Heathkit of the Month #123:
by Bob Eckweiler, AF6C

MISCELLANEOUS – AUTOMOTIVE

Heathkit CI-1080 Exhaust Gas Analyzer

Introduction:

This article completes the triumvirate of Heathkit automotive test equipment that helped keep my 1971 sports car in tune for over 239 thousand miles (the average distance between the earth and moon). The other two are the previously covered ID-29 Automotive Tune-up Meter (HotM #73)[1] and the CI-1020 Automotive Timing Light (HotM #120)[2].

With California mandating smog inspections for post 1966 model year cars, an exhaust gas analyzer became almost a necessity for shade tree mechanics who did their own tune-ups. In the summer 1974 catalog, Heath introduced the CI-1080 Exhaust Gas Analyzer for $59.95. One was purchased by mail order from Benton Harbor MI and arrived in mid-August (Shipping was $2.48 for 6 lbs.).

The CI-1080 Exhaust Gas Analyzer:

The CI-1080 is based on a Fenwal G126B sensor. It mounts to a probe housing and stand that is placed on the ground near the car exhaust. A flexible metal tube connects to the probe housing, and its other end is inserted into the car's tailpipe. A 21 foot, heavy three-conductor flat cable connects the probe to the instrument. There is also a power cable that has two large battery clips and connects to the automobile battery (or other 6 to 12 VDC source.)

Here is a link to the index of Heathkit of the Month (HotM) articles:
http://www.w6ze.org/Heathkit/Heathkit_Index.html

1. Notes begin on page 13

Figure 1: Author's Heathkit CI-1080 Exhaust Gas Analyzer purchased mail order in August 1974. (Apologies for the reflection on the meter face.)

As shown in **Figure 1**, the instrument, cables, probe with housing, pipe and stand, all fit in a blue molded plastic instrument case. The filled case weighs 4¾ lbs. and measures about 15¼" L x 8" W x 4¼ D". The carrying handle folds flush to the case when not being used.

By Christmas of 1975 the CI-1080 price had risen $5 to $64.95 The price increased at least eight times over its product's life, more than doubling from $59.95 $129.95. (See **Table 1**.)

The cost of the Fenwal sensor fluctuated over the years. No price was given in the early 595-

CI-1080 SELLING PRICE OVER THE YEARS

CATALOG *		PRICE A nickel short of:	
Summer	1974	$60	Introduced
Christmas	1975	$65	
Christmas	1976	$65	
Christmas	1977	$65	
Winter	1978	$68	
Winter	1979	$70	
Christmas	1979	$80	
Christmas	1980	$80	
Christmas	1981	$100	
Christmas	1982	$115	
Christmas	1983	$120	
Christmas	1984	$120	
Christmas	1985	$130	
::	::	::	
Spring	1989	$130	Last ap-pearedHeathkit

* See Note #3 on page 13

CI-1080 SPECIFICATIONS

Meter Scales (3)	11.5 – 15.0 Air Fuel Ratio. 70% – 90% Combustion Efficiency. 0 – 8% Carbon Monoxide.
Exhaust Type	From 4–cycle gasoline engines.
Accuracy	Within 1 Air-fuel Ratio depending fuel used.
Meter	4-½" 100–0–100 μA 500Ω.
Connections	Battery Cord, 7 feet. Sensor Cord, 21 feet Exhaust flexible tube, 30 inches.
Power Requirements	6-volt or 12-volt car battery less than 150 mA.
Weight	4 lbs. 12 oz. (2.15 kg.)

TABLE II

1675 manual; instead there was a note: *"Write to Heath Co. for price information"*. At least four versions of the Fenwal sensor existed by 1984.

In 1989 Heath dropped the automotive section from their catalog. In the Winter[3] and Spring 1989 catalogs, no automotive instruments are listed, with the exception of the CI-1080, which shows up in the "Home Products" section. Sometime between Spring 1989 and Winter 1990 the CI-1080 was also discontinued.

Table II shows the specifications, from the manual, for the CI-1080.

Operating the CI-1080 Analyzer:

The CI-1080 has only a center-zero meter and a balance control that is accessed on the back of the analyzer cabinet. Also on the back are feet. The two upper feet are hook shape so the cabinet can be hung on a partially open car window. Simple operating instructions are printed on the back. **Figure 2** is a view of the rear of the CI-1080 cabinet.

Figure 2: Rear cabinet view, showing balance control, hooked feet and simple instructions.

Before using, get the car warmed up, preferably by driving it until it reaches normal operating temperature. Be sure the car hood is open and the sensor assembly (**Figure 3**) is placed on the ground near the car exhaust. (Do not place the hose in the exhaust yet). Place the analyzer where the meter can easily be seen, and be sure the meter is mechanically centered. Now follow the instructions on the back of the analyzer cabinet:

Figure 3: Probe assembly, consisting of Sensor, Sensor cover, Probe Body, Knurled Collar, & Probe Stand. Also shown attached is the flexible tube.

1. **WARM ENGINE:** If the engine has cooled some during set up, let it run until it again reaches operating temperature.

2. **CONNECT BATTERY:** Connect the red and black alligator clips to the car battery (Either 6 V or 12 V can be used.) Observe polarity – the analyzer is protected against accidentally connecting the cables backwards.

3. **BALANCE METER:** Using the **BALANCE** potentiometer control on the rear of the analyzer cabinet, set the meter pointer to the 'Δ' calibration mark on the "AIR FUEL RATIO" (AFR) scale between 13.2 and 13.3. (**Figure 4**).

4. **INSERT PROBE:** With the engine idling, the flexible tubing should be inserted 6" to 12" into the tail pipe.

After the meter stabilizes read the relative air fuel ratio. Also note the combustion efficiency and percent CO (carbon monoxide.) at idle.

The test should be repeated with the engine running at cruising RPM, typically 2,000 RPM; but unless you have access to a dynamometer, this won't be as accurate as doing the test under load. **Figure 5**, from the manual, shows a typical setup.

CI-1080 Analyzer Assembly:

Construction of the CI-1080 is not difficult. It could be considered a one or two evening kit. Most components mount on a small circuit board (**Figure 6**); five precision resistors, two diodes, an internal calibration pot, an internal DPDT slide switch (**NORMAL – CALI-**

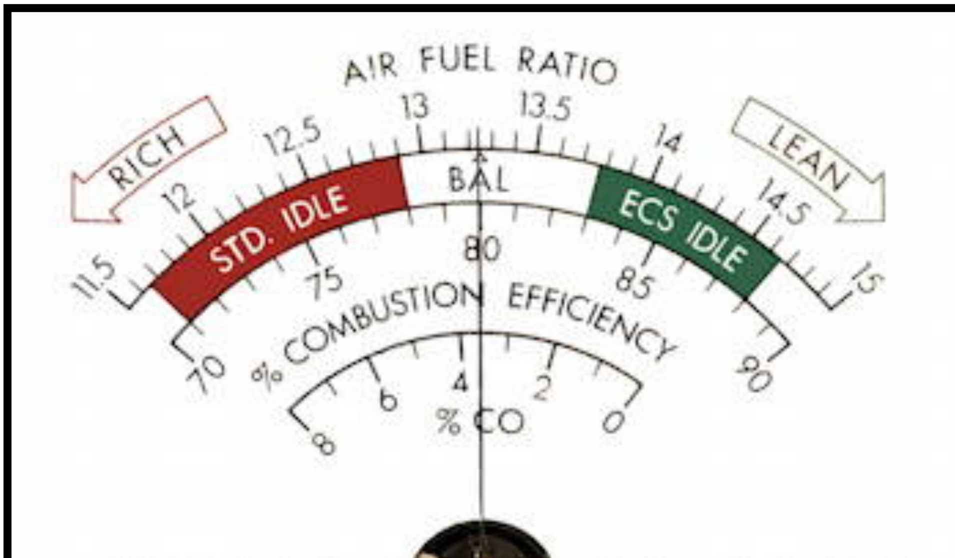


Figure 4: CI-1080 Exhaust Gas Analyzer Meter showing the three scales – Air Fuel Ratio, % Combustion Efficiency & % CO

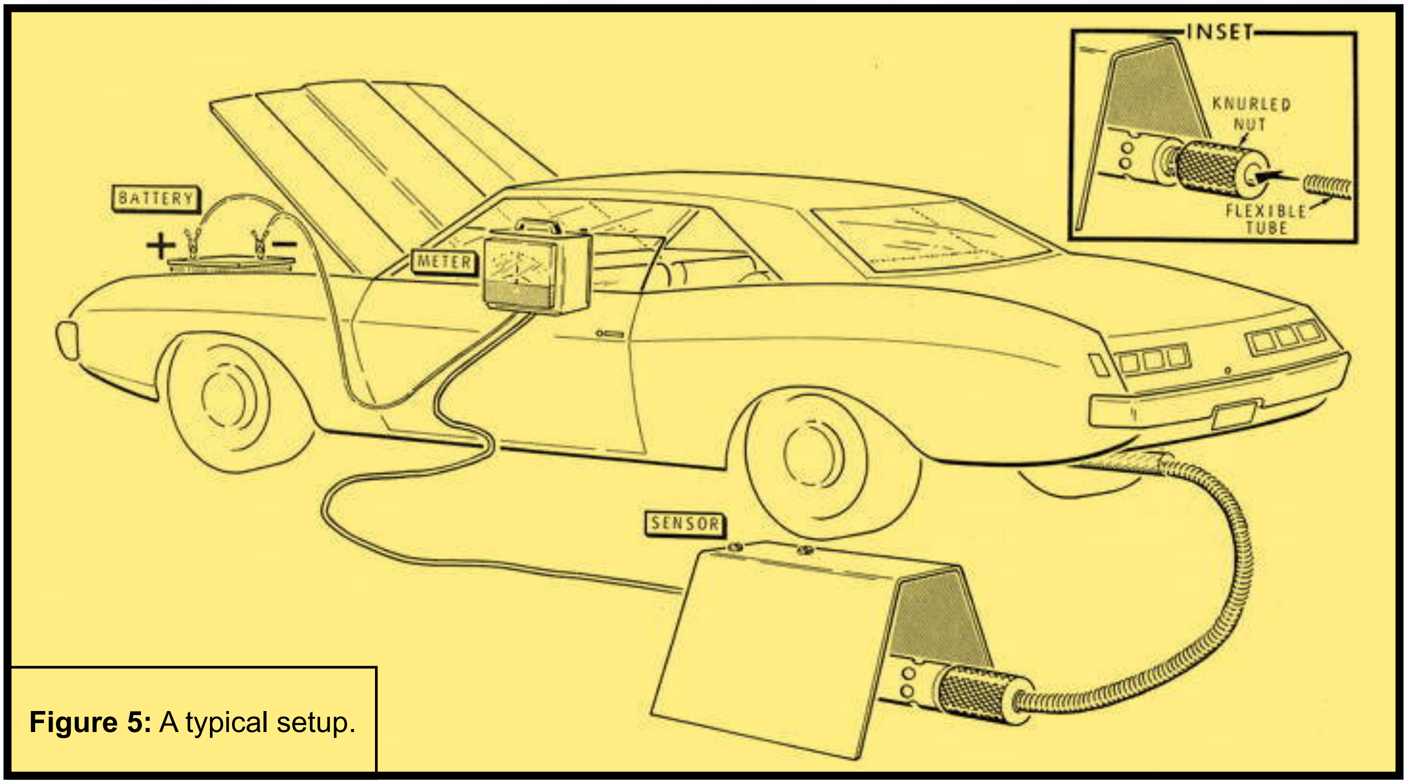


Figure 5: A typical setup.

BRATE), a lamp socket with a #53 lamp[4] and the BALANCE pot. The balance pot mounts on the foil side of the circuit board. The completed circuit board is put aside, and the sensor probe assembly is constructed.

First, the sensor is bolted to the probe body, being sure the holes in each align. Then, a length of heavy, 3-conductor cord is soldered to the sensor, and the sensor cover is mounted over the connections, clamping the wires. Finally, the knurled collar is screwed onto the probe body and the assembled probe is attached to the U-shaped probe stand.

Assembly next focuses on the analyzer cabinet. The meter is attached to the cabinet[5]. One end of a length of heavy 2-conductor cord is prepared with battery clips, (black clip to the ribbed lead). The other end of the two conductor cord and the free end of the sensor cord are then stripped and tinned. Next, they are fed through holes in the cabinet and soldered to the circuit board[6,7]. Both

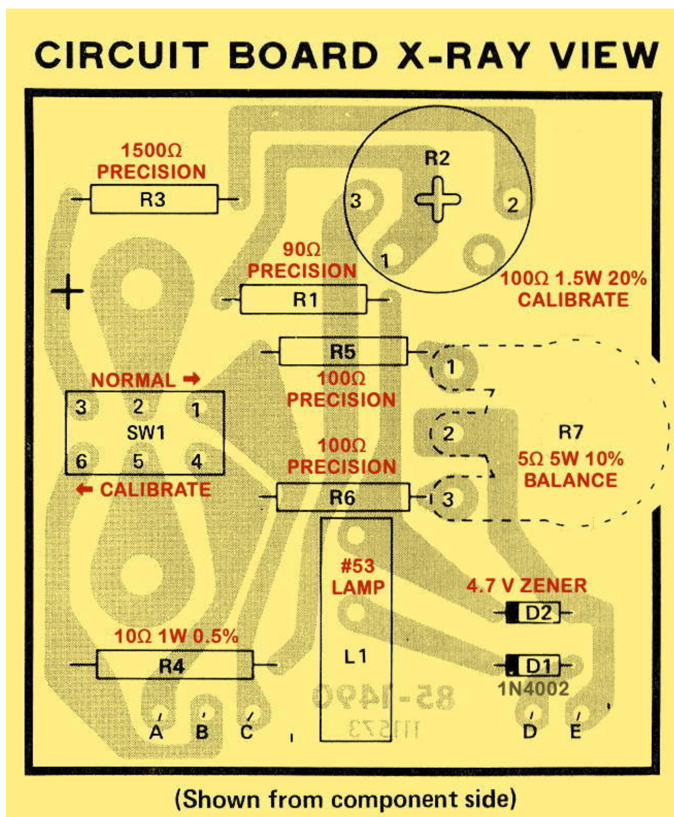


Figure 6: Author enhanced circuit board drawing from the manual. R7 (dashed) mounts on the foil side of the board. Large unused holes above and below SW1 fit the meter terminals. Plus is marked.

cords are secured to the cabinet using Heyco strain relief bushings, and the circuit board, component side up, is mounted to the meter terminals.

Following testing and calibration (next section), final assembly commences. The rear cover is prepared by adding feet, plastic mounting hooks, the handle and the blue and white identity label. It is then installed on the cabinet, being sure the BALANCE control shaft fits through the rear cabinet hole.

CI-1020 Testing and Calibration:

Testing –

1. Be sure the meter mechanical adjustment is set to the 'Δ' calibration mark.
2. Place SW1 in the NORMAL position,
3. Connect the power leads to a 6 or 12 volt car battery (red to positive.) The ballast lamp should light with a 12V battery and <u>may</u> light dimly with a 6V battery.
4. Turn the balance control R7 to be sure the meter can be adjusted well to both sides of the 'Δ' calibration mark.

This completes testing.

Calibration –

1. Move SW1 to the CALIBRATE position.
2. Adjust R2 until the meter reads 15 on the "AIR FUEL RATIO" scale.
3. Return SW1 to the NORMAL position.
4. Reset the meter needle to the 'Δ' calibration mark on the meter, if it has moved.

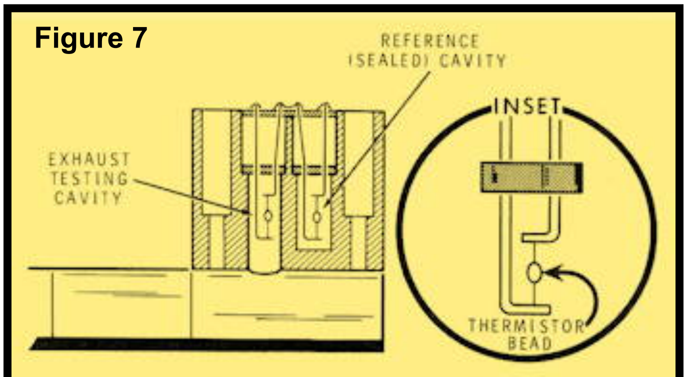
This completes calibration.

CI-1080 Analyzer Circuit Description:
Refer to **Figure 8** for the schematic.

<u>Power Conditioner</u>: The power conditioning consists of D1, D2 and L1. It turns the 6V or 12V battery voltage into a regulated 4.7 volt source. D1 prevents damage, should the battery clips be connected backwards. Diode D2 is a 4.7V zener[8]. Lamp L1 acts as a ballast resistor. It will have higher resistance with 12 V input due to the added current draw causing the lamp to light moderately. The current draw will be a lot less with 6V causing the lamp to not light or just light dimly. In either case the output at the junction of L1 and D2 will be 4.7 volts.

<u>Sensor</u>: The Fenwal G126B sensor consists of a machined housing containing two well-matched tiny thermistor beads (**Figure 7**). One bead sits in a sealed, air-filled chamber; the other sits in a chamber open to the probe exhaust gas. Between the probe entrance and the open chamber are a series of baffles to make the gas that reaches the chamber be as static as possible, with little movement that can cause errors.

Figure 7



The tiny beads have a large negative temperature coefficient; their resistance drops quickly as they get hot: 2000 Ω at room temperature to 100 Ω at 150°C. When gas is introduced into the active cavity it changes the thermal conductivity of the atmosphere around the bead and causes its temperature, and thus resistance, to change.

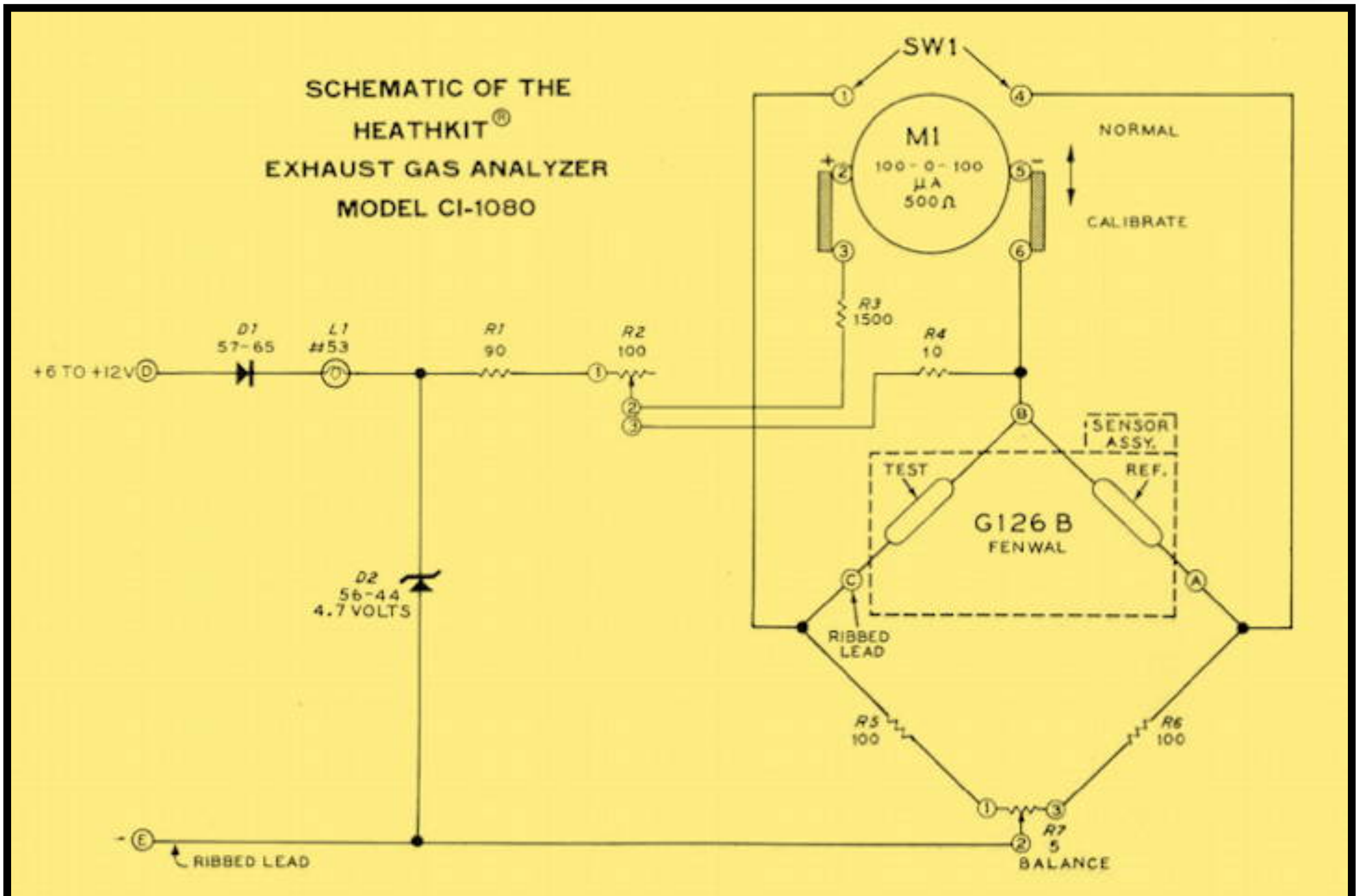


Figure 8

The Bridge: The Wheatstone bridge, consists of the two sensor beads and two precision 100Ω resistors. A small balance potentiometer compensates for any slight differences in the bridge legs. The meter is connected between the center point of each leg. When power is supplied to the analyzer, 20 mA will flow through the bridge; 10 mA through each leg. The tiny beads will heat up quickly to around 150ºC Since they are well matched around that temperature, the meter may move significantly for a few seconds, as the sensor warms up, then settle near the center. It can then be balanced by the BALANCE control, if needed.

Exhaust gas varies in thermal conductivity from air. When exhaust gas is introduced into the chamber, the thermal conductivity of the gas changes the temperature of the sensor bead. If the thermal conductivity of the gas is higher than air, the bead will cool, increase in resistance, and the meter will move to the left. However, if the thermal conductivity of the gas is lower, the bead will get hotter, decrease in resistance, and the meter will move to the right. An air fuel ratio of about 13.25 is close to the thermal conductivity of air.

The Calibration Circuit: The sensor is designed to output accurately when the bridge has 20 mA flowing through it (10 mA in each leg), and the beads have reached their operating temperature. Balance occurs when the active sensor is exposed to ambient air. Any slight imbalance can be corrected by the BALANCE control.

When SW1 is moved to the CALIBRATE position, the meter is switched to read the current into the bridge, and the output from the bridge is disconnected. **Figure 9** shows the circuit when SW1 is in the calibrate position.

The meter is connected in series with a precision 1500 Ω resistor (R3). They are connected between terminal 2 of potentiometer R2 and the top of the bridge circuit. R4 also sits across the same point, though it uses terminal 3 of R2 which is internally connected to terminal 2.

The meter's internal resistance is 500 Ω so, combined with the 1500 Ω series resistor, a voltage of 200 mV will cause the meter needle to move from center zero to + full scale. This is a simple Ohm's law calculation:

$$E = IR$$

$$E = 100\mu A\left(1500\Omega + 500\Omega\right)$$

$$E = 200mV$$

In order for the meter to reach full scale, enough current must be flowing through R4 to drop 200 mV across it. Again, using Ohm's law:

$$I = \frac{E}{R}$$

$$I = \frac{200mV}{10\Omega} = 20mA$$

The denominator should actually be 10 Ω in parallel with 2000 Ω (9.95 Ω) but the error (½%) is small and can be ignored.

Thus, when R2 is adjusted for full scale, (the meter needle at 15 on the air fuel ratio scale) the calibration is correct.

Comments:

Here are some items the user should be aware of:

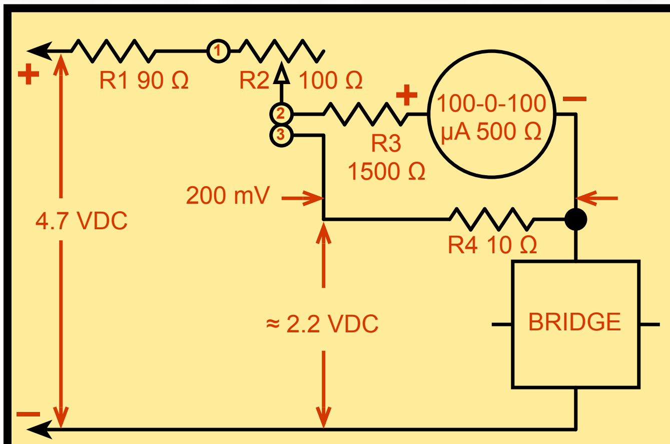


FIGURE 9: Circuit when the NORMAL - CALIBRATE switch (SW1) is in the CALIBRATE position. Voltages shown are with meter reading +100 µA (Air Fuel Ratio of 15) and the current into the bridge is 20 mA (The calibrated condition).

1. Carbon monoxide is deadly, make sure there is adequate ventilation .
2. Do not use with diesel vehicles or cars with 2-cycle engines, or cars that burn oil excessively. This can damage the sensor.
3. Cars with ECS[9] should run and idle in the right side (LEAN), Older cars may read in the left side when idling, but move to the right side when the engine speeds up.
4. Readings above the stoichiometric value of most efficient combustion (14.7 AFR) are not reliable.
5. The CI-1080 is not intended for use with Chrysler "Lean Burn" engines.
6. Technical Exchange Bulletin CI-1080-1 **Warning**: *When the EGR valve is removed, be sure to stay clear of the engine compartment; rapid deceleration can cause engine backfire.*

The CI-1080 proved to be a useful instrument. It can tell you when you need to tune up your vehicle and add confidence when you are due to visit the smog test facility.

In the next installment of HotM, I hope to get back to some amateur equipment.

Recently an SBA-300-3 6-meter converter was acquired to go along with the SBA-300-4 2-meter converter on my SB-301 receiver. The receiver is going through restoration. It has worked well for over 55 years. Perhaps that will be a future article?

I also have an SB-614 solid-state monitor scope that I need to get working. It would make a good article.

73, from AF6C

Notes:

1. Heathkit of the Month #120 CI-1020 Automotive Timing Light: https://www.w6ze.org/Heathkit/Heathkit_120_CI1020.pdf
2. Heathkit of the Month #73 ID-29 Automotive Tune-Up Meter: https://www.w6ze.org/Heathkit/Heathkit_073_ID29.pdf
3. The order of Heathkit catalogs over a full year usually goes: Winter, Spring, Summer, Fall, and Christmas.
4. #53 lamp - 14.4V 0.12A miniature bayonet (BA9s).
5. Heath recommends you use a soft cloth on your workbench to prevent scratching the meter face.
6. The 3-conductor cord attaches to the circuit board with the ribbed lead to hole C, the center lead to hold B and the other lead to hole A.
7. The 2-conductor cord attaches to the circuit board with the ribbed lead to hole E and the other lead to hole D.
8. 1N4732A Zener Diode, 4.7 volts, 1 watt (0.21 A max).
9. ECS - Emission Control System.

Notes for HotM #123 (CI-10801) 5/2024