Weak battery | Charge or replace battery |
| | Damaged output transistors | Replace transistors |
| | Weak motor | Replace motor |
| | Bind in servo mechanics | Disassemble servo. Check gear teeth. Check for binds in all drive components. |
| Servo jumpy. Operation erratic. | Loose pot wiper | Adjust wiper arms |
| | Loose solder joint | Resolder |
| | Plug contacts loose | Tighten female plug contacts |
| | C5 defective | Replace |

MECHANICAL REPAIR

a. Servo mechanical parts requiring repair or replacement will become obvious on close inspection. Replacement is recommended where there is any question of serviceability.

b. Clicking noises in servos are usually caused by defective gear teeth. Small burrs can be removed with a sharp Xacto knife. Gears with chipped or broken teeth should be replaced.

SERVO REPLACEMENT PARTS LIST

| ITEM | PRICE (ea) |
|---------------------|------------|
| Motor | \$6.95 |
| Case top | 1.25 |
| Case center | 1.50 |
| Case bottom | 1.00 |
| No. 1 gear | .50 |
| No. 2 gear | .50 |
| No. 3 gear | .50 |
| No. 4 gear (output) | 1.00 |
| Pot wiper | 1.00 |
| Feedback pot | 1.00 |
| Brass shaft | .15 |
| Output arm | .50 |
| Screws | .05 |

ORDERING INFORMATION

On all servo parts orders under \$10.00, include .50 for cost of shipping and handling. Minimum order \$1.00 (+.50). No C.O.D.'s.

REPAIR SERVICE

In event of trouble send unit direct to the factory, NOT to the dealer. Repairs are not priced for dealer discounts. Equipment will be serviced and returned within a few days. Be sure and include detailed information on the problem. After repair is completed, you will be notified regarding cost and shipping.

KITS ARE WARRANTED ONLY FOR COMPLETENESS OF PARTS. NO PARTS EXCHANGE WILL BE MADE AFTER THE PART HAS BEEN INSTALLED OR SOLDERED ON.

Litho in U.S.A.
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