Assembly and Operation of the HEATHKIT® THUMB® TACH

MODEL GD-69

TABLE OF CONTENTS

® Reg. U.S. Pat. Off.

HEATH COMPANY
BENTON HARBOR, MICHIGAN 49022

INTRODUCTION

The Heathkit Model GD-69 Thumb® Tach is a compact Tachometer designed to measure the rpm of model engines. Engine rpm can now be checked easily and quickly without the need of the Tachometer touching or being physically connected to the engine.

Variations in light intensity are picked up by a photo resistor in the Tachometer. These light variations are converted into electrical impulses, and the resultant rpm can be read directly on the meter's two ranges: 0 to 5,000 rpm, or 0 to 25,000 rpm. All solid-state circuitry and a single circuit board make the Tachometer easy to assemble. A zener diode is used to regulate the meter circuit voltage and precision resistors keep the Tachometer ranges accurate.

The metal cabinet has a tough, blue wrinkle finish that is scratch resistant. A handy, pull-out stand leaves both hands free to make engine adjustments.

The Tachometer will be very useful in enabling you to select the proper propellers, fuels, glo-plugs, and needle valve settings to obtain peak performance from your engine.

A 9 volt transistor battery (NEDA type #1604) is required to operate the Tachometer. This battery is not furnished with the kit. You may wish to obtain one at this time so it will be available when the assembly is completed.

Refer to the "Kit Builders Guide" for complete information on unpacking, parts identification, tools, wiring, soldering, and step-by-step assembly procedure.

PARTS LIST

The numbers in parentheses are keyed to the numbers on the Parts Pictorial (fold-out from Page 3).

To order replacement parts, refer to the Replacement Parts Price List and use the Parts Order Form furnished with this kit.

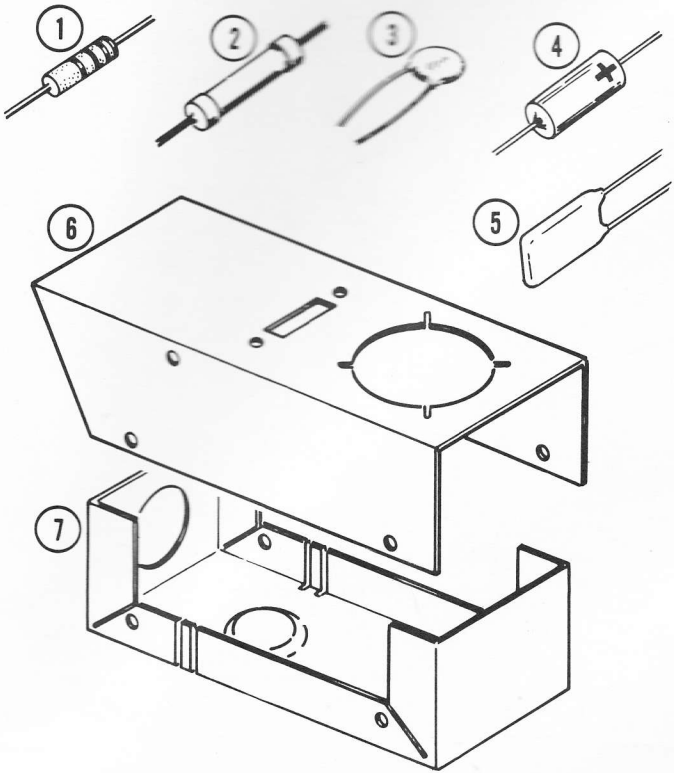
	PART No.	PARTS Per Kit	DESCRIPTION
RESISTORS			
(All Resistors are 1/2 Watt)			
(1)	1-6	1	470 Ω (yellow-violet-brown)
	1-7	2	680 Ω (blue-gray-brown)
	1-11	1	1500 Ω (brown-green-red)
	1-18	1	5600 Ω (green-blue-red)
	1-73	2	8200 Ω (gray-red-red)

Resistors (cont'd.)

PART No.	PARTS Per Kit	DESCRIPTION
Resistors (cont'd.)		
1-20	1	10 kΩ (brown-black-orange)
1-21	1	15 kΩ (brown-green-orange)
1-22	2	22 kΩ (red-red-orange)
1-24	2	33 kΩ (orange-orange-orange)
1-102	1	82 kΩ (gray-red-orange)
1-26	2	100 kΩ (brown-black-yellow)
1-27	1	150 kΩ (brown-green-yellow)
(2)2-124	1	80 kΩ precision
2-211	1	333 kΩ precision
CAPACITORS		
(3)21-75	1	100 pF disc
(4)25-123	1	2 μF electrolytic
25-54	3	10 μF electrolytic
(5)27-74	1	.01 μF Mylar*
METAL PARTS		
(6)90-448	1	Cabinet front
(7)90-449	1	Cabinet back
(8)204-9	2	Angle bracket
(9)266-146	1	Wire stand
GENERAL		
(10)9-11	1	Photo resistor
(11)10-286	1	5000 Ω control

*DuPont Registered Trademark

PART No.	PARTS Per Kit	DESCRIPTION
General (cont'd.)		
(12)56-63	1	Zener diode
(13)60-22	1	Slide switch
(14)73-77	1	Rubber gasket
(15)75-93	1	Insulator
85-313-1	1	Circuit board
344-92	1	Red hookup wire
346-1	1	Sleeving
(16)407-144	1	Meter
(17)413-17	1	Lens (with nut)
(18)417-118	6	2N3393 transistor
(19)432-33	1	Battery connector
(20)490-5	1	Nut starter
597-308	1	Kit Builders Guide
597-260	1	Parts Order Form
391-34	1	Blue and white label
		Manual (See front cover for part number.)
		Solder
HARDWARE		
(21)250-213	2	4-40 x 5/16" screw
(22)252-2	2	4-40 nut
(23)254-9	6	#4 lockwasher
(24)250-155	4	#6 x 3/8" black sheet metal screw
(25)250-270	4	6-32 x 3/8" black screw
(26)252-3	2	6-32 nut
(27)254-1	2	#6 lockwasher


1
2
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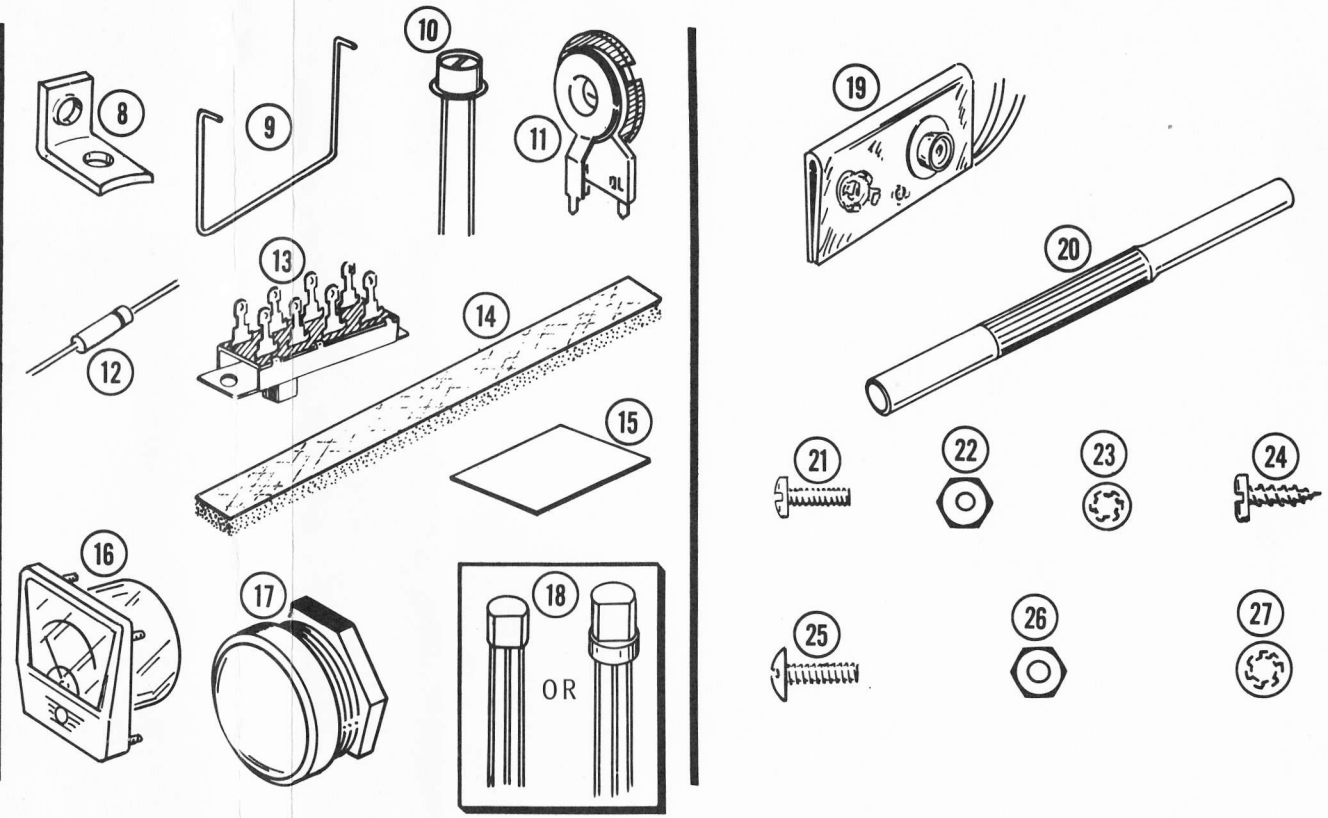
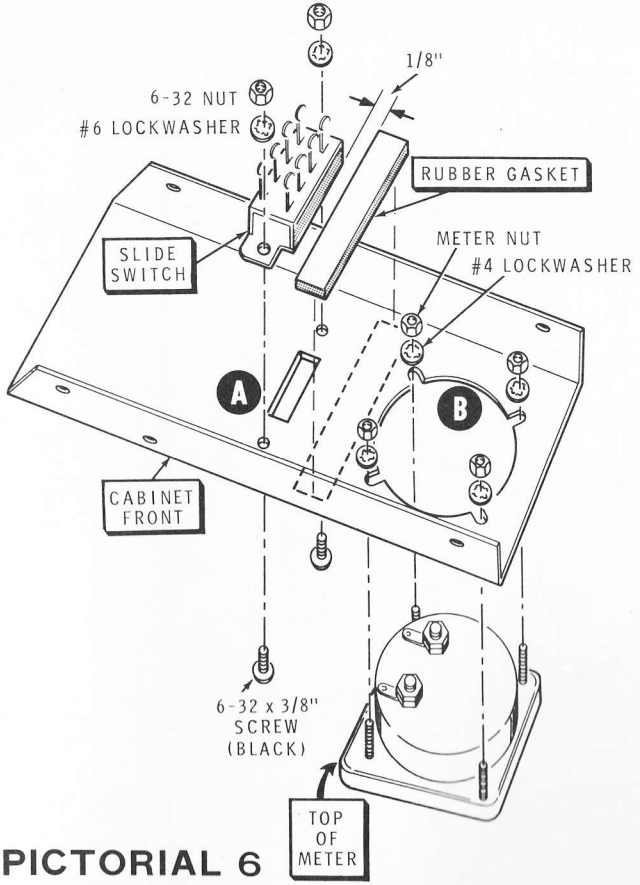
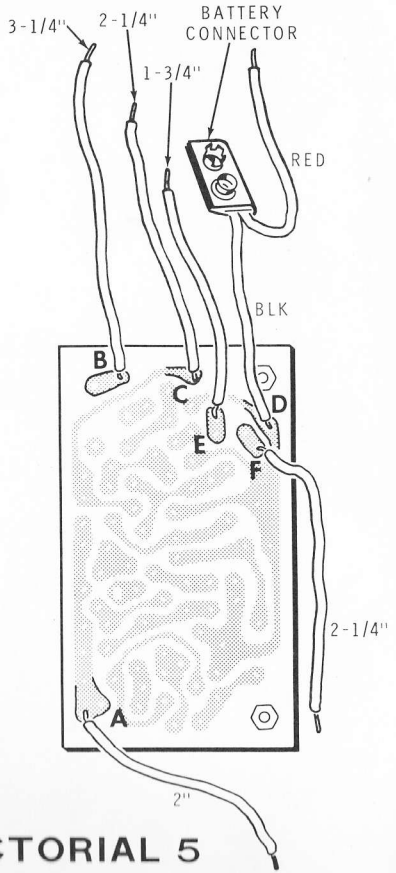
PARTS PICTORIAL

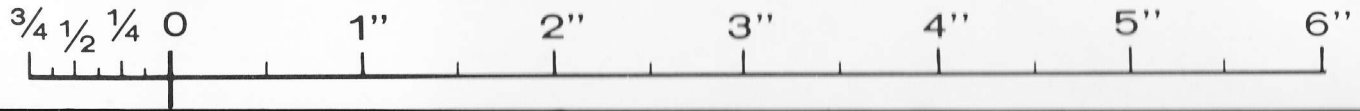




PICTORIAL 6



PICTORIAL 5



STEP-BY-STEP ASSEMBLY

CIRCUIT BOARD ASSEMBLY NOTES

The circuit board is quite small, and there are a considerable number of components to be installed on it. Therefore, we suggest that you take your time in its assembly to prevent any errors.

Because the circuit board is so small, there is not sufficient room on it to letter the value of each component. Therefore, all component locations, except for resistors, are shown on the board with only an outline of the component. The locations where resistors are to be installed are blanked in. Use extreme care when installing components so that they fit directly over their outline on the circuit board. Position all components down tight against the circuit board, unless directed otherwise in a step.

Keep all parts as perpendicular to the circuit board as possible and within the outside edge of the circuit board.

When soldering the circuit board you will find it helpful to place the circuit board on a cloth to prevent it from sliding around. Use a soldering iron rated at 30 or 40 watts. The soldering iron tip should be chisel shaped and approximately 1/8" wide. Solder the leads to the foil as each component is installed. Be very careful not to cover unused holes and avoid making solder bridges between adjacent foils. Then cut off the excess lead lengths close to the foil.

Resistors will be called out by resistance value (in Ω and kΩ) and color code. Capacitors will be called out by capacitance value and type. Refer to Figure 1 for identification of component symbols on the lettered side of the circuit board.

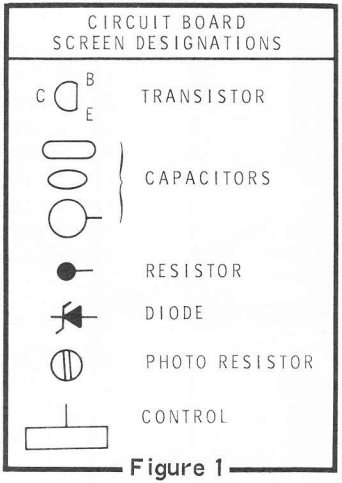
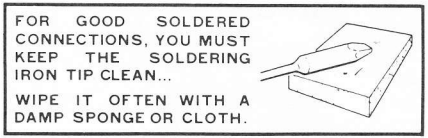


Figure 1

CIRCUIT BOARD ASSEMBLY

Locate the circuit board and position it as shown in Pictorial 1. Then complete each step on Pictorials 1 through 4.

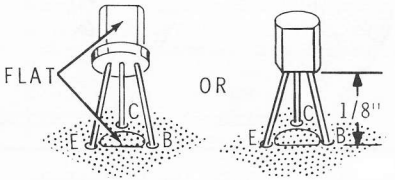


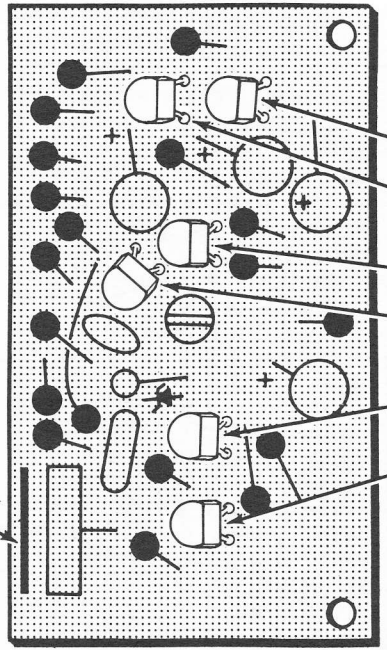
START

NOTE: There are no specific steps for soldering the component leads to the foil on the circuit board. Solder the leads of each component to the foil as it is installed.

The transistors installed in the following steps are all of the same type, however, they may appear physically different. Be very careful to install them properly.

When installing these transistors, align the flat of the transistor with the flat of the outline on the board. Position the E, C, and B leads of the transistor in the corresponding E, C, and B holes of the board. Position each transistor 1/8" above the circuit board.





PICTORIAL 1

CONTINUE

( ) 2N3393 transistor (#417-118).

( ) 2N3393 transistor (#417-118).

( ) 2N3393 transistor (#417-118).

( ) 2N3393 transistor (#417-118).

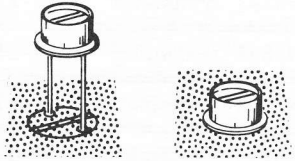
( ) 2N3393 transistor (#417-118).

( ) Check to see that all connections are soldered and that the excess lead lengths are cut off.

PROCEED TO PICTORIAL 2.

START

NOTE: When installing the photo resistor in the next step, position it over the outline on the circuit board. Place the leads in the indicated holes with the photo resistor pushed down tight against the circuit boad.

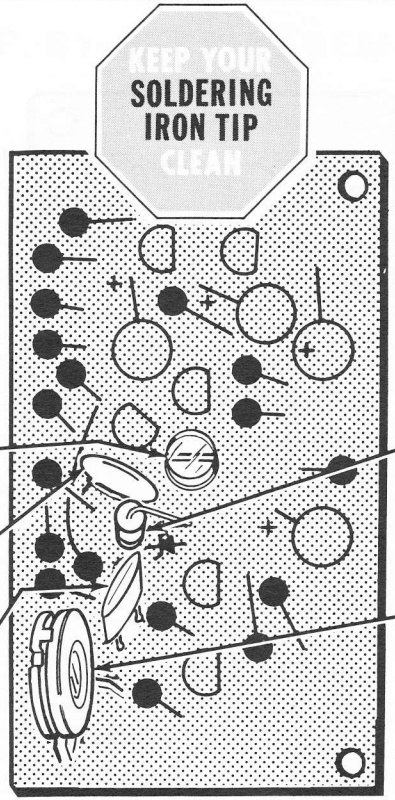


( ) Photo resistor (#9-11).

NOTE: Remove any ceramic material from the leads of the 100 pF capacitor before installing it on the circuit board.

( ) 100 pF disc.

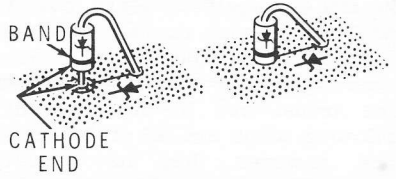
( ) .01 μF Mylar.



PICTORIAL 2

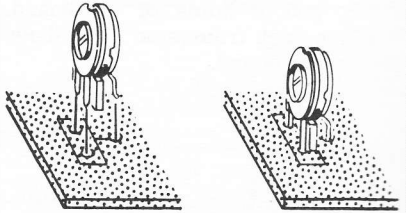
CONTINUE

NOTE: When installing the diode in the next step, be sure to position the cathode end as shown. The cathode end is the banded end.



( ) Zener diode (#56-63).

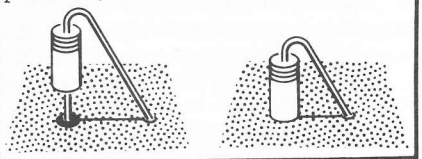
( ) 5000 Ω control (#10-286). Insert the three pins in the proper holes, and push the control tight against the circuit board. Then solder all three pins to the foil.



PROCEED TO PICTORIAL 3.

START

NOTE: Position all resistors as perpendicular to the circuit board as possible.



( ) 8200 Ω (gray-red-red).

( ) 33 kΩ (orange-orange-orange).

( ) 82 kΩ (gray-red-orange).

( ) 15 kΩ (brown-green-orange).

( ) 150 kΩ (brown-green-yellow). See Caution at top of Page.

( ) 8200 Ω (gray-red-red).

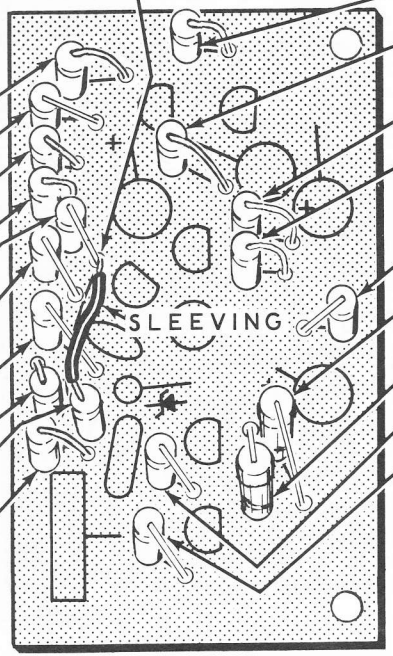
( ) 5600 Ω (green-blue-red).

( ) 470 Ω (yellow-violet-brown).

( ) 100 kΩ (brown-black-yellow). Use a 5/8" length of sleeving on the indicated lead.

( ) 22 kΩ (red-red-orange).

CAUTION: Two leads go in this hole. Do not solder the connection until the second lead is installed.



PICTORIAL 3

CONTINUE

( ) 33 kΩ (orange-orange-orange).

( ) 1500 Ω (brown-green-red).

( ) 10 kΩ (brown-black-orange).

( ) 680 Ω (blue-gray-brown).

( ) 100 kΩ (brown-black-yellow).

( ) 333 kΩ precision.

( ) 80 kΩ precision.

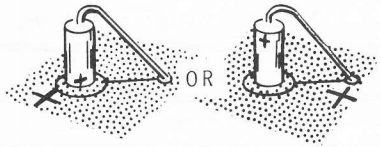
( ) 22 kΩ (red-red-orange).

( ) 680 Ω (blue-gray-brown).

PROCEED TO PICTORIAL 4.

START

NOTE: When installing electrolytic capacitors, the lead from the (+) marked end must be positioned in the (+) marked hole of the circuit board. DO NOT bend the leads tight against the top of the capacitor. Otherwise, the capacitor may short circuit.



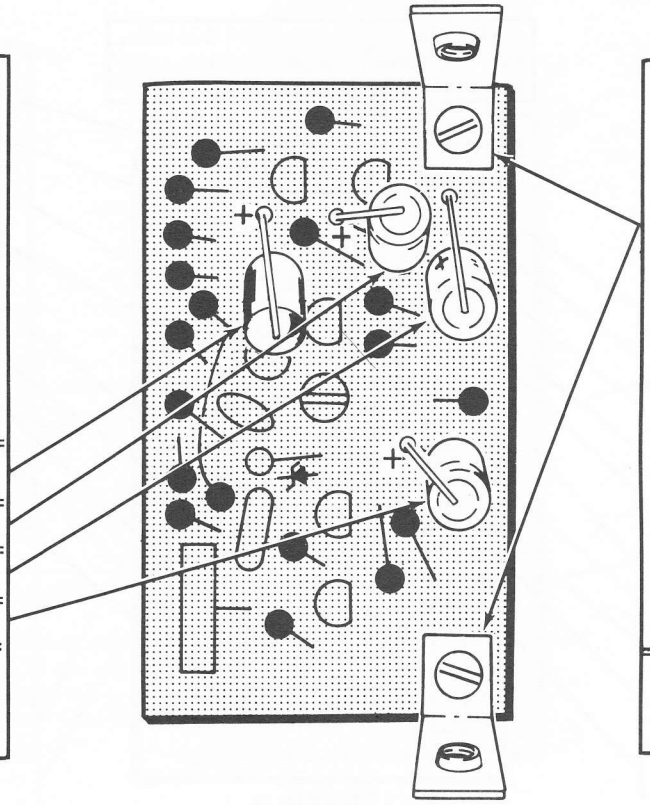
( ) 2 μF electrolytic.

( ) 10 μF electrolytic.

( ) 10 μF electrolytic.

( ) 10 μF electrolytic.

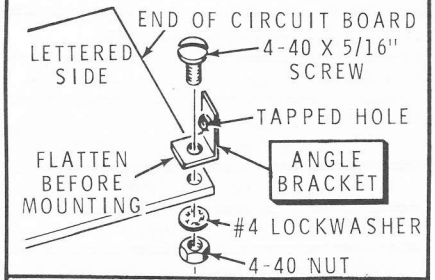
NOTE: The plastic nut starter provided with the kit can be used for picking up and starting nuts on screws.



PICTORIAL 4

CONTINUE

( ) Flatten the indicated side of each angle bracket. Then install a bracket at each of the two locations on the lettered side of the circuit board. Use 4-40 x 5/16" screws, #4 lockwashers, and 4-40 nuts in the untapped holes of the angle brackets. Position each bracket as shown with its edge even with the end of the circuit board.



( ) Check to see that all connections are soldered and that the excess lead lengths are cut off.

FINISH

Circuit Board Wiring

Refer to Pictorial 5 (fold-out from Page 4) for the following steps.

NOTE: Lengths of wire will be connected to the foil side of the circuit board in the following steps. Do not push the insulation of the wire tight against the foil. Leave the insulation approximately 1/16" away from the foil to assure a good solder connection to the foil and wire.

When preparing hookup wire, as in the next steps, cut the wire to the indicated length and remove 1/4" of insulation from each end of the wire. Twist the small wire strands together. Then melt a small amount of solder on the wire ends to keep the wire strands together. Only one end of each wire will be connected at this time. The free ends will be connected later. Solder each wire as it is installed.

( ) Position the circuit board foil side up as shown in Pictorial 5.

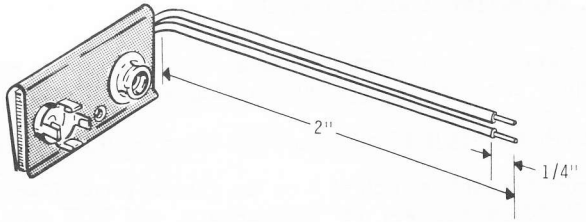
( ) 2" wire to hole A (S-1).

( ) 3-1/4" wire to hole B (S-1).

( ) 2-1/4" wire to hole C (S-1).

( ) 1-3/4" wire to hole E (S-1).

( ) 2-1/4" wire to hole F (S-1).



Detail 5A

( ) Locate the battery connector and cut both leads to 2" lengths, (see Detail 5A). Remove 1/4" of insulation from each lead. Twist the small wire strands together. Then, if necessary, melt a small amount of solder on the lead ends to keep the wire strands together.

( ) Connect the black lead of the battery connector to hole D of the circuit board and solder the lead to the foil. The red wire will be connected later.

( ) Clip off the excess ends of those wires that extend from the lettered side of the circuit board.

This completes the assembly of the circuit board. Inspect it carefully to see that all connections are soldered and that the excess lead lengths are cut off. Be sure there are no solder bridges between foils. Set the circuit board aside until it is called for later.

PARTS MOUNTING-CABINET FRONT

NOTE: Place a soft cloth on your work surface to prevent scratching the meter when performing the following steps.

Refer to Pictorial 6 (fold-out from Page 4) for the following steps.

( ) Mount the slide switch at A on the cabinet front. Use 6-32 x 3/8" black screws, #6 lockwashers, and 6-32 nuts. The switch is symmetrical and can be mounted either way.

( ) Cut a 2" length of rubber gasket and remove the protective backing. Position the rubber gasket parallel to and 1/8" away from the slide switch. Then press the rubber gasket in place.

( ) Mount the meter at B with the nuts furnished with the meter and #4 lockwashers. Position the meter as shown. Do not overtighten the hardware as the meter case can be broken. Discard the lockwashers furnished with the meter.

WIRING

Refer to Pictorial 7 for the following steps.

( ) Prepare the ends of a 1" length of hookup wire. Connect this wire between lugs 1 (NS) and 3 (S-1) of switch A. Position the wire as shown.

( ) Lay the circuit board in the cabinet front as shown. Connect the free ends of the wires coming from the circuit board as follows:

( ) Wire from A to lug 1 of switch A (S-2).

( ) Wire from F to lug 5 of switch A (NS).

( ) Wire from C to lug 6 of switch A (NS).

( ) Wire from E to lug 7 of switch A (S-1).

( ) Rotate the meter lugs to the position shown in Pictorial 7.

( ) Wire from B to lug 2 of meter B (S-1).

( ) Prepare the ends of a 3-1/2" length of hookup wire. Remove 1/2" of insulation from one end of the wire and 1/4" insulation from the other end.

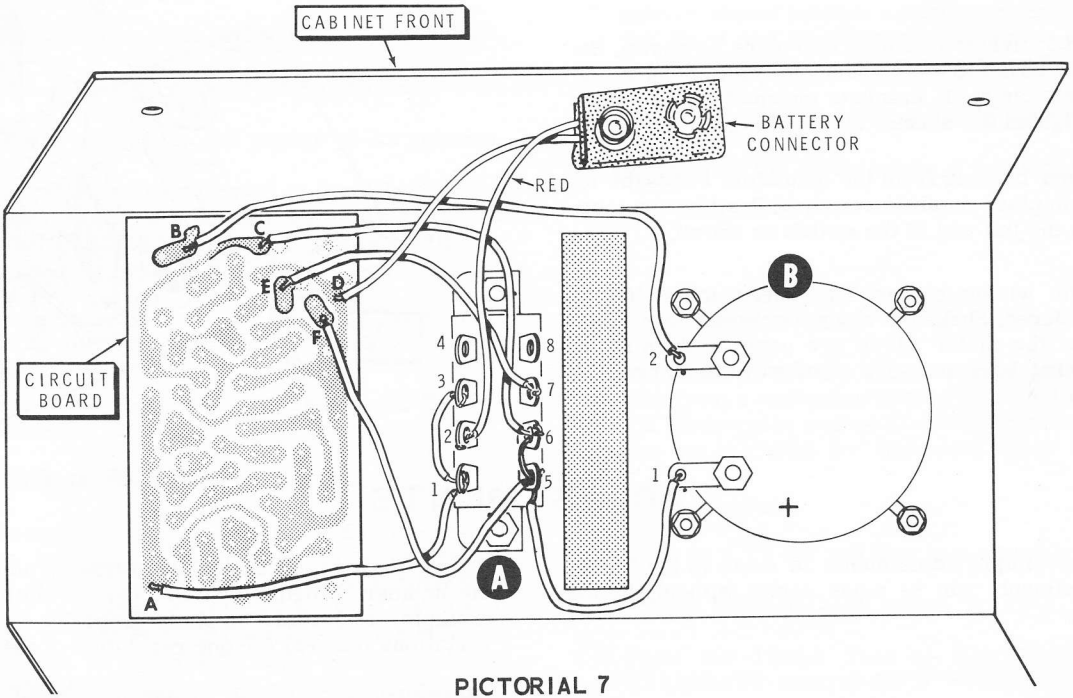
NOTE: Where a wire passes through a connection and goes to another point, as in the next step, it will count as two wires in the solder instructions (S-2), one entering and one leaving the connection.

( ) Pass the 1/2" bare end of this wire through lug 5 (S-3) to lug 6 (S-2) of switch A.

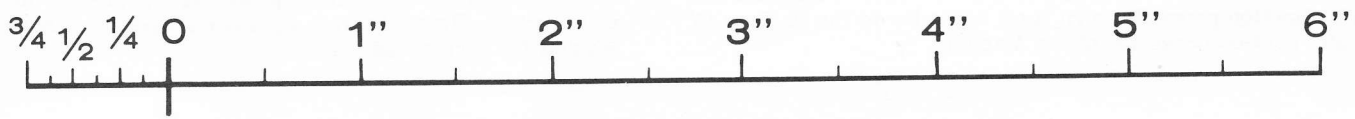
( ) Connect the other end of this wire to lug 1 of meter B (S-1).

( ) Connect the free end of the red wire coming from the battery connector to lug 2 of switch A (S-1). Be careful not to melt the insulation of any of the other wires.

KEEP YOUR
Soldering iron tip
~~WIPE~~ CLEAN



PICTORIAL 7

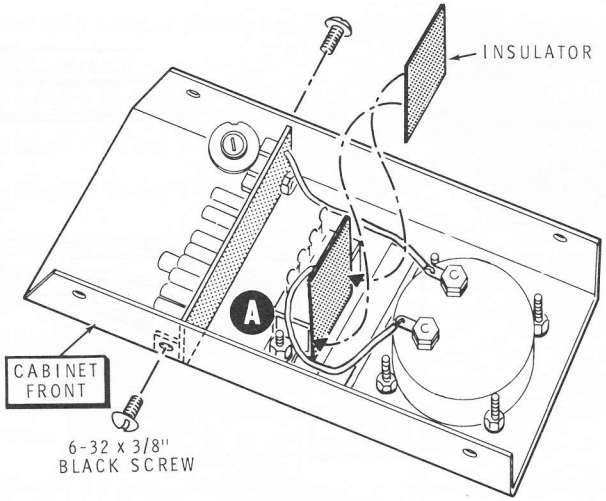


Refer to Pictorial 8 for the following steps.

( ) Carefully tip the circuit board up into place as shown. Secure the circuit board to the cabinet front with 6-32 x 3/8" black screws into the angle brackets mounted on the circuit board. Do not tighten the screws at this time.

( ) Remove the paper backing from the insulator. Press the insulator firmly in place on slide switch A. Position the insulator even with the left end of the switch as shown.

This completes the wiring of the kit. Check to see that all connections are soldered. Shake out any wire clippings or solder splashes. Be sure the meter wires are positioned as shown, otherwise, the cabinet back and wire stand will not fit properly when installed later.



PICTORIAL 8

ADJUSTMENTS

There are only two simple adjustments to make in the Thumb Tach. These adjustments can be made easily without the use of other equipment.

If at any time during these adjustments the Thumb Tach does not seem to function properly, turn it off and refer to the In Case Of Difficulty section (Page 19) of the Manual.

Before performing any of the following adjustments, determine the number of light variations per revolution of the engine. For example, a 2-blade airplane propeller will produce two light variations (pulses) for one revolution of the engine.

Therefore, if you wish to use the Thumb Tach to indicate the correct rpm of a 2-blade propeller, perform the Standard Calibration. Refer to the Operation section (Page 16) of the Manual for further information.

STANDARD CALIBRATION

Refer to Figure 2 (fold-out from Page 15) for the following steps.

( ) Place the OFF-HI-LOW switch in the OFF position.

( ) Set the CALIBRATE control to the center of its rotation.

( ) Check the meter to see that its pointer is directly over the "0" on the meter scale. If it is not, carefully adjust the METER MECHANICAL ZERO ADJUST screw until the pointer is positioned properly.

( ) Snap the battery connector onto the battery. The recommended battery is a 9 volt transistor battery NEDA #1604.

( ) Position the battery in the cabinet front as shown. Be sure no wires are under the battery.

( ) Place the OFF-HI-LOW switch in its LOW position.

( ) Hold the battery in place and point the top end of the Thumb Tach toward an incandescent light bulb operating from a 60 cycle power source. Adjust the CALIBRATE control so the meter pointer is at 3600 on the 0 to 5 scale of the meter. (Adjust to 3000 if light bulb is operated from a 50 cycle power source.) The HI (0-25,000) range is automatically calibrated when the LOW range is set properly.

( ) Move the OFF-HI-LOW switch to its HI position. The meter pointer should move to a point approximately halfway between the third and fourth small marks on the 0 to 25 scale (to the third mark if calibrated on 50 cycles).

( ) Move the OFF-HI-LOW switch to the OFF position.

This completes the Adjustments of the Thumb Tach.

SPECIAL CALIBRATION

If you intend to use the Thumb Tach regularly to measure rpm directly from a one-pulse source (flywheel with one marker), or from a three-pulse source (3-blade propeller), the Thumb Tach can be recalibrated for use with these sources as follows:

One-Pulse Source

( ) Turn on a TV Set and tune in a program.

( ) Set the OFF-HI-LOW switch to LOW.

( ) Point the Thumb Tach at the TV picture and adjust the CALIBRATE control for a meter indication of 3600 rpm.

Three-Pulse Source

( ) Set the OFF-HI-LOW switch to LOW.

( ) Aim the Thumb Tach toward an incandescent bulb and set the CALIBRATE control for a meter indication of 2400 rpm.

With the Thumb Tach calibrated to either a one-pulse or a three-pulse source, rather than to a two-pulse source as in the previous Adjustments section, the formulas in the Operation section of the Manual will not hold true. These are only for use with the two-pulse calibration.

FINAL ASSEMBLY

Refer to Detail 9A for the following steps.

( ) Clean both sides of the lens with a soft, lint-free cloth.

( ) Mount the lens at C on the cabinet back. Use the nut furnished with the lens.

( ) Cut a 2" length of rubber gasket and remove the protective backing. Press the rubber gasket in place in the cabinet back. Use the dimensions on Detail 9A.

( ) Cut two 2" lengths of rubber gasket and remove the protective backing. Press these in place on the first length of rubber gasket.

( ) Remove the paper backing from the blue and white label. Press the label in place at the location shown in the cabinet back. Refer to the Model and Series numbers on this label in any communications you may have with the Heath Company about your kit.

Refer to Pictorial 9 for the following steps.

( ) Move any wires away from the sides of the cabinet front. Otherwise, they may be damaged when the wire stand is installed.

( ) Fit the wire stand into the indicated notches of the cabinet back. Position the wire stand as shown.

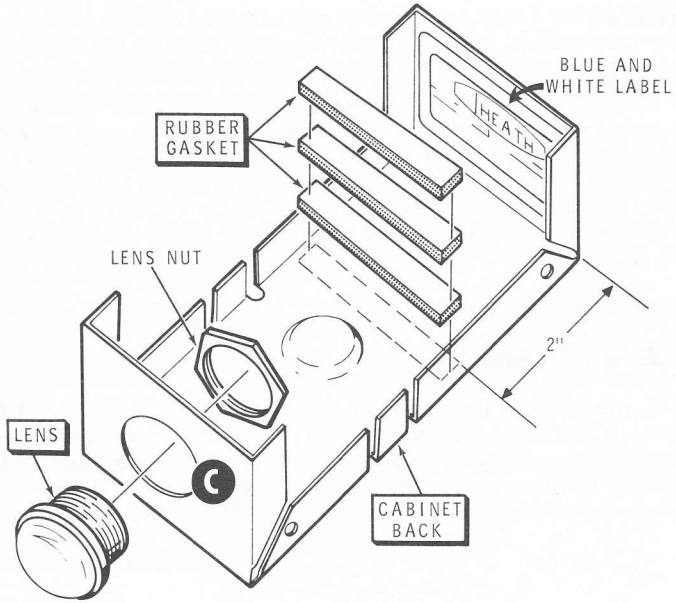
( ) Squeeze the open end of the wire stand together so it will fit between the sides of the cabinet front. Be sure the lens is pointing in the direction shown.

( ) Now position the cabinet back and wire stand into place in the cabinet front. Make sure the circuit board fits into the indicated notches in the cabinet back.

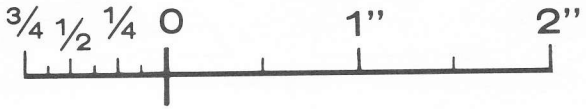
( ) Secure the cabinet front and cabinet back together with four #6 x 3/8" black sheet metal screws.

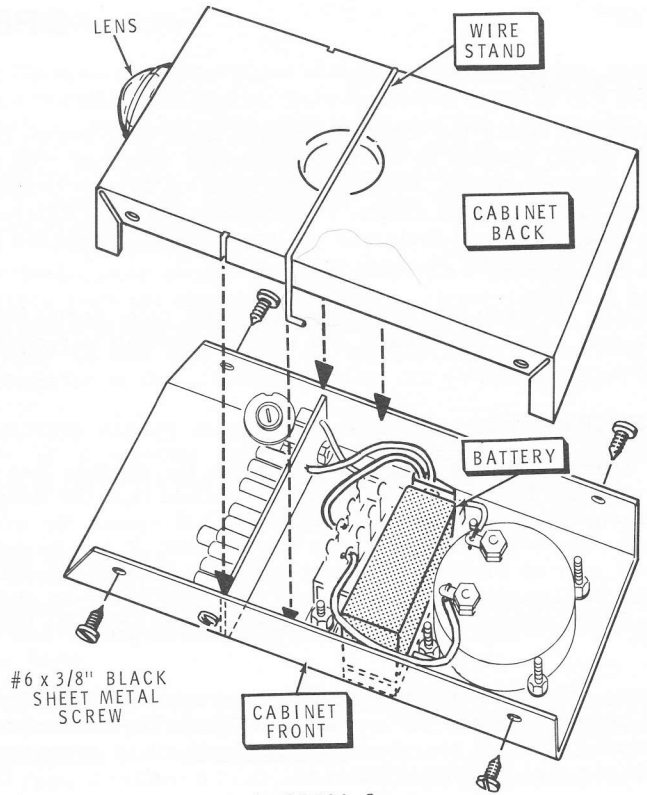
( ) Now tighten the screws that hold the circuit board in the cabinet.

This completes the assembly of the kit.



Detail 9A





PICTORIAL 9

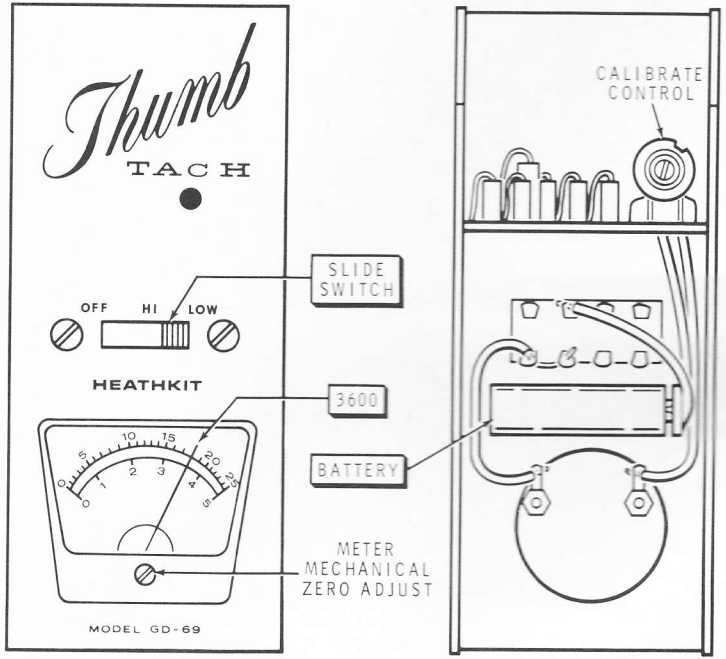

Thumb
TACH
OFF
HI
LOW
HEATHKIT
MODEL GD-69
SLIDE SWITCH
3600
BATTERY
METER MECHANICAL ZERO ADJUST
CALIBRATE CONTROL

FIGURE 2

OPERATION

APPLICATIONS

In order to obtain the top performance from your model, the engine should operate at the manufacturer's specified rpm to insure peak efficiency. An engine that runs too slow or too fast will not give maximum torque. The performance from different propellers, brands of fuels and glo-plugs can be compared by using the Tachometer to check engine rpm.

CAUTION: Protect the plastic meter case from engine fuel which will cloud the plastic and make it difficult to read the meter.

CONSIDERATIONS

The Thumb Tach is intended primarily for outdoor use in natural light. Normally when there is sufficient light for flying, the Tachometer will work satisfactorily. It cannot be used indoors where fluorescent lights are present. It can be used indoors with an incandescent light that does not shine directly into the Tachometer lens. A flashlight, car head lights, or other lights operated from a DC supply would be the best artificial light.

In order to obtain a meter reading, the intensity of the light being picked up by the Tachometer must vary. The Tachometer will work if the light source is reflected from, or is interrupted by, the moving object being checked.

A rotating propeller, even with a natural wood finish, will provide enough contrast to the light to give a proper reading. However, a shiny flywheel in a model car or boat requires strips of black tape (or paint) on it to obtain the necessary light intensity variations. For the same reason, it will be necessary to place strips of white tape (or paint) on a black tire of a model car.

USING THE TACHOMETER

Reading The Meter

With the switch in the LOW position, the lower scale of the meter (0 through 5) is used. This represents readings between 0 and 5000 rpm. When the lower scale is used, each small mark between the numbers is equal to 200 rpm. Figure 3 shows the meter face with example readings of 2000 rpm and 4250 rpm.

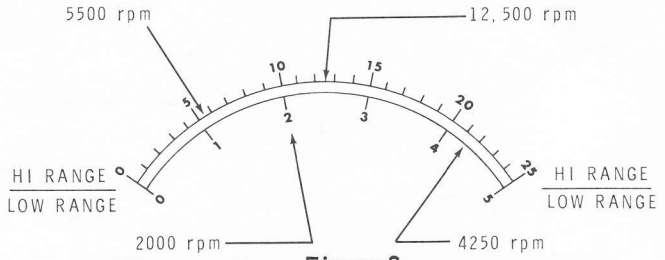


Figure 3

When using the HI range of the switch, the upper meter scale (0 through 25) is used. This scale is from 0 to 25,000 rpm with each small mark representing 1000 rpm. Figure 3 shows example readings of 5500 rpm and 12,500 rpm.

The meter indicates one revolution per minute for each two pulses of light. This type of signal is created by a 2-blade airplane propeller. Therefore, when taking rpm readings from flywheels or tires, use two strips of tape for direct engine rpm readings. These strips of tape should be spaced as equally as possible on the flywheel or tires (180 degrees apart).

If the rpm is quite low (below 800 rpm) causing an erratic meter indication, you should use four equally spaced strips of tape (90 degrees apart). The actual rpm would then be exactly one-half that shown on the meter.

EXAMPLE: Four input pulses = $\frac{\text{meter reading}}{2}$ = actual rpm

or $\frac{1500}{2}$ = 750 rpm.

On 3-blade propellers, the actual rpm would be 2/3 that of the meter reading.

EXAMPLE: Three input pulses = $\frac{\text{meter reading}}{3}$ x 2 = actual rpm

or $\frac{3900}{3}$ x 2 = 2600 rpm.

Unwanted Reflections

The Tachometer is sensitive enough to detect propeller shadow or glare reflections coming from the wing or fuselage of a plane, therefore, some considerations in aiming the Tachometer are necessary. If the rpm reading is not steady, or seems to be considerably higher than it should be, change the angle at which the Tachometer is being aimed. This will usually eliminate unwanted reflections.

The Tachometer should be positioned at a convenient but safe distance from the object being checked. Figure 4 shows it being hand held and also sitting on its stand. Using the stand allows the operator to use both hands for making adjustments. Aim the Tachometer at the propeller blades, not at the propeller hub.

WARNING: Always keep your body and face out of line with the ends of a rotating propeller. Propeller blades sometimes break at high rpm and can cause serious injury.

Model Airplanes

In addition to the previous information, it is important to remember that the engine in a plane will increase its rpm once the plane is in flight.

Low-pitch propellers (between 1 and 6) can increase speed by 1000 to 2000 rpm after leaving the ground, whereas, a high-pitch propeller (6 and up) may increase speed by as much as 2000 to 4000 rpm. It is therefore important to select the proper propeller to obtain the proper in-flight rpm.

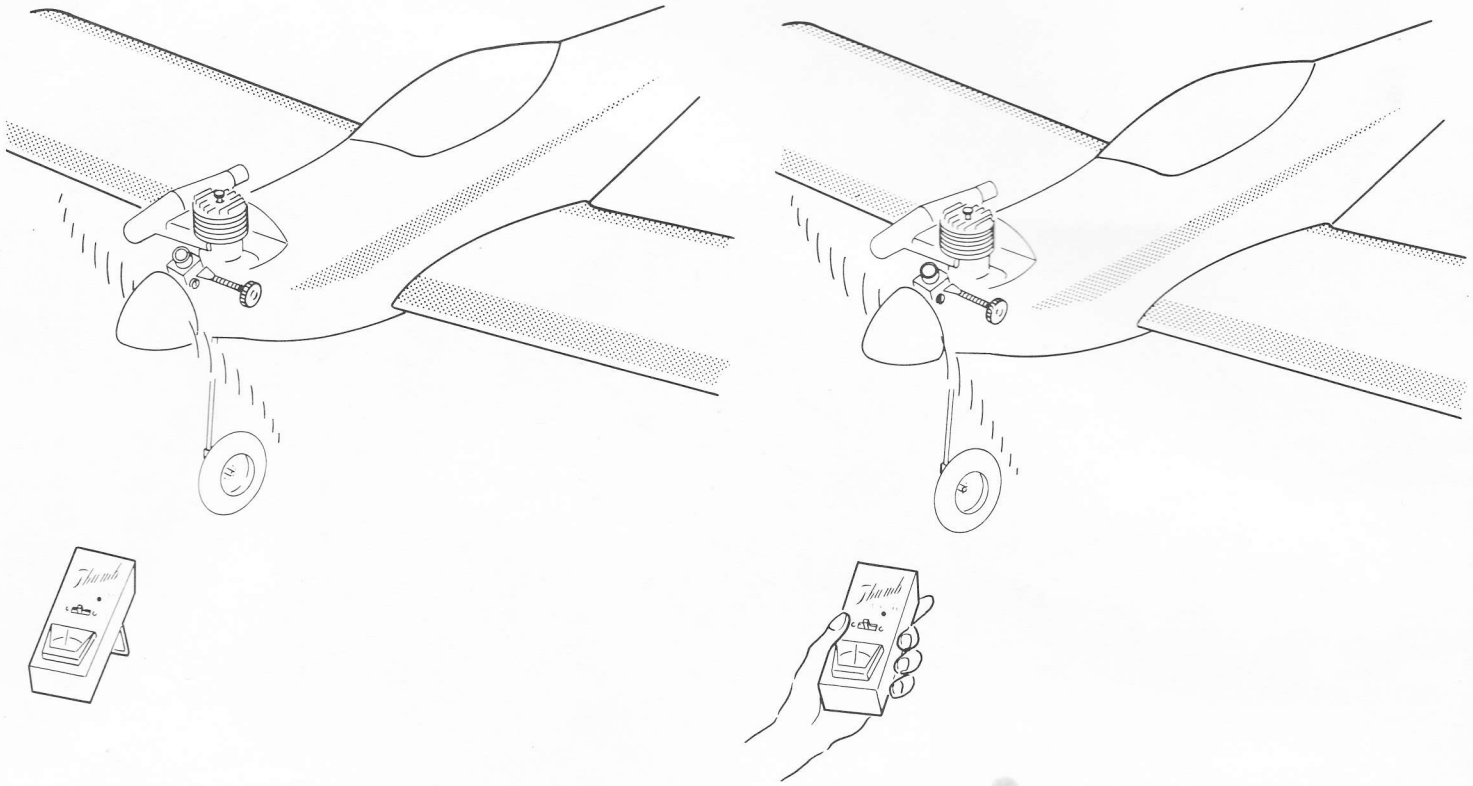


FIGURE 4

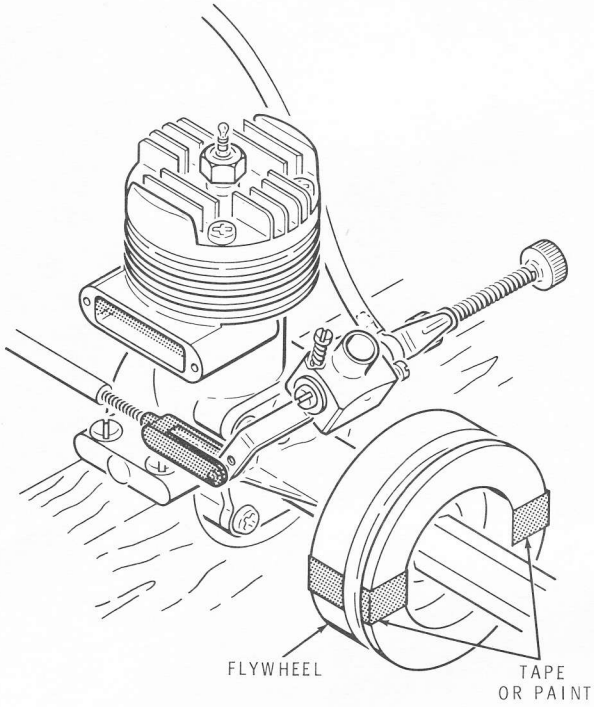


FIGURE 5

Model Boats

The rpm of an engine in a boat can best be measured at the flywheel. Placing two strips of tape (or paint lines) on the front or side of the flywheel, as shown in Figure 5, will give the actual rpm of the engine.

If the engine is tested under load, with the boat propeller in the water, the engine will speed up once the boat is underway. However, if the engine is tested with the boat propeller out of the water, the engine rpm will be reduced when the boat is placed in actual use in water.

Model Car

The engine in a model car will probably be tested under no-load conditions, however, the engine will slow down in actual use.

Engine rpm in a car can be checked by the flywheel method as in a boat, or at the tire. If the tire is used, and its rpm is too low for an accurate measurement, it may be necessary to use four strips of tape instead of two. In either case, the gear ratio between the engine and driven wheel must be taken into consideration to obtain actual engine rpm.

When using two marks on the tire, as shown in Figure 6, the meter reading must be multiplied by the gear ratio to determine the actual engine rpm.

EXAMPLE: Two marks = meter reading x gear ratio = actual rpm

or 800 x 6 (6 to 1 ratio) = 4800 rpm.

If it becomes necessary to use four marks on the tire, the actual engine rpm is one-half the meter reading times the gear ratio.

EXAMPLE: $\frac{\text{meter reading}}{2}$ x gear ratio = actual rpm

or $\frac{1600}{2}$ x 6 (6 to 1 ratio) = 4800 rpm.

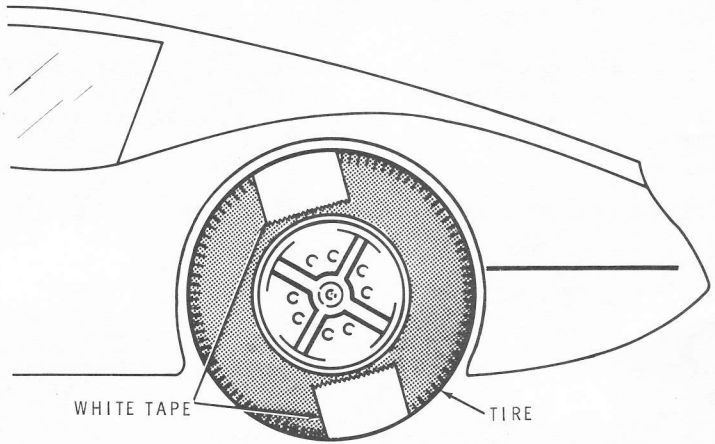


Figure 6

IN CASE OF DIFFICULTY

NOTE: Refer to the Circuit Board X-Ray View on Page 23 for the physical location of parts.

1. Recheck the wiring. It is frequently helpful to have a friend check your work. Someone who is not familiar with the unit may notice something you have consistently overlooked.

2. About 90% of the kits that are returned to the Heath Company for repair do not function properly due to poor connections and soldering. Therefore, many troubles can be eliminated by reheating all connections to make sure they are soldered as described in the Soldering section of the Kit Builders Guide.

3. Check the value of parts. Be sure that the proper part has been wired into the circuit for each step, as shown in the Pictorial diagrams and as called out in the wiring instructions.

4. Check for bits of solder, wire ends, or other foreign matter which may be lodged in the wiring or between adjacent foils on the circuit board.

5. If, after careful check the trouble is still not located and a voltmeter is available, check voltage reading against those shown on the Voltage Chart on Page 23.

6. A review of the Circuit Description may also help you find the trouble if you have a knowledge of electronics.

NOTE: In an extreme case where you are unable to resolve a difficulty, refer to the "Customer Service" information inside the rear cover of this Manual. Your Warranty is inside the front cover.

Troubleshooting Chart

DIFFICULTY	POSSIBLE CAUSES
No meter deflection.	1. Diode ZD1 installed backward. 2. Dead battery.
Cannot be calibrated.	1. Diode ZD1 installed backward. 2. Capacitor C6 defective. 3. Resistor R13, R15, or R19 wrong value.

DIFFICULTY	POSSIBLE CAUSE
Meter reads properly on Low scale but is off on High scale. (A small variation is normal.)	1. Excessive variation - resistor R13 or R14 out of tolerance. 2. Battery getting weak.
Calibration changes in short time.	1. Weak battery.
Meter increases normally and then drops suddenly to a lower reading.	1. Capacitor C6 out of tolerance. 2. Diode ZD1 defective.
More than one reading obtained at the same rpm.	1. Picking up unwanted reflections. 2. Picking up 60 cps light source along with wanted signal. 3. Aiming unit at wrong angle toward rotating object.
Meter slow acting.	1. Capacitor C4 interchanged with capacitor C1, C2, or C3.
Poor sensitivity.	1. Dirty lens or photo resistor. 2. Weak battery. (Should be able to get a reading through 5 Manual pages when 1" or 2" from 60 watt bulb with no other lighting.)
Meter needle shakes on readings.	1. Normal below 800 rpm. (Use more markers.) 2. Not enough light.
Meter will not read - bounces.	1. Not enough light. 2. Interference from other light sources. 3. Faulty photo resistor, Q1, Q2, R2, or C1.

SPECIFICATIONS

Range	0 to 5000 rpm. 0 to 25,000 rpm.
Accuracy	Within 3% of meter indication (0 degrees to 160 degrees F).
Intensity Requirement	Enough light for safe flying should be sufficient.
Pulse Ratio	One, two, or three input pulses per rpm.
Power (Battery Requirements)	9 volt NEDA type #1604.
Finish	Blue wrinkle.
Dimensions	1-17/32" high x 2-1/2" wide x 5-3/4" long.
Battery Life	Minimum of 40 hours.
Net Weight	10 oz. (less battery).

The Heath Company reserves the right to discontinue instruments and to change specifications at any time without incurring any obligation to incorporate new features in instruments previously sold.

CIRCUIT DESCRIPTION

Refer to the Schematic Diagram (fold-out from Page 23) while reading this description.

AMPLIFIER

Resistor R2 and the photo resistor form a voltage divider. The voltage across this voltage divider will remain constant as long as the light on the photo resistor does not change. Any variation in light intensity will cause the resistance of the photo resistor to change and result in a change in the voltage across the voltage divider. These voltage variations are coupled through capacitor C2 to the base of transistor Q1. Transistor Q1 operates as a voltage amplifier and is connected directly to Q2, another voltage amplifier.

SCHMITT TRIGGER

These amplified voltage variations (pulses) are coupled through capacitor C4 to the base of transistor Q3. Transistors Q3 and Q4 function as a Schmitt trigger circuit. This circuit has two stable states: if Q3 is conducting, Q4 will be cut off; if Q3 is cut off, Q4 is conducting. With no pulse from Q2, resistors R7 and R8 bias the base of Q3 so that it will remain in one of its two states, either conducting or cut off. A positive going pulse from Q2 will cause Q3 to conduct, whereas, a negative going pulse causes Q3 to cut off. Transistor Q4, controlled by Q3, will then switch to its opposite state. This switching action is almost instantaneous and causes the collector voltage of Q4 to go from zero to nearly the level of the supply voltage, or vice versa, depending on which state it is in. The sharp fall time (pulse) present at the collector of Q4 is coupled through capacitor C5 to the base of Q5.

MONOSTABLE MULTIVIBRATOR

Transistors Q5 and Q6 work together as a monostable multivibrator. With no pulses from Q4, a positive bias current at the base of Q5 keeps Q5 conducting. As a result, there is low voltage at the collector of Q5 which prevents Q6 from conducting.

A negative-going pulse from Q4 switches Q5 to cutoff which causes Q6 to conduct and capacitor C6 to discharge. The discharge of C6 keeps Q5 cut off for a length of time determined by the RC time constant of C6 and resistor R13 or resistors R13 and R14 (depending on OFF-HI-LOW switch position). When the base of Q5 becomes positive enough, Q5 turns on and Q6 turns off. The multi-vibrator is then returned to its normal state until the next pulse from Q4. Resistor R16 couples a positive voltage to the base of Q4 so it cannot turn off until Q5 is turned on. This prevents the fall time of the Schmitt trigger from occurring during the off time of Q5.

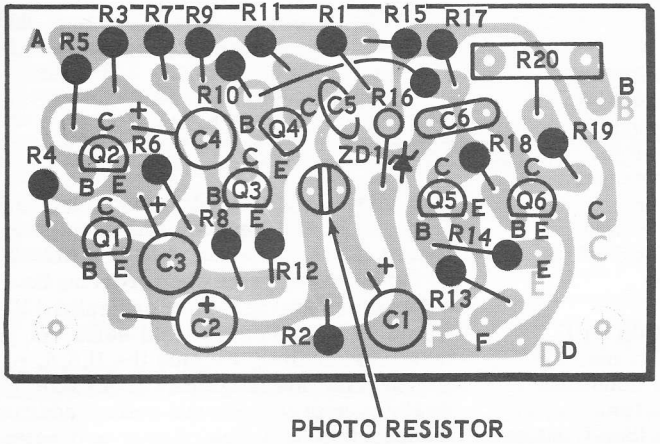
Therefore, the pulse width at the collector of Q6 will not vary as the frequency of the trigger pulses varies.

When Q6 is conducting, current flows through resistor R19, Calibrate control R20, and the meter. The meter will deflect and indicate the average current for the on and off time of transistor Q6. As the light intensity variations increase in frequency at the photo resistor, the average current increases. The increase in the average current will increase the meter reading.

Zener diode ZD1 holds the supply voltage to Q5 and Q6 at a constant level keeping the Tachometer in calibration as the battery becomes weaker with use.

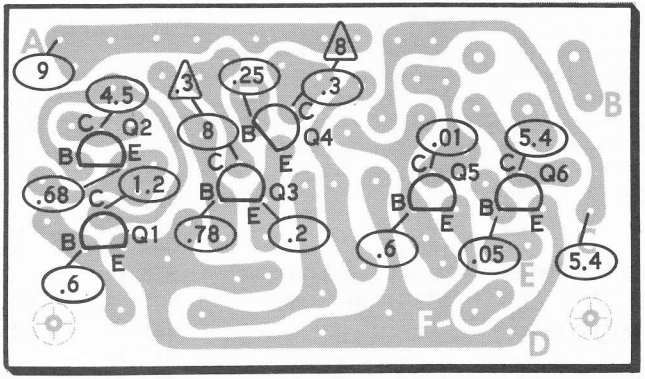
CIRCUIT BOARD X-RAY VIEW

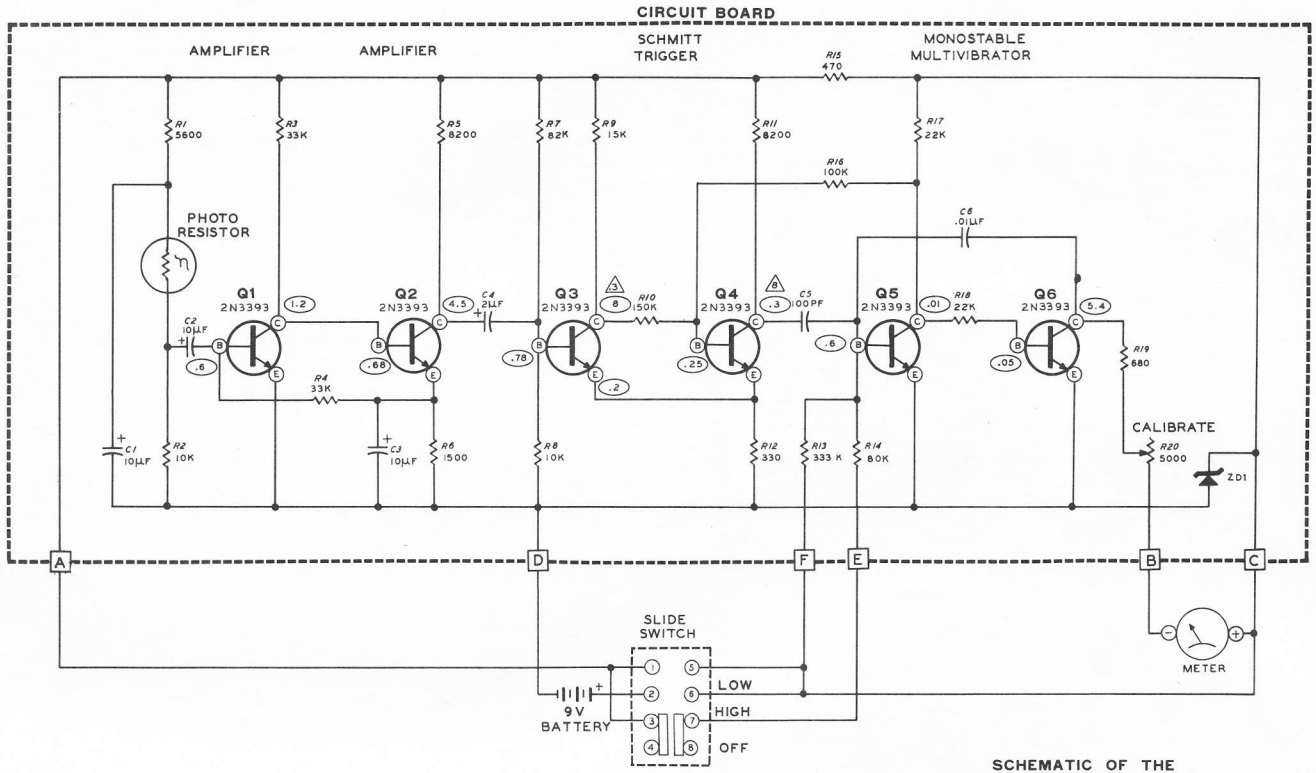
(VIEWED FROM FOIL SIDE)



VOLTAGE CHART

(VIEWED FROM FOIL SIDE)





NOTES:

1. ALL RESISTORS ARE 1/2 WATT. RESISTOR VALUES ARE IN OHMS (K=1,000).
2. □ THIS SYMBOL INDICATES AN EXTERNAL CONNECTION TO THE CIRCUIT BOARD.
3. REFER TO THE CIRCUIT BOARD X-RAY VIEWS FOR PHYSICAL LOCATION OF PARTS.
4. ⬭ THIS SYMBOL INDICATES A POSITIVE DC VOLTAGE MEASURED FROM THE POINT INDICATED TO CIRCUIT GROUND (POINT D). VOLTAGE MEASUREMENTS WERE TAKEN WITH AN 11 MEGOHM VOLTMETER WITH THE PHOTO RESISTOR COVERED. VOLTAGES MAY ±20%.
5. △ THIS SYMBOL INDICATES DC VOLTAGES TAKEN WHEN THE SCHMITT TRIGGER IS IN ITS ALTERNATE STATE.

SCHEMATIC OF THE HEATHKIT® THUMB® TACH MODEL GD-69