Heathkit of the Month #124:
by Bob Eckweiler, AF6C

HEATH EDUCATIONAL PRODUCTS
(MALMSTADT-ENKE INSTRUMENTATION LAB)
(BERKELEY PHYSICS LAB)

Heathkit EUW-18
Lab Meter - With Shunts

Introduction:

In the early '60s Heathkit began designing and selling educational kits. Products like the Basic Electricity Course (EK-1), the two-part Basic Radio Course (EK-2A and EK-2B), the Basic Transistor Course (EK-3); the "How to Understand and Use…" educational products, such as "How to Understand and Use Your VTVM" (EF–1), "…Your Oscilloscope" (EF-2), "…Your Signal Generator (EF-3); and the "Electronic Workshop" kits: "6" (SK-30), "11" (SK-40) and "19" (SK-50) - the number refers to how many Heath designed experiments you can perform with each kit. While the SK-30 and SK-40 were dropped quickly, the SK-50 remained; evidently buyers opted for the more expanded kit.

Heathkit also expanded their educational products to support high schools and universities with the **Heath Berkeley Physics Laboratory** (**Figure 2**) and the **Malmstadt-Enke Instrumentation Lab** (**Figure 3**). These were

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 6.

Figure 1: Heath EUW-18 Lab Meter, 0–1 mA, 50Ω meter movement (shown less shunts).

used throughout the U.S. in higher education institutions and research labs.

The Heath Berkeley Physics Lab:

The Heath Berkeley Lab consisted of three standard Heathkits, each available as a kit or factory wired: (the IP/[IPW]-32 Regulated HV Power Supply, the IM/[IMW]-11 VTVM and the IG-82[1] Sine - Square Wave Generator); two slightly modified Heathkits, the IO/[IOW]-12S[2] 5" Oscilloscope and the IG/[IGW]-102S[3] RF Signal Generator; an EUW-17[4] factory wired 0–35 VDC Transistorized Power Supply; and three items specifically for conducting experiments: the assembled EPW-14 Test Chassis and Small Parts for Group 'A' experiments[5], with binder and Lab Manual, EPA-10-1 Battery Set[6], and the assembled EPW-24 Cathode-Ray Tube & Deflection Coil Set with lab manual. In 1966 the Berkeley Physics Complete 2-student Lab sold for $336.72 in kit form (EP-100A) or $545.26 factory assembled (EPW-100A). Both are 110 lbs. shipping. Additional instruments and experiments were added in the months and years that followed.

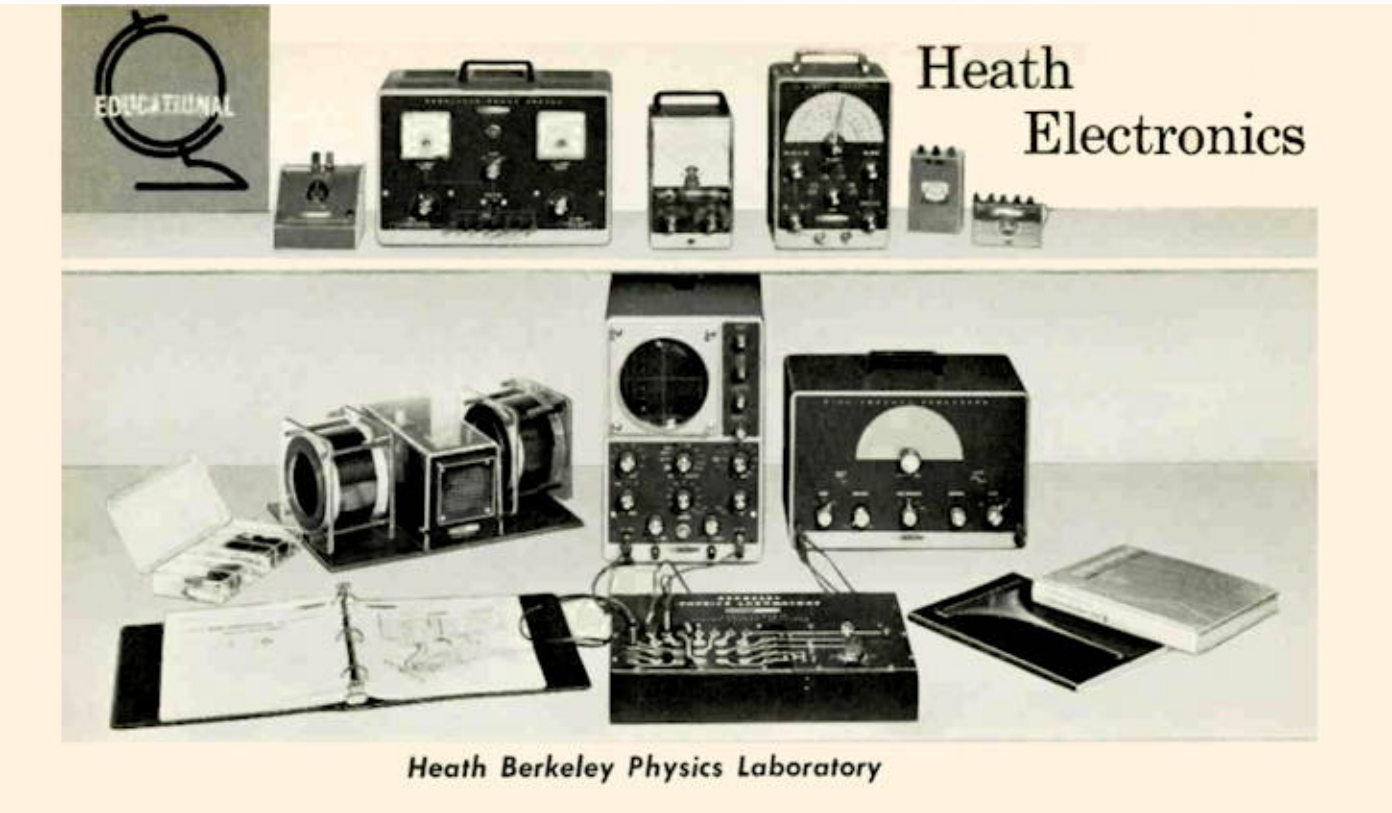


Figure 2: The Heath Berkeley Physics Lab (From Catalog 810/60A - 1966).
(Left to Right) Top Row: EUW-17 Transistorized Power Supply; IP-32 HV Power Supply; IM-11 VTVM; IG-102S RF Signal Generator; EP-10-1 Battery Set (2 pcs.). Row 2: Parts Package 'A'; EPW-24 Cathode-Ray Tube & Deflection Coil Set; IO-12S Laboratory 5" Oscilloscope; IG-82 Sine-Square Wave Generator; Row 3: Binder with Lab Manual; EPW-14 Test Chassis; Textbook and Workbook.

The Malmstadt-Enke Instrumentation Lab:
As of the 1966 catalog [810/60A] the M – E Lab consisted of thirteen fully assembled instruments, two experimental chassis with parts (A group), manual, textbook and deluxe tool kit. The items could be purchased sepa-

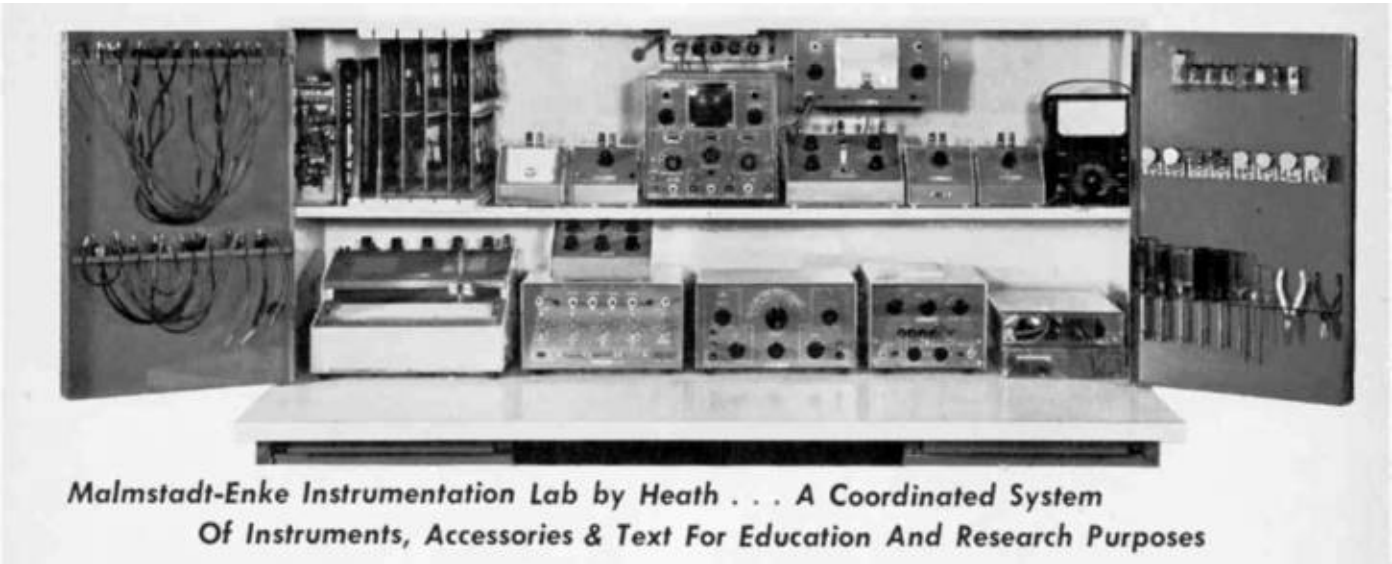


Figure 3: Malmstadt - Enke Instrumentation Laboratory, See Table I for contents.

Malkstadt-Enke Instrumentation Lab

Part #	Description	Price
EUA-11	Manual	$ 2.50
EUP-11	Textbook, *Electronics For Scientists*	$ 11.50
EU-13A	Universal Experimental Chassis & Parts	$ 177.00
EU-14A	Special Experimental Chassis & Parts	$ 64.00
EUW-15	Universal Power Supply [a]	$ 75.00
EUW-16	Voltage Reference Source [a]	$ 65.00
EUW-17	Transistorized Power Supply [a]	$ 20.00
EUW-18	Lab Meter With Shunts [a]	$ 22.00
EUW-19A	Operational Amplifier System [a]	$ 135.00
EUW-20A	Servo Chart Recorder [a]	$ 199.00
EUW-24	Vacuum Tube Voltmeter [a]	$ 62.00
EUW-25	DC Oscilloscope [a]	$ 163.00
EUP-26	Weston 980 Volt-Ohmmeter [a]	$ 55.00
EUW-27	Sine & Square wave Generator [a]	$ 94.00
EUW-28	Resistance Substitution Box [a]	$ 16.00
EUW-29	Capacitance Substitution Box [a]	$ 14.00
EUW-30	Decade Resistance Box [a]	$ 34.00
GH-25	Deluxe Tool Set [7]	$ 16.95
Total:		$1,225.95
EU-100A	Special Group Price (All above)	$1,100.00
EUP-22A	All Steel Desk top Cabinet	$ 130.00

a) factory Assembled Item.

TABLE I

rately or as a set of eighteen items at about an 11½% discount **(TABLE I)**. Some instruments were updated, added and replaced during the Lab's lifetime extending to 1974.

All the Heath factory built instruments in the M – E Lab originally came in a special style: a green front panel with white lettering and a cream colored cabinet. In later years there were some styling changes.

That is an overview of the early Heathkit movement into serious educational instrumentation for higher education institutions and research labs.

After that long introduction, let's look at one of the simpler M – E instruments; the EUW-18 Laboratory Meter with shunts. **Figure 1**.

The Heath EUW-18 Laboratory Meter:

Most volt-ohmmeters (VOMs) also measure current, but sometimes it is valuable to have a dedicated meter that can be left in the circuit while your VOM is being used for other measurements. The EUW-18 is just that. It is a simple analog milliammeter mounted in a small sloping housing. The meter is precision with a range of 0–1 mA and an accurate internal meter resistance of 50 Ω. The meter leads are terminated at two 5-way binding posts on the top of the housing; one binding post is red (positive) and the other is black (negative). The two binding posts are 0.75 inches apart on centers, an industry standard. The meter has two linear scales 0 – 15 in increments of one, and 0 – 50 in increments of two. (**Figure 4**).

The Heath EUW-18 Accessory Shunts:

The meter came with four shunts that plugged into the two banana posts on the top

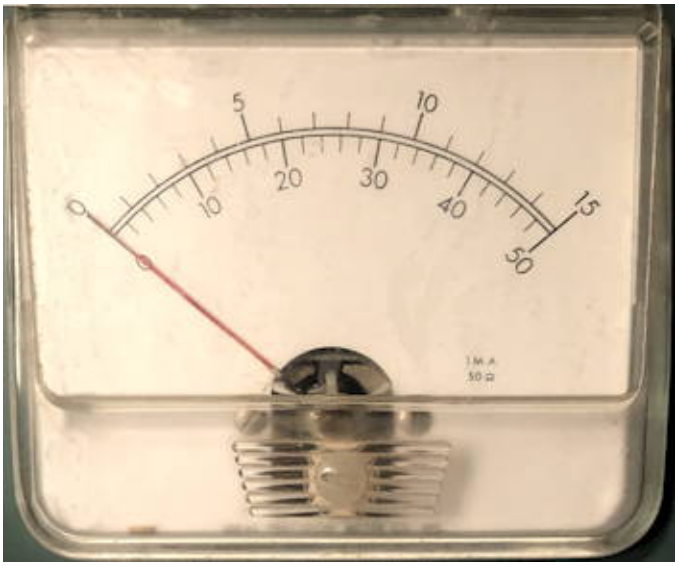


Figure 4: EUW-18 Laboratory Meter showing the two linear meter scales. Note: in small print are the meter specs: 1 mA [full scale] and 50 Ω [coil resistance]. The meter accuracy spec is 2% of FS.

of the meter cabinet. Though the meter came factory wired (just two wires and four solder joints!), the shunts came as set of parts. The four shunts have full-scale ranges of 1.5 mA, 5 mA, 15 mA and 50 mA.

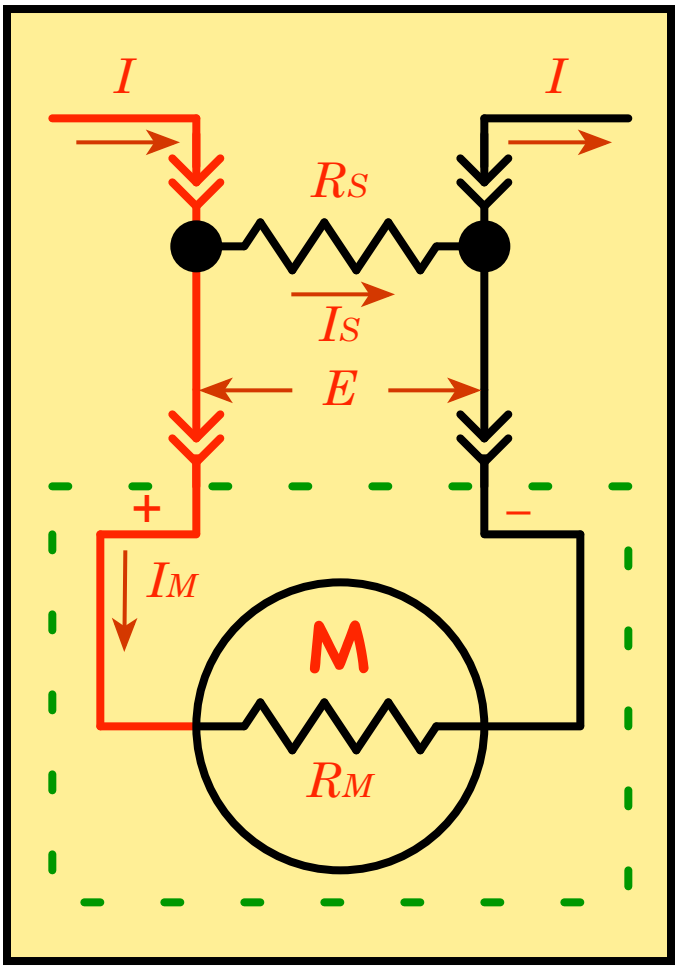


Figure 5: Schematic of the EUW-18 Lab Meter showing shunt resistor and current flow.
R_M = 50 Ω, I_M = 1 mA

The shunt parts were four dual-banana-plugs, two precision resistors (100 Ω 1% and 1.02 Ω 1%), two-feet of resistance wire at 9.99 Ω/ft and a length of insulated sleeving. These were used to construct the four shunts.

Calculating the shunt resistor values:

Figure 5 is a schematic of the Lab Meter with a shunt plugged in. The meter will read full scale when a current of I_M is flowing through the resistance R_M of the meter coil. This results in a voltage E appearing across the meter terminals.

$$E = I_M R_M \qquad \text{(Eq. 1)}$$

$$E = 1_{mA} * 50_{\Omega} = 50_{mV}$$

I_S, the current through the shunt when the meter is reading full scale, has to be:

$$I_S = I - I_M \qquad \text{(Eq. 2)}$$

where I is the desired full-scale current with the shunt resistor R_S across the meter terminals.

The voltage E across the shunt resistor is:

$$E = I_S R_S = (I - I_M) R_S \qquad \text{(Eq. 3)}$$

Since the meter and shunt are in parallel the voltage E across each are the same. Combining equations (Eq. 1) and (Eq. 3):

$$I_M R_M = (I - I_M) R_S$$

Simplifying, and solving for R_S:

$$R_S = \frac{I_M R_M}{(I - I_M)} \qquad \text{(Eq. 4)}$$

Table II shows the calculated shunt resistances for the four current shunts. Heath supplied 1% resistors for the 1.5 mA and 50 mA shunts. The other two shunts are made from the supplied two-foot length of resistance wire. The proper wire length is calcu-

Full Scale Current (mA)	Shunt Resistance (ohms)
1.5 mA	100.00 ohms
5.0 mA	12.50 ohms
15.0 mA	3.57 ohms
50.0 mA	1.02 ohms

Table II

Figure 6: Black Dual Banana Plug

lated, and a length about 1½" longer is cut off. The wire is then attached to one terminal of the dual banana plug, sleeved, wrapped around the dual banana plug and connected to the other banana plug terminal. **Figure 6** shows a typical dual banana plug. The wire is then shortened until the desired resistance is obtained. Calculated lengths for the two resistance wires are 15.02" for 12.5Ω and 4.29" for 3.57Ω. Since 3.57 is a standard 1% resistor value, one has to wonder why a resistor wasn't also used? Also, 12.4Ω is a standard value and will only give an error of about 0.6%, smaller than the resistor and meter tolerances. **Figure 7** shows the banana plug with shunt resistor plugged into the EUW-18.

Equation Eq. 4 (on page 8) can be solved for I to calculate the full-scale current value for a given shunt resistance R_S:

$$I = \frac{I_M(R_M + R_S)}{R_S} \qquad \text{(Eq. 5)}$$

One needs to be concerned about power dissipation in shunt resistors at higher currents (the power increases as the square of the current), so it is wise to check wattage. In this case it is trivial, with the 1.5 mA, 5 mA

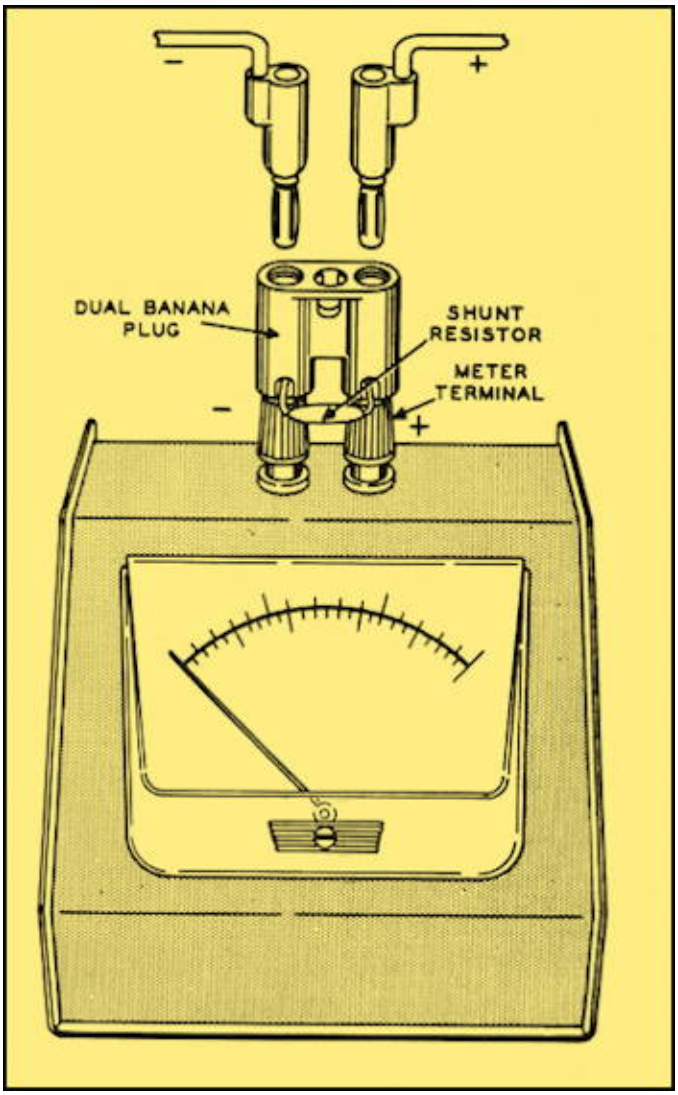


Figure 7: Meter with shunt attached.

and 15 mA shunts dissipating less than a milliwatt each., and the 50 mA shunt dissipating just over 2.5 mW.

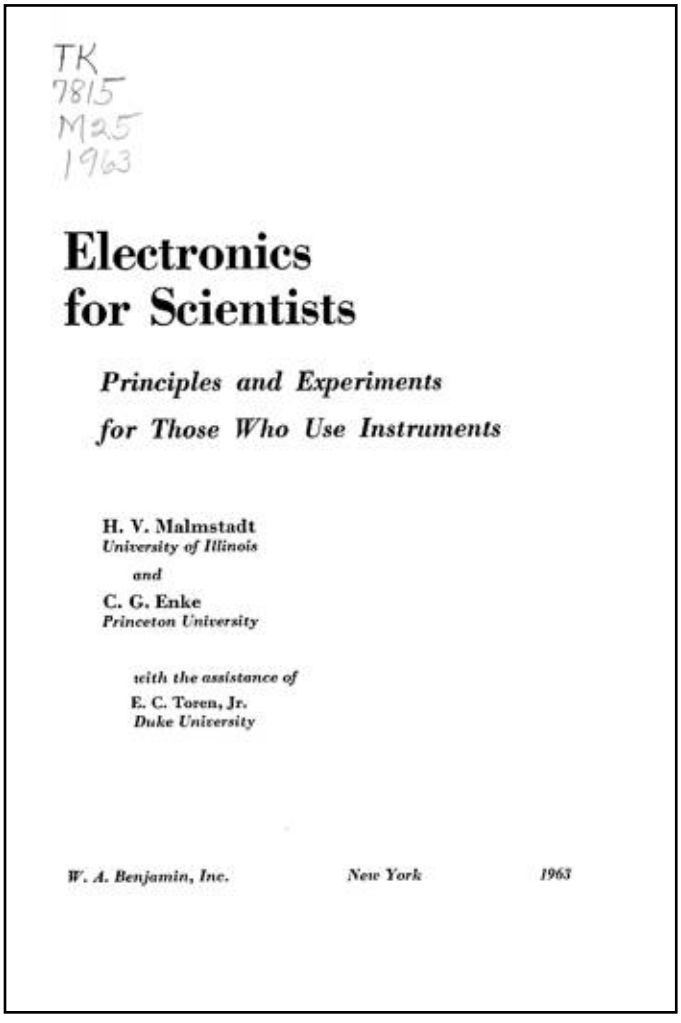
Author Comments:

I remember being assigned the building of a Heathkit IP-32 in school as part of my physics class homework. By that time I'd had a lot of kit building experience and it was a very pleasant assignment, though it had to be done in the lab, on my own time.

The Heath EUW-18 Laboratory Meter was the first M – E Heath item added to my collection. It came without the four shunts and

was, for years, just a 1 mA meter in a box. I did put together a 150 mA shunt. The 150 mA shunt consisted of three precision 1Ω resistors in parallel giving 0.3333Ω instead of the calculated 0.3356Ω. The result is actually a 151 mA shunt, which is well inside the tolerance band.

Recently, Chuck Penson – WA7ZZE sent me a copy of ***Electronics For Scientists*** by Howard V. Malmstadt[8] and Christie G. Enke[9]. This textbook came as part of the M – E Lab. In the book was a discussion of the Ayrton shunt, which I had used occasionally, but never knew its name. The Ayrton shunt turned out to be ideal for the EUW-18. See the *Bob's Tech Talk* article #55.


TK
7815
M25
1963

Electronics
for Scientists

Principles and Experiments
for Those Who Use Instruments

H. V. Malmstadt
University of Illinois
and
C. G. Enke
Princeton University

with the assistance of
E. C. Toren, Jr.
Duke University

W. A. Benjamin, Inc. *New York* *1963*

Figure 8: Title page of H. Malmstadt & C. Enke textbook.

I currently have one other M – E instrument in my collection, the EUW-27 Sine-Square Wave Generator. It is working and I recently succeeded in repairing and freeing up the vernier tuning control. The previous owner appears to have broken it while trying to unfreeze it, and ended up epoxying the concentric shafts together.

73, from AF6C

Notes:

1. The Heathkit IG-82 was not available factory wired. Instead, you were sent the EUW-27 Sine - Square Wave Generator, which is similar to the IG-82 electronically but packaged differently. It is actually part of the Malmstadt - Enke Lab Instruments.
2. The IO-12S is the same as the IO-12 scope but includes *"special jacks that permit connection to the HV and sweep circuits of the scope"*.
3. The IG102S is the same as the IO-102 *"except that accuracy is 3% and includes RF jacks"*. In Canada it was sold as the IGW-19.
4. The EUW-17 was also part of the Malmstadt / Enke Lab.
5. The Berkeley Lab had parts groups A, B, C, and D. At the time of the catalog only the A parts group was available.
6. The Battery Set consists of a 0–22½–45 V. battery and a 0–1½–3–4½–6–7½ V battery.
7. GH-25 Tool Kit contents: Soldering iron, solder, solder aid, solder joint brush, needle-nose pliers, wire cutter - stripper, three-screwdriver set, a five-nut driver set and a Heath nut starter tool.
8. Howard Vincent Malmstadt Ph.D. Chemist (b. 1922, d. 2003). Widely considered the father of modern electronic and computerized instrumentation for chemistry.
9. Christie G. Enke Ph.D. Chemistry (b. 1933).Known for development of advanced mass spectrometry and chemical instrumentation.

Notes for HotM #124 (EUW-18) 6/2024

Remember, if you are getting rid of any old Heathkit Manuals or Catalogs, please pass them along to me for my research.

Thanks - AF6C