

## CY7/670 Series Temperature Sensors

### Application Notes

M-4447/0307

#### INSTALLATION AND OPERATION

Three aspects of using a temperature sensor are critical to its optimum performance:

- the proper electrical and thermal installation of the connecting leads that run to the sensor
- the actual mounting of the sensor to the sample assembly
- the measurement electronics used for reading and recording temperature data from the sensor

#### Connecting Leads

Although the majority of the CY7/CY670 series sensors are two-lead devices, measurements are preferably made using a four-wire configuration to avoid all uncertainties associated with lead resistance. This is done by using four connecting leads to the device and connecting the V+ and I+ leads to the anode and the V- and I- leads to the cathode as shown in Figure 1. The exact point at which the connecting leads are soldered to the device leads results in negligible temperature measurement uncertainties.

In a two-wire measurement configuration, the voltage connections (point A in Figure 1) are made near or at the current source, so only two leads are actually connected to the device. Some loss in accuracy can be expected since the voltage measured at the voltmeter is the sum of the diode voltage and the voltage drop across the connecting leads. The exact temperature uncertainty will depend on the temperature range and lead resistance. For a 10-ohm lead resistance, the diode voltage will be offset by 0.1 mV, which gives a negligible temperature error at liquid helium temperature but a 50 mK error near liquid nitrogen temperature. Note the PI and CY adapter can be used only in a two-wire configuration.

An excessive heat flow through the connecting leads to any temperature sensor can create a situation where the active sensing element (for the CY7/670 series this is the diode chip) is at a different temperature than the sample to which the sensor is mounted. This is then reflected as a real temperature offset between what is measured and the true sample temperature. Such temperature errors can be eliminated by proper selection and installation of the connecting leads.

In order to minimize any heat flow through the leads, the leads should be of small diameter and low thermal conductivity. Phosphor-bronze or manganin wire is commonly used in sizes 32 or 36 AWG. These wires have a fairly poor thermal conductivity yet the resistivities are not so large as to create any problems in four-wire measurements.

Lead wires should also be thermally anchored at several temperatures between room temperature and cryogenic temperatures to guarantee that heat is not being conducted through the leads to the sensor. A final thermal anchor at the sample itself is a good practice to assure thermal equilibrium between the sample and the temperature sensor. Note that the CU, CY, SO, and DI mounting adapters serve as their own sample thermal anchor.

If the connecting leads have only a thin insulation such as vinyl acetal or other varnish type coating, a simple thermal anchor can be made by winding the wires around a copper post or other thermal mass and bonding them in place with a thin layer of CYAV varnish. There are a variety of other ways in which thermal anchors can be fabricated; a number of guidelines can be found in detail in the following references.

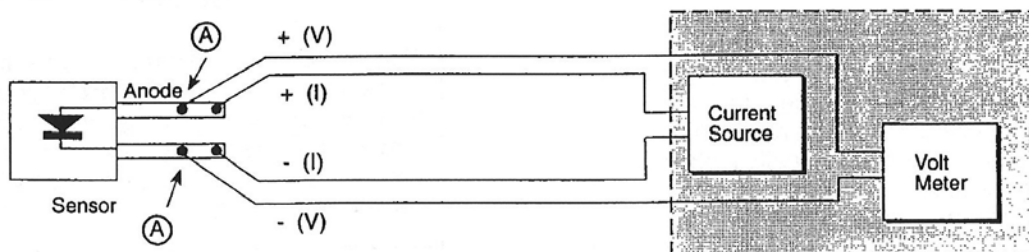


Figure 1. Four-Wire Configuration for CY7/670 Series Sensor Installation

## Sensor Mounting

### General Comments

Before installing the CY7/670 series sensor, identify which lead is the anode and which lead is the cathode by referring to the accompanying device drawings. Be sure that lead identification remains clear even after installation of the sensor, and record the serial number and location.

The procedure used to solder the connecting leads is not very critical and there is very little danger in overheating the sensor. If for some reason the leads need to be cut short, they should be heat sunk with a copper clip or needle-nose pliers before soldering. Standard rosin-core electronic solder (m.p. 180C) is suitable for most applications. Applications involving the use of the SD package up to 200 °C require a higher melting point solder. A 90% Pb 10% Sn solder has been used quite successfully with a rosin flux.

For all adapters except the CY, CU, and DI, the leads are gold-plated Kovar. Prolonged soldering times may cause the solder to creep up the gold-plated leads as the solder and the gold alloy. This is not detrimental to the device performance.

When installing the sensor:

- Make sure there are no shorts or leakage resistance between the leads or between the leads and ground. CYAV varnish or epoxy may soften varnish-type insulations so that high resistance shunts appear between wires if sufficient time for curing is not allowed. Teflon spaghetti tubing is useful for sliding over bare leads when the possibility of shorting exists.
- Avoid putting stress on the device leads and allow for the contractions that occur during cooling that could fracture a solder joint or lead if installed under tension at room temperature.

The CY7/670 series sensor is designed for easy removal for recalibration checks or replacement, and the following discussions for each of the adapters are geared in this direction. If semi-permanent mountings are desired, the use of OB-CY10 or OB-CY20 low temperature epoxy can replace the use of CYAG grease. In all cases, the mounting of the sensor should be periodically inspected to verify that good thermal contact to the mounting surface is maintained.

### CY7/670-SD

The SD version is the basic package for the CY7/670 series sensor line, from which all other configurations are made using the appropriate adapter. The base of the device has a gold metallized surface and is the largest flat surface on the sensor. The base is electrically isolated from the sensing element and leads, and all thermal contact to the sensor must be made through the base.

A thin braze joint around the sides of the SD package is electrically connected to the sensing element. Contact to the sides with any electrically conductive material must be avoided. When viewed base down and with leads towards the observer, the positive lead (anode) is on the right.

For a removable mount, the SD sensor can be held against the mounting surface with the CO adapter (see below) or similar clamping mechanism. Any method of clamping the sensor must avoid excessive pressure and should be designed so that thermal contractions or expansions do not loosen contact with the sensor. For uses restricted to below 325 K, a thin layer of CYAG grease should be used between the sensor and sample to enhance thermal contact.

The SD package can also be bonded with a low temperature epoxy. The sensor should be pressed firmly against the surface during curing to assure a thin epoxy layer and a good thermal contact. The device may be removed in the future by using the appropriate epoxy stripper.

The SD adapter can be soldered using a rosin flux (non-corrosive) if extreme care is exercised.

1. Tin the base of the sensor using a low wattage, temperature controlled soldering iron that will not exceed 200 °C. Use only a minimal amount of solder. Tin the surface to which the sensor is to be bonded and again, avoid an excessive thickness of solder. Clean both the sensor and the mounting surface of any residual flux.
2. Reheat the mounting surface to the melting point of the solder, press the device into position and allow the sensor to warm to the melting point of the solder.
3. After both tinned surfaces have flowed together, remove the heat source and let the sample and sensor cool.

Under no circumstance should the sensor be heated above 200 °C and the solder must be limited to only the base of the sensor. Excess solder running up the sides of the SD package can create shorts. Repeated mounting and demounting of a soldered sensor may eventually cause wetting deterioration and ruin the thermal contact to the sensing element, although the nickel buffer layer should minimize these problems.

### CAUTION

**The preferred method for mounting the SD sensor is either the CO adapter or bonding with epoxy. Omega Engineering, Inc. will not warranty replace any device damaged by a user-designed clamp or damaged through solder mounting.**

## CY7/670-LR

The gold-coated copper LR adapter is designed for insertion into a 1/8-inch diameter tube. A thin layer of CYAG grease should be applied to the copper adapter before insertion. This eases installation at room temperature and enhances the thermal contact.

## CY7/670-CU/DI/CY

The gold-coated copper CU, DI and CY adapters serve as both a sensor and a thermal anchor assembly. These adapters are designed to be mounted to a flat surface using a 4-40 brass screw. Avoid over-tightening the screw; use only enough force to firmly hold the sensor in place. Brass is recommended for the screw as the differential thermal contraction between the adapter and the screw will cause the mounting assembly to tighten as opposed to loosen when the system is cooled. A thin layer of CYAG grease should be used to enhance the thermal contact between the adapter and the mounting surface.

The CU adapter has four color-coded leads: red (I-), green (V-), clear (V+), and blue (I+). The CY adapter has two color-coded leads: yellow (+) and green (-). The green lead on the DI adapter is the cathode.

## CY7/670-ET/MT

Both adapters are gold-plated copper hex head bolts with the SD package mounted in a slot on the adapter head. The ET adapter screws into a 1/4 inch deep, 6-32 threaded hole while the MT adapter screws into a 6 mm deep, 3 x 0.5 mm threaded hole. Before assembly, the threads should be lightly greased with CYAG grease. Do not over-tighten, since the threads are copper and can be easily sheared. Finger-tight should be sufficient.

## CY7/670-BO

The BO adapter should be mounted in the same manner as the CU. The BO adapter contains its own thermal anchor and is an epoxy-free assembly.

## CY7/670-CO

The CO adapter is used to attach the CY7/670-SD package to a flat surface. The adapter is a spring-loaded clamp designed to maintain pressure on the SD package as the temperature is varied.

1. Remove the hold down cap that holds the three-piece CO assembly together. The CO assembly should appear as shown in the accompanying drawings.
2. Bolt the assembly into a 4-40 threaded hole. The stop on the brass screw should rest against the mounting surface and it also prevents overcompressing the spring.

3. Lift the edge of the clip using a small pair of pliers or screwdriver.
4. Slide the SD package into place underneath the clip and gently lower the clip onto the lid of the SD package. Note that a slot is cut underneath the clip to accept the SD package. Refer to the drawing for details.

If the device is to be used only below 325 K, a layer of CYAG grease should be used between the SD package and mounting surface to enhance the thermal contact.

## Sensor Operation

Temperature controllers and thermometer instrumentation offered by Omega Engineering, Inc. are designed to be directly compatible with the CY7/670 series sensor to give optimum performance and accuracy together with direct temperature readouts. Simply follow the instructions provided with the instrument concerning sensor connection and instrument operation. If a user-supplied current source, voltmeter, or other instrumentation is going to be used with the CY7/670 series sensor, special attention should be given to the following details.

The CY7/670 series sensors are designed to operate at a constant current of 10  $\mu$ A while the voltage variation with temperature measurement depends directly on the specifications of the current source and the voltmeter. A current source operating at the level of +0.01  $\mu$ A ( $\pm$ 0.01 K) is probably suitable for most applications. The voltmeter resolution required can be estimated from the sensitivity (dV/dT) of the CY7/670 sensor:

Temperature (K)	Sensitivity (mV/K)
305	2.4
77	1.9
4.2	33

Multiplying the above sensitivity by the desired temperature resolution in K will give the required voltage resolution in mV.

The static impedance of the CY7/670 series sensor operating at 10  $\mu$ A current is on the order of 100,000 ohms. Therefore, the input impedance of the voltmeter must be significantly larger than this to avoid measurement errors. Voltmeters with input impedances of greater than 109 or 1010 ohms should be used.

Good quality instrumentation must be used and all instrumentation and wiring should be properly grounded and shielded. Temperature measurement errors will result if there is excessive AC noise or ripple in the circuitry. Further details can be found in the article by Krause and Dodrill given in the references.

Note: All materials mentioned above that are used in sensor installation are available from OMEGA Engineering, Inc.

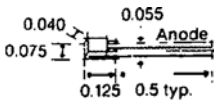
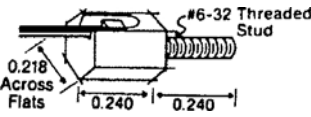
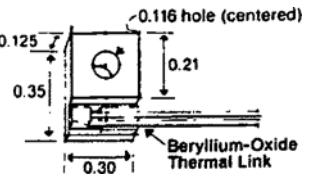
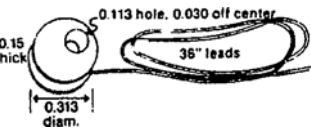
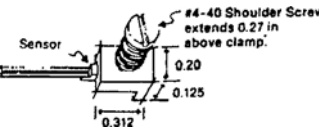
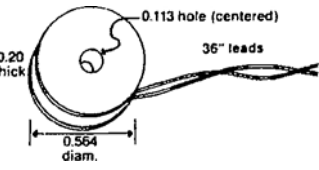
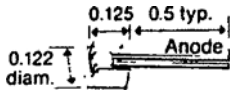
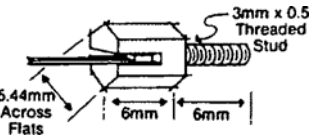
## REFERENCES

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White, G.K. (1979). Experimental Techniques in Low Temperature Physics. Clarendon Press, Oxford.

<p><b>CY7/670-SD</b></p>  <p>Dimensions in inches unless otherwise noted.</p> <p>Basic sensor package style. Temperature range: 1.4 to 475 K Mass: 0.03 g</p>	<p><b>CY7/670-ET</b></p>  <p>Basic sensor soldered onto SAE-threaded copper adapter. Temperature range: 1.4 to 325 K Mass: 1.4 g</p>	<p><b>CY7/670-BO</b></p>  <p>Basic sensor soldered onto bolt-on copper block with leads thermally anchored to block. Temperature range: 1.4 to 325 K Mass: 1.5 g</p>	<p><b>CY7/670-CU/DI</b></p>  <p>Basic sensor mounted into bolt-on disk with leads thermally anchored to disk with low temperature epoxy. CU version is 4-lead. DI is 2-lead. Temperature range: 1.4 to 325 K Mass (excluding leads): 4.3 g</p>
<p><b>CY7/670-CO</b></p>  <p>Basic sensor with spring-loaded brass clamp to hold sensor to sample. Temperature range: 1.4 to 475 K Mass (without sensor): 1.7 g</p>	<p><b>CY7/670-CY</b></p>  <p>Basic sensor epoxied into relatively large copper disk. 30 AWG stranded copper lead pair is thermally anchored to disk. Temperature range: 1.4 to 325 K Mass (excluding leads): 4.3 g</p>	<p><b>CY7/670-LR</b></p>  <p>Basic sensor soldered into cylindrical copper adapter. Temperature range: 1.4 to 325 K Mass: 0.15 g</p>	<p><b>CY7/670-MT</b></p>  <p>Basic sensor soldered into metric-threaded copper adapter. Temperature range: 1.4 to 325 K Mass: 1.4 g</p>

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