RAE KIT

VANCOUVER EDMONTON SASKATOON
WINNIPEG TORONTO MONCTON HALIFAX

Specifications

Physical Dimensions:	11.1 x 7.1 x 4.7 cm.
Temperature Range:	-55.0° — +150.0°C or -67.0° — +199.9°F
Operating Voltage:	6.8 — 15 volts D.C.
Operating Current:	1.5 ma.
Battery Life:*	Zinc-Carbon 9V — 100 hrs. Mercury 8.4V — 200 hrs. (Eveready E146X)

*The circuit will not operate properly below 6.8 volts.

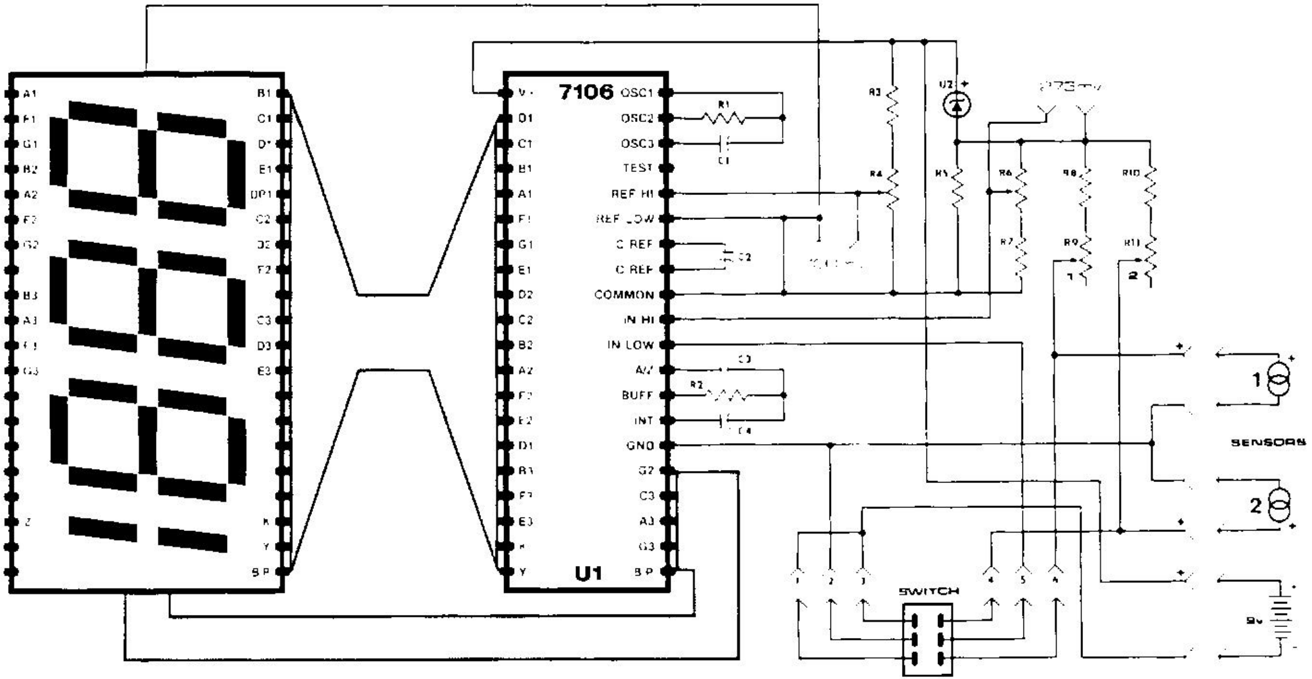
Because the voltage of standard zinc-carbon batteries decreases rapidly during use, it is recommended that mercury batteries be used. These batteries supply a nearly constant voltage throughout their lifetimes.

As the battery dies, and its voltage falls below 6.8 volts, the circuit will immediately begin to display much higher readings than it was calibrated for. When this happens, the battery must be replaced. Remember that zinc carbon batteries will have over half their lives left, and may still power other types of circuits.

12 Volt Operation

This kit is ideally suited to automotive and marine applications because of its low power consumption. While it has a wide operating voltage range, it is recommended that you use a 78M08 voltage regulator I.C. to ensure that the kit is not damaged by voltage transients. This I.C. and its data sheet are available from R-A-E.

3200D DIGITAL THERMOMETER



Theory of Operation

Most of the circuitry of the thermometer is contained in integrated circuit U1. Inside this chip is a complete digital voltmeter system, which directly drives the liquid crystal display. The range of this voltmeter is 0-200mv., and it is set by applying 1/2 of the full scale voltage to the REF HI and REF LO pins on the chip (100.0mv). This chip supplies a precision, temperature stable voltage reference of 2.8 volts between the COMMON and V+ pins. This 2.8 volts is reduced to 10 0mv. by the voltage-dividing resistors R3 and R4.

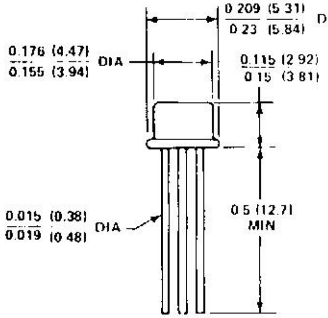
The AD590 sensors pass a current proportional to absolute temperature (°K). This current passes through resistors R8 and R9. The voltage across these resistors is therefore proportional to absolute temperature, and is 1.0mv./°K. The difference between the °C and the °K scales is 273°, and therefore 273mv. must be subtracted from the voltage to produce a 1.0mv./°C signal, applied to the IN HI and IN LO pins on the chip.

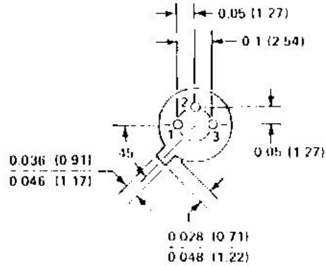
Integrated circuit U2 is a precision 1.2 volt regulator which further regulates the 2.8 volts produced by U1. The voltage of U2 is reduced by voltage-dividing resistors R6 and R7 to exactly 273mv., to supply the necessary voltage offset for the temperature sensor's signal.

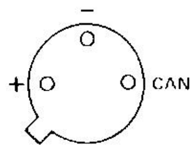
Complete data sheets on voltmeter chip U1 and the temperature sensor AD590 are available from R-A-E.

Package Outlines

TO-52 PACKAGE

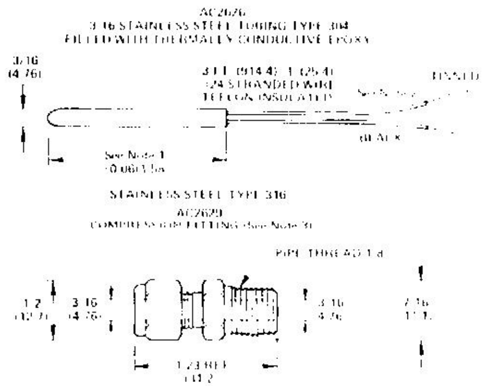






BOTTOM VIEW

(Dimensions shown in inches and (mm))



NOTE 1 [illegible]

NOTE 2 [illegible]

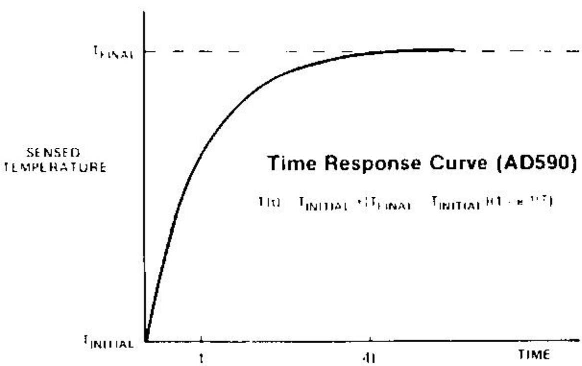
NOTE 3 [illegible]

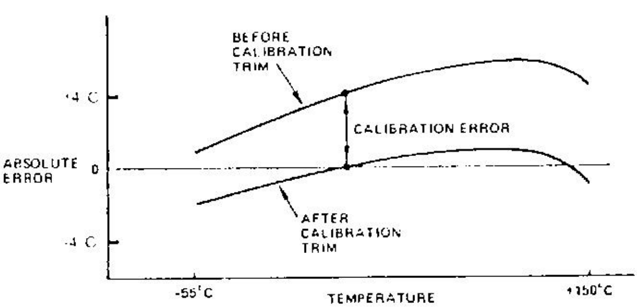
Sensor Characteristics

Time Response Curve (AD590)

MEDIUM	TIME (t)
Aluminum Block	1.2 sec
Stirred Liquid Bath	3.4 sec
Moving Air[1] — Heat Sink	5.0 sec
Moving Air[1] — No Heat Sink	12.0 sec
Still Air — Heat Sink	108.0 sec
Still Air — No Heat Sink	60.0 sec

[1]Air Velocity = 9 ft./sec.





Effect of Calibration Trim on Accuracy

Accuracy

The thermometer uses a solid-state sensor which passes a current directly proportional to absolute temperature (°K). Most other temperature sensors produce a *voltage* which is temperature dependant, and hence they are affected by the voltage drop in the wires that connect them to the circuitry. The kit's AD590 sensor can be located up to a kilometre away from the circuit board, with no re-calibration or loss in accuracy.

There are a number of factors contributing to errors in temperature measurement with this kit. The most obvious is the calibration error. The temperature reading can only be as accurate as the reference thermometer with which you calibrate it.

Another factor which contributes to the overall error is that the sensor, because it has a current passing through it, will tend to heat itself up. In still air, the sensor will heat itself up about 1°C, while in a stirred liquid almost all of the heat will be dissipated, resulting in an unmeasureably small temperature rise.

This self-heating error is also proportional to absolute temperature, and is removed when the thermometer is calibrated. For the best possible accuracy, the thermometer's sensors should be calibrated in the same thermal environment in which they will be used (e.g. in liquid, still air or moving air). If you are using two sensors, note that regardless of which sensor is being used, both have power applied. This feature ensures that both sensors will be "warmed-up" when switching back and forth between them.

The most significant error in temperature measurement comes from the non-linearity of the sensor. Over the -55 to +150°C range of the sensor, its output current is proportional to absolute temperature, within a certain tolerance. The sensor supplied with the kit has a ±2.0°C tolerance over the entire temperature range. This does *not* mean that the thermometer will usually be 2°C wrong. Most applications will not use the full temperature range of the sensor. The thermometer should be calibrated near the temperature at which it will be used. Readings near the calibration temperature will be much more accurate. A small temperature change of 2°C can be resolved with 0.1°C accurcy. A typical temperature range of 0-25°C will be accurate to ± 0.5°C. For applications requiring extreme accuracy over the entire range, higher grades of the AD590 sensor are available from R-A-E.

Testing and Calibration

Calibration of the thermometer involves setting two reference voltages on the board, and then trimming each sensor to one known temperature.

1. Connect a 9 volt battery to the battery snap. Turn the circuit on by clicking the toggle switch out of its centre position.

2. Connect an accurate high-impedance voltmeter, preferably a digital one, to the two terminal posts marked "100", at the end of U1.

3. Use a screwdriver to adjust trimmer R4, marked "100", so that the voltmeter reads exactly 100.0 millivolts. Note that all the trimmers require 20 turns to span their full range.

4. Connect the voltmeter to the other terminal posts, marked "273".

5. Adjust trimmer R6, marked "273", so that the voltmeter reads exactly 273.0 millivolts. If you have constructed the kit to read in °Fahrenheit, adjust R6 to read 459.8 millivolts.

6. Plug the sensor into the jack connected to the X1 pads on the circuit board. Set the toggle switch to the position which gives a reading on the display other than -1. Use a screwdriver to adjust calibration trimmer R9, marked "1", so that the display shows the ambient temperature.

7. Place the sensor next to an accurate thermometer, and then don't touch them for about five minutes. After the temperature reading has stabilized, re-adjust the calibration trimmer to match the temperature on the display to that on the thermometer.

8. Repeat the previous two steps for the second sensor, if you are using one. Adjust the corresponding calibration trimmer R11.

30. ☐ Fit the panel and pins into the circuit board, and place the panel face down on a flat surface. Solder the pins. Then briefly re-heat each pin you have soldered, while pulling it up with pliers. This will seat each pin head below the surface of the panel.

40. ☐ Transferring the black foil label to the acrylic panel is tricky, and sticky. You have one chance to get it on in the right place, because it is difficult to remove. First, carefully remove the label from its backing sheet, keeping it as flat as possible. Then line up the top edge of the label exactly on the top edge of the acrylic panel. Note that the top of the p.c. board should be under the top of the panel. With the edge lined up, smooth the rest of the label down over the panel. Then, apply extra pressure along the edges of the label to ensure that it won't lift up. If you get any dirt or a fingerprint on the panel, it can be wiped off with tissue and rubbing alcohol.

41. ☐ Install the jack connected to the X1 terminals on the board in the top hole on the side of the case. Install the X2 jack in the bottom hole.

42. ☐ Plug a sensor into the top jack and determine which switch position corresponds to sensor #1. Install the switch in the centre hole on the side of the case so that the handle points to the top jack.

43. ☐ Place the foam filler over the nylon spacer on the back of the board. Then put the battery in the left side of the case. Fit the panel and p.c. board into the case, making sure that the wires clear the nylon spacer. The hole in the spacer should line up with the hole in the bottom of the case, with no wires in the way. Install the 4-40 nylon screw in the case to secure the panel.

This completes the assembly of the kit.

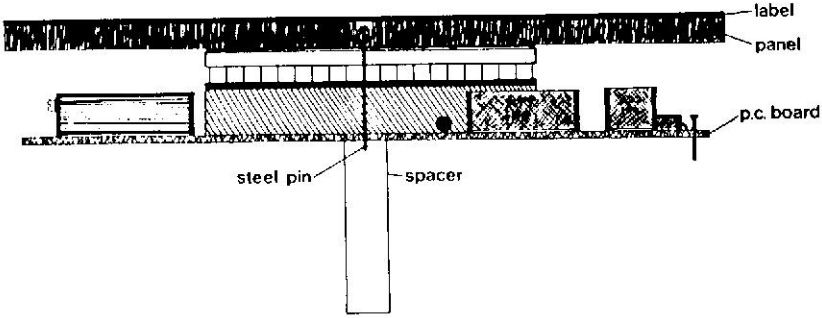
25. ☐ Use the *metal* 4-40 screw to mount the nylon spacer in the centre of the board. The spacer should stick out the back of the board.

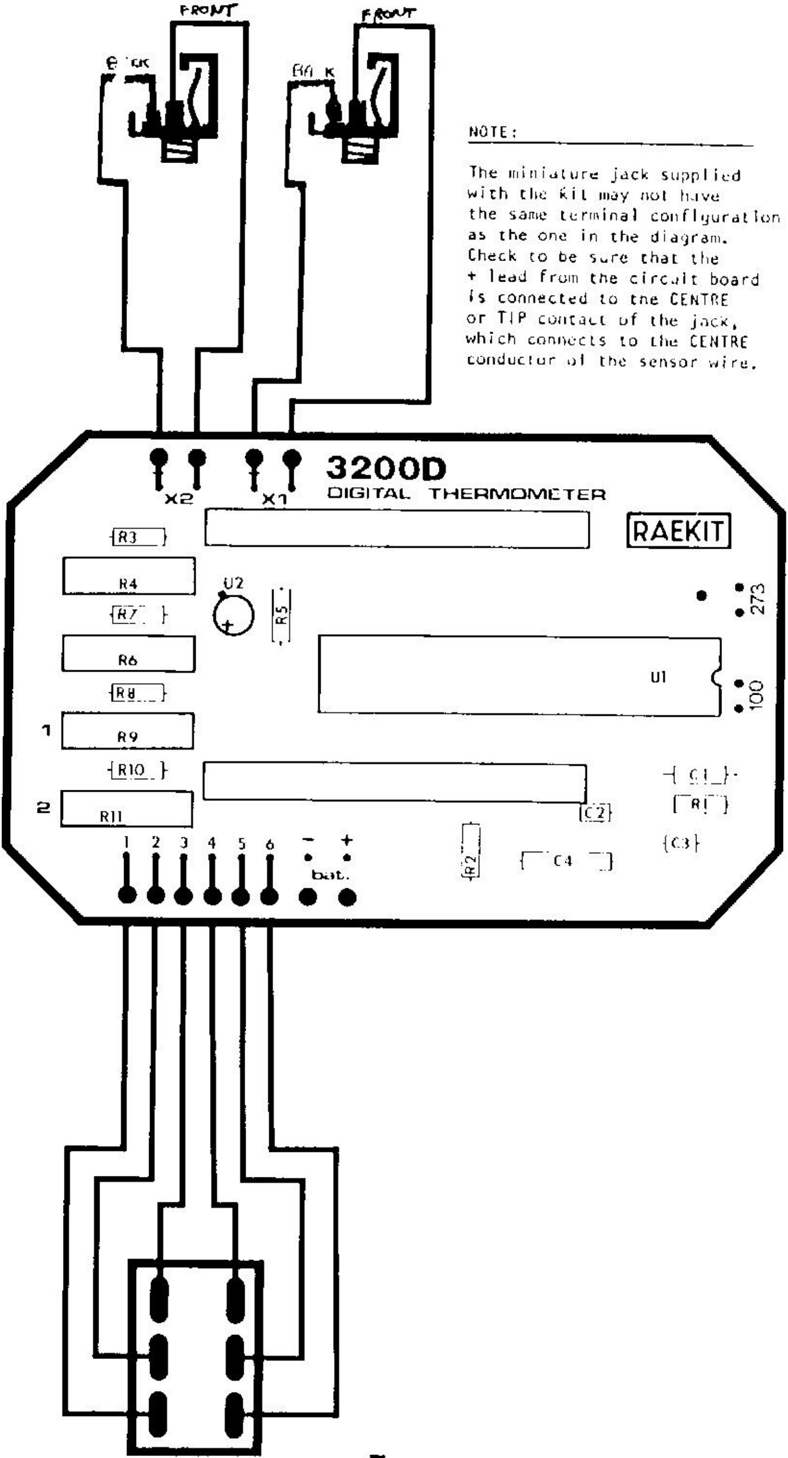
26. ☐ Carefully remove the ICL7106 integrated circuit from its protective carbon foam, and insert it into the 40-pin socket. The notch on the ICL7106 should be on the right hand side of the p.c. board. The I.C. will be easier to insert if you first bend the leads on each side slightly inward, by pressing them against a flat surface.

27. ☐ *Do not* remove the sockets from the display. Locate the dot in each corner of one side of the display face. Install the display on top of the ICL7106 I.C., with the dots on the left hand side of the board. Carefully solder all 40 pins of the sockets.

28. ☐ Before final assembly of the thermometer, proceed to the Testing and Calibration section of this manual, and verify that the circuit is working properly.

29. ☐ When you are satisfied that the circuit works properly, the acrylic panel can be installed over the front of the circuit board. The panel is held in place by three pins, which are soldered into the circuit board. First remove the protective paper from both sides of the panel. Then insert the three pins into the holes. The heads should drop into the panel, and will not protrude above the hole.





NOTE:

The miniature jack supplied with the kit may not have the same terminal configuration as the one in the diagram. Check to be sure that the + lead from the circuit board is connected to the CENTRE or TIP contact of the jack, which connects to the CENTRE conductor of the sensor wire.

20. [ ] Cut 10 lengths of #22 Stranded wire 12 cm. long. Strip 5 mm. of insulation from all the ends of the wires.

21. [ ] Use 4 cut lengths of wire to connect the two miniature phone jacks to the p.c. board exactly as shown in the diagram. Bring each wire through the large hole at the edge of the board up to the component side. Then insert the stripped end of the wire into the adjacent hole, and solder it. This extra loop of wire provides strain relief.

22. [ ] Use the remaining cut lengths of wire to connect the toggle switch to the p.c. board as shown in the diagram and described in the previous step.

23. [ ] Assemble the temperature sensor cable as shown below. To prepare each end of the 1 m. length of cable, strip off 10 mm. of the black insulation, being careful not to cut through the braid beneath it. Separate the braid from the centre conductor and twist it tightly. Then strip 3 mm. of insulation off the centre conductor. Before soldering the cable to the temperature sensor, snip off the sensor's third extra lead, which is connected to the case. Also be sure that the cable goes through the plug cover. You must connect the centre conductor of the cable to the sensor lead *next to the notch* on its case. On the other side, the centre conductor is connected to the *small* lug on the **plug.**

24. [ ] After you have finished soldering the cable, crimp the lugs on the **plug** around the cable. The temperature sensor leads can be encapsulated with epoxy or silicone sealant if you wish. If you plan to make liquid measurements, consider the RAEKIT 3202 stainless steel accessory probe, which is completely waterproof.

11. [ ] Install the 4 terminal posts from the back of the board

12. [ ] C1 120 pf Capacitor

13. [ ] R1 100K Resistor (brown-black-yellow)

14. [ ] C3 0.47 mf Capacitor (u47)

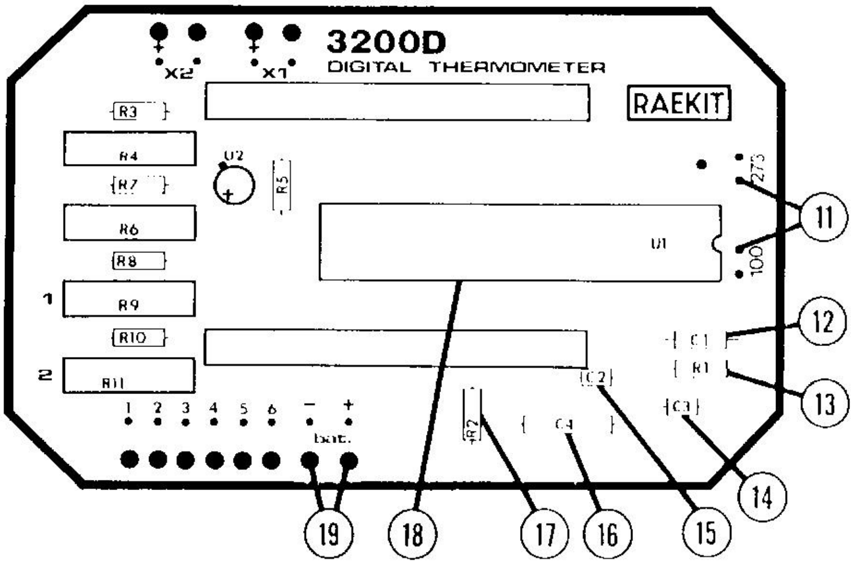
15. [ ] C2 0.1 mf Capacitor (u1)

16. [ ] C4 0.22 mf Capacitor (u22)

17. [ ] R2 47K (yellow-violet-orange)

18. [ ] 40 Pin Dual-Inline Socket

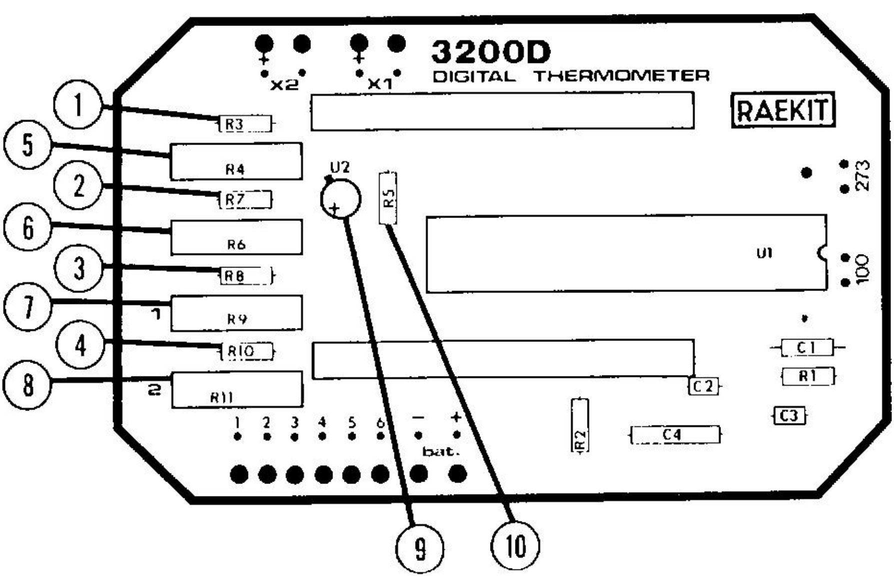
19. [ ] Bring the red lead of the battery snap from the back of the board through the large hole next to the "bat". Then insert the stripped end of the wire into the smaller hole marked "+". Repeat this step with the black wire and the hole marked "-".



Assembly Instructions

Install and solder the following parts, referring to the numbered diagrams. The components are mounted on the side of the board which has identification markings on it. Remember to keep the soldering time on the component leads as *brief as possible.* Trim off all excess leads after soldering.

1.	☐	R3	180K Resistor (brown-grey-yellow-red, or 1823F)
2.	☐	R7	24K Resistor (red-yellow-orange-red)
3.	☐	R8	953 Ohm Resistor (9530F) *For °Fahrenheit install 1740 Ohm (1741F).*
4.	☐	R10	953 Ohms (9530F) *Optional — for second sensor only.* *For °Fahrenheit install 1740 Ohm (1741F).*
5.	☐	R4	10K Trimmer
6.	☐	R6	10K Trimmer
7.	☐	R9	100 Ohm Trimmer *For °Fahrenheit install 200 Ohn Trimmer.*
8.	☐	R11	100 Ohm Trimmer *Optional — for second sensor only.* *For °Fahrenheit install 200 Ohm Trimmer*
9.	☐	U2	ICL8069 Voltage Regulator *Note the position notch on the case.*
10.	☐	R5	10K Resistor (brown-black-orange)



Miscellaneous

Qty.	Description
2 ☐	20 Pin Sockets *(attached to display — DO NOT REMOVE)*
1 ☐	40 Pin Dual-Inline Socket
3 ☐	Steel Pins
4 ☐	Terminal Posts
1 ☐	9V Battery Snap
1 ☐	Case
1 ☐	Acrylic Panel
1 ☐	Panel Label
1 ☐	4-40 x 1" Spacer
2 ☐	4-40 x 1/4" Screws
2 ☐	Miniature Phone Jacks
1 ☐	Miniature Phone Plug
1 ☐	DPDT Centre-Off Toggle Switch
1 ☐	Printed Circuit Board
1 ☐	1.5 m #22 Stranded Wire
1 ☐	1.0 m RG174U Coaxial Cable
1 ☐	Foam Insert

Optional Parts:

The 3200D kit is supplied with one sensor, and reads in °Celsius. An additional temperature sensor can be plugged into the second miniature phone jack supplied, providing that the following parts have been installed:

1 ☐	R10	953 Ohm (9530F)
1 ☐	R11	100 Ohm Trimmer

It is possible to construct the kit so that *both* sensors will read in °Fahrenheit. Note that both sensors must have the same scale. The following new parts must be substituted for those included in the kit:

2 ☐	R8, 10	1740 Ohm (1741F)
2 ☐	R9, 11	200 Ohm Trimmers

Parts List

Before starting to assemble this kit, please check that you have all the parts listed below.

Warning: The ICL7106 Integrated Circuit included in this kit is a MOS (metal-oxide-silicon) device, and is subject to damage from very large static electric charges. It is inserted into a special conductive foam for protection during packaging and shipping, and we suggest that you leave it in until you are ready to install it. Before handling the chip out of the foam, make sure that you do not have an excess static charge in your body, by touching any large metal object.

Resistors

Qty.	No.	Description
1 [ ]	R1	100K (brown-black-yellow)
1 [ ]	R2	47K (yellow-violet-orange)
1 [ ]	R3	180K (brown-grey-yellow-red, or 1823F)
2 [ ]	R4, 6	10K Trimmer
1 [ ]	R5	10K (brown-black-orange)
1 [ ]	R7	24K (red-yellow-orange-red)
1 [ ]	R8	953 Ohms (9530F)
1 [ ]	R9	100 Ohm Trimmer

Capacitors

1 [ ]	C1	120 pf
1 [ ]	C2	0.1 mf Mylar (u1)
1 [ ]	C3	0.47 mf Mylar (u47)
1 [ ]	C4	0.22 mf Mylar (u22)

Semiconductors

1 [ ]	U1	ICL7106 Integrated Circuit
1 [ ]	U2	ICL8069 Voltage Regulator
1 [ ]		AD590J Temperature Sensor
1 [ ]		43D5R03 Liquid Crystal Display

IMPORTANT NOTE

Before starting to assemble this kit, read through the assembly instructions and familiarize yourself with each step. Most of the problems we encounter are the result of poor soldering techniques or instructions not followed. The following is a list of Do's and Don'ts which may be helpful.

- Use a 25 to 30 watt soldering pencil with a fine tip.
- Use only fine-gauge rosin-core solder.
- Make certain the components are flat against the P.C. board before soldering. You may find it convenient to bend the leads at a 45 degree angle to hold the components in place while soldering.
- Touch the soldering iron to the P.C. board and the lead to be soldered; then touch the solder to them. Do not use excessive heat!
- Use the correct amount of solder to form a small bead that just covers the foil pad on the P.C. Board. A properly soldered connection should be smooth and shiny, *not* dull and lumpy.
- After soldering, diagonal cutters should be used to clip off the excess component leads close to the bead of solder.
- Do *not* use acid core solder.
- Do *not* use flux or soldering paste.
- Do *not* use a soldering gun.
- Do *not* use excess solder.
- Do *not* use excess heat.

RAE KIT

Instruction Manual

3200D DIGITAL THERMOMETER

This compact, precision digital thermometer measures temperature over the wide range of -55 - +150° Celsius. The kit comes with one sensor, and provides for an additional sensor to be plugged in. This special current-source sensor is also available in a stainless steel probe. The use of a liquid crystal display enables the circuit to operate for several hundred hours on a 9 Volt battery. The kit can also be assembled to read in °Fahrenheit.