Heathkit of the Month #129:
by Bob Eckweiler, AF6C

HEATH EDUCATIONAL PRODUCTS

Heathkit ET-3100/A/B
Electronic Design Experimenter/Trainer
(and Associated Heath Offered Courses)

Introduction:
If you read HotM #124[1], you know that in the mid-1960s Heath was offering scientific-level lab equipment for colleges, universities, and industry, supporting the Berkeley Physics Lab and the Malmstadt-Enke Instrumentation Lab as part of their expansion into the educational field. Earlier that decade they also released some basic courses: Three "*How to use and Understand your...*" courses, for the VTVM, Oscilloscope and Signal Generator, as well as various other courses focused on the Heathkit consumer, more than the university student.

In their 1975 Christmas catalog[2], Heathkit dedicated four pages to introduce the ET-3100 Electronic Design Experimenter/Trainer (**Figure 1**). In the same ad Heath announced three courses utilizing the ET-3100 Trainer: the EE-3101 DC Electronics course, the EE-3102 AC Electronics course and the EE-3103 Semiconductor Devices course. Stand-alone, the ET-3100 trainer originally sold for $59.95, and each course was an additional $39.95. However, if you bought one of the courses with the trainer, you saved $9.95 ($89.95). The trainer, along with all three courses, was offered for $154.95, a savings of $24.95. Later, Heath added three more

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 17

Figure 1: Original ET-3100 Electronic Design Experimenter (Trainer) showing the two power supply controls, the 15/30 VAC line frequency terminals, the generator controls, the two undedicated potentiometer controls and the breadboard area.

courses that utilized the ET-3100 trainer. More details on these courses, as well as other ET-3100 series related courses, appear later.

In the same four-page ad the ET-3200 Digital Design Experimenter/Trainer was also introduced, initially along with one course. Perhaps this will be a topic for a future article?

ET-3100 Series Breadboard Trainers:
Through its life, three versions of the ET-3100 were produced. The original unit was introduced in the Christmas 1975 catalog (#806). It originally sold for $59.95. In the Fall 1981 catalog (#854) it was quietly replaced by the slightly modified ET-3100A. It was introduced at $79.95, the price the ET-3100 was currently selling for. Just over a year later, in the Christmas 1982 catalog (#859), a more heavily modified ET-3100B was released for $84.95. The 'B' model remained for sale until it was replaced in the fall 1987 catalog with the expandable ET-3600. At that time the ET-3100B was selling for $109.95 and the ET-3600 was introduced at

$119.95 The ET-3600 will not be covered in this article. Schematics for the ET-3100 versions are available online[3].

Originally, the ET-3100 was available only as a kit. In the spring of 1977 Heath offered a factory wired version (the ETW-3100) for an additional $30. Heath continued to offer factory wired versions along with the kit versions. When the ET(W)-3100 series was discontinued at the end of 1985 the factory wired unit cost an additional $70.00, and increased to $80 with the introduction of the ETW-3600.

ET-3100:
The ET-3100 consists of a breadboarding area; two adjustable DC power supplies covering 1.2 to 15 VDC – one positive and one negative; a 15V/30V AC **LINE FREQ**uency source; a signal generator covering 200 Hz to 20,000 Hz in two one-decade ranges and two undedicated potentiometers (1 KΩ and 100 KΩ) that may be used in breadboarded circuits. The ET-3100 has a two-wire power cord, a neon-bulb pilot lamp and a power transformer (54-892) with a dual primary and a single 30 VCT 200 mA secondary. Its fuse mounts internally in clips in a box molded into the cabinet with a screw-on access cover. The trainer can be wired for 120 or 240 VAC power.

Figure 2: The ET-3100 Ad from the Winter 1976 catalog. Note the ***'1.2 to 16 volts, current rating 120 mA'*** specifications. See text for details.

ET-3100A:
The ET-3100A is a slightly modified version of the ET-3100. The most significant change is a modified primary circuit. The two-wire power cord has been replaced with a three wire cord. A fuse holder has been added, accessible on the left side of the cabinet, making the fuse replaceable without opening the cabinet. Insulation has been added around the power switch and its terminals. The neon pilot lamp has been replaced with a low-voltage LED. All these moves are for electrical safety. It is difficult to be exposed to line voltage with the cabinet open as long as the cover remains on the molded box that holds the primary wiring. Jeff Tranter, in a video on YouTube[4] discussing the ET-3100A, believes this was to meet Canadian CSA standards. It probably helped meet any new US and European standards too. It is interesting to note in Heath's Master Part list the ET-3100A circuit board (#85-2571) is described as "UL/CSA Screened".

The new LED pilot lamp is driven off the zener regulated +15 volt DC supply. **R101** was changed from 27 KΩ, when it was used to limit the current for the NE-2H neon bulb, to 1 KΩ to current limit the 15 volts to the LED. **R104**, the limiting resistor for the zener diode, was reduced from 220 Ω ½ watt to 150 Ω 1 watt to compensate for the current drawn by the LED. Its companion resistor on the negative supply remained 220 Ω but was also increased to

1 watt. The specifications from the manuals for the ET-3100 and ET-3100A are identical and are listed in **Table I**.

There seems to have been a battle between the people who wrote the manuals and the people who wrote the catalog ads as to the specs of the two DC voltage supplies. The manuals state the voltages to be from 1.2 to 15 volts at 100 mA, and the catalog ads state it to be between 1.2 and 16 volts at 120 mA. (**See Figures 2 and 3**). The conflict ended when Heath came out with a 'B' model that included significant changes.

ET-3100 and ET-3100A Specifications

POWER SUPPLIES:	
Positive Supply Output:	1.2 to 15 DC. continuously variable.
Load Regulation:	Better than 1% no load to full load.
Current Output:	100 mA with short circuit protection.
Negative Supply Output:	1.2 to 15 DC. continuously variable.
Load Regulation:	Better than 1% no load to full load.
Current Output:	100 mA with short circuit protection.
SIGNAL GENERATOR:	
Range Selector Sw.:	LO, 200 Hz to 2,000 Hz HI, 2,000 Hz to 20,000 Hz continuously variable.
Sine Wave Output:	1 volt rms from 600 ohms at less than 4% distortion.
Square wave Output:	15 volts peak-to-peak (+15 volts maximum, 0.1 volt minimum) with rise time less than 1 µ second and nominal duty cycle of 30%.
60 Hz SINE WAVE OUTPUT:	
Volts:	15 and 30 volts rms.
Current	200 mA maximum (total current from all supplies must not exceed 200 mA.
GENERAL:	
Power requirements:	105-130 volts or 210-260 volts RMS 50-60 Hz, 7 watts maximum.
Dimensions:	12-⅛ wide x 11-¾ deep x 3-½ high.
Net Weight:	4 lbs.
Shipping Weight:	6 lbs.

TABLE I

ET-3100B:

The ET-3100B has heavier power supplies than its siblings. To accomplish this it has a new power transformer (#54-1005) with dual secondary windings. One winding has the same specifications as the single winding of the earlier transformer (30 VCT @ 200 mA). The new secondary is spec'd at 20 VCT at 600 mA[5]. This is incorrect and should be 40 VCT (20 V - 0 - 20 V) at 300 mA. While the power supply current is now increased from 100 mA to 250 mA,

ET-3100B Specifications

POWER SUPPLIES:	
Positive Supply Output:	1.2 to 15 DC. continuously variable.
Load Regulation:	Better than 2% no load to full load.
Current Output:	250 mA with short circuit protection.
Negative Supply Output:	1.2 to 15 DC. continuously variable.
Load Regulation:	Better than 2% no load to full load.
Current Output:	250 mA with short circuit protection.
SIGNAL GENERATOR:	
Range Selector Sw.:	LO, 200 Hz to 2,000 Hz HI, 2,000 Hz to 20,000 Hz continuously variable.
Sine Wave Output:	1 volt rms from 600 ohms at less than 4% distortion.
Square wave Output:	15 volts peak-to-peak (+15 volts maximum, 0.1 volt minimum) with rise time less than 1 µ second and nominal duty cycle of 30%.
60 Hz SINE WAVE OUTPUT:	
Volts:	15 and 30 volts rms.
Current	200 mA maximum ~~(total current from all supplies must not exceed 200 mA).~~
GENERAL:	
Power requirements:	105-130 volts or 210-260 volts RMS 50-60 Hz, 25 watts maximum.
Dimensions:	12-⅛ wide x 11-¾ deep x 3-½ high.
Net Weight:	4.2 lbs.
Shipping Weight:	6 lbs.

Differences from TABLE I are shown in RED

TABLE II

Experimenter/Trainer augments electronics courses

$79.95

- **Get hands-on experience building circuits, doing course experiments**
- **Use the ET-3100A later for breadboarding and experimenting**

Seven of our popular electronics courses use this versatile Trainer. **The ET-3100A** Experimenter/Trainer is designed for use with the DC, AC, Semiconductor, Electronic circuits, Electronic Communications, Electronics for Hobbyists and Test Instruments Self-Instruction Courses. You'll get maximum benefit out of each of these Courses by doing the hands-on experiments on this Trainer.

The Experimenter/Trainer features solderless breadboarding sockets for ease of component substitution, a 2-range variable sine and square wave (200 – 20,000 Hz) signal source, dual-variable power supplies for positive and negative voltages (1.2 to 16 volts, 120 mA), 1 k and 100 k linear potentiometers. A center tapped transformer provides 30 volts rms, 60 Hz for line experiments.

The Heathkit/Zenith ET-3100A Experimenter/Trainer can be wired for either 120 or 240 VAC, 50/60 Hz operation. The instrument measures a compact 3½"H x 12⅛"W x 11¾"D (8.9 x 30.8 x 29.8 cm).

The ET-3100A has been designed to give you exactly the kind of invaluable, practical experience you need. It works side-by-side with text materials to drive home important points made in the Heathkit/Zenith Educational Courses which are designed for use with this trainer.

And your Heathkit/Zenith Experimenter/Trainer will continue to give you value, even after you've completed your basic electronics courses. It's ideal for putting your newly acquired knowledge to use in breadboarding your own circuits and experiments with circuit design.

Save money by getting your Experimenter/Trainer with a course – or, for even bigger savings, as part of the basic electronics system.

Heathkit/Zenith ET-3100A Experimenter/Trainer.
Kit ET-3100A, Shpg. wt. 6 lbs. **79.95**
Kit ET-3100AS, ET-3100 with Spanish manual, Shpg. wt. 6 lbs. **80.00**
ETW-3100A, Factory Assembled Trainer, Shpg. wt. 6 lbs. **139.95**

Figure 3: The ET-3100A Ad from the December 1981 catalog. Note the ***'1.2 to 16 volts, current rating 120 mA'*** specifications. See text for details. Note also that a Spanish language Manual was available.

the circuit remains identical, except heavier duty pass transistors are used and they are mounted on metal heatsinks., The resistors determining the current limiting (**R105** & **R115**) have been decreased from 4.7 Ω to 1.8 Ω. Due to the higher current output, the regulation specification has changed from "better than 1%" to "better than 2%".

The 30 VCT winding is now exclusively used for the 60 Hz sine wave output, and maximum current available is 200 mA regardless of what

Figure 4: The ET-3100B, showing a brown color style silkscreened on the circuit board (85-2730-1) that makes up the front panel.

Figure 5: The ET-3100B, showing a white color style silkscreened on the circuit board (85-2730-3) that makes up the front panel.

the DC power supplies are drawing. Note that the center tap is at ground potential.

The signal generator circuit has been changed substantially, though the specifications remain the same. The ET-3100B uses two LM-301 op amps (442-39) and two NPN MPSA20 transistors (417-801), while the older models used one 741 op-amp (442-22) and four transistors; three MPSA20 and one PNP 2N4121 (417-235).

The pilot light circuit was changed again. The LED is now driven off the positive 26 VDC unregulated line instead of the 15 zener supply, and its current limiting resistor (R101) has been increased to 1800 Ω. The series resistor for the +15 zener regulated supply was changed back to 220 Ω.

The ET-3100B also underwent styling changes from the earlier units. Since the circuit board makes up a significant part of the front panel, different color schemes may be silkscreened on the board. Heath produced three versions of this circuit board (85-2730-1, –2 and -3). The -1 board is brown **(Figure 4)** and the -3 is white. **(Figure 5)**. No example of the -2 board has been found to this point.

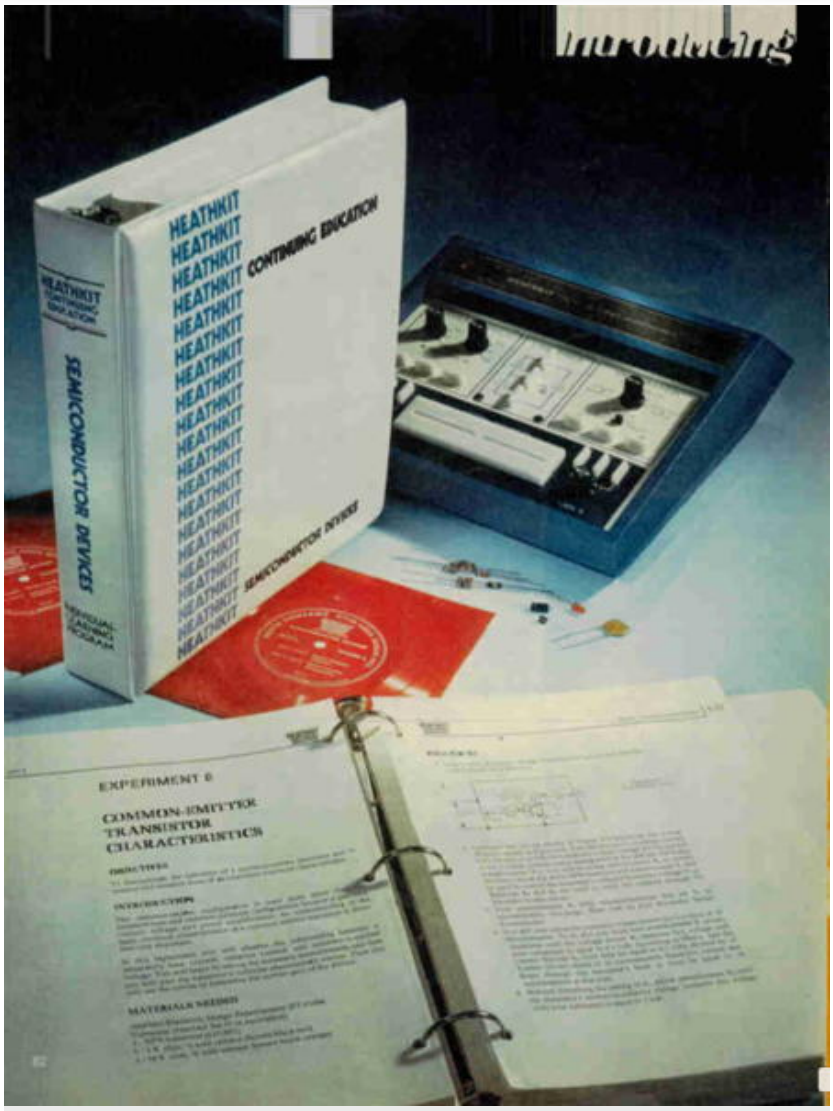


Figure 6: Page one of the four page introduction of the ET–3100 and the first three courses announced with it. DC Electronics, AC Electronics and Semiconductor Devices. (Christmas 1975 Catalog)

EE–3100 Courses Using the ET-3100 Series Experimenter/Trainer:

When the ET-3100 was first introduced in the Christmas 1975 catalog (**Figure 6**) three courses, each a single module, were listed that use the ET-3100. Each course came with a looseleaf binder, the needed components for the experiments and flexible colored vinyl audio records. Later, three more courses were added, including one that had four separate stand-alone modules (EE-3105 Electronic Test Equipment Course). Here are the six major courses that Heathkit offered and that used the ET-3100 series trainer

EE–3101 DC Electronics Course:
8 Unit-Subjects: 1. Electron Theory; 2. Voltage; 3. Resistance; 4. Ohm's Law; 5. Magnetism; 6. Electrical Measurements; 7. Network Theorems; 8. Inductance & Capacitance. Includes 56 components and parts.

EE–3102 AC Electronics Course:
6 Unit-Subjects: 1. AC Fundamentals; 2. AC Measurements; 3. AC in Capacitive Circuits; 4. AC in Inductive Circuits; 5. Transformers; 6. Tuned Circuits. Includes 16 components and parts.

EE–3103 Semiconductor Devices Course:
10 Unit-Subjects: 1. Semiconductor Fundamentals; 2. Semiconductor Diodes; 3. Zener Diodes; 4. Special Diodes; 5. Bipolar Transistor Operation; 6. Bipolar Transistor Characteristics; 7. Field Effect Transistors; 8. Thyristors; 9. Integrated Circuits; 10. Optoelectronic Devices. Includes 31 components and parts.

EE–3104 Electronic Circuits Course:
In the Christmas 1976 catalog Heath announced a fourth course to be added soon (**Figure 7**). The course was first listed in the Spring 1977 catalog (**Figure 8**). It initially sold for $49.95.

COMING SOON:

Part 4: Electronic Circuits and Applications Covers power supplies, amplifiers, oscillators, regulators, op amps, AM/FM, pulse circuits. Emphasizes integrated circuit applications.

Figure 7: In the Christmas 1976 Catalog Heath announced the fourth course for the ET-3100.

7 Unit-Subjects: 1. Basic Amplifiers; 2. Typical Amplifiers; 3. Operational Amplifiers; 4. Power Supplies; 5. Oscillators; 6. Pulse Circuits; 7. Modulation. Includes over 110 components and parts.

EE–3105 Electronic Test Equipment Course:
In the Winter 1979 catalog (1978 - 1979) a fifth course was introduced, the Electronic Test Equipment course. This course included 4 modules with a total of 6 unit subjects, but no records Each module came with its own binder. Only the first two modules were introduced in the Winter 1979 catalog; the remaining two modules were introduced in the Spring/Summer 1979 catalog. Heath advised: ***"NOTE: Each module requires the test instruments discussed in that module for effective learning."*** These courses surely contributed to the sale of a lot of Heathkit test equipment.

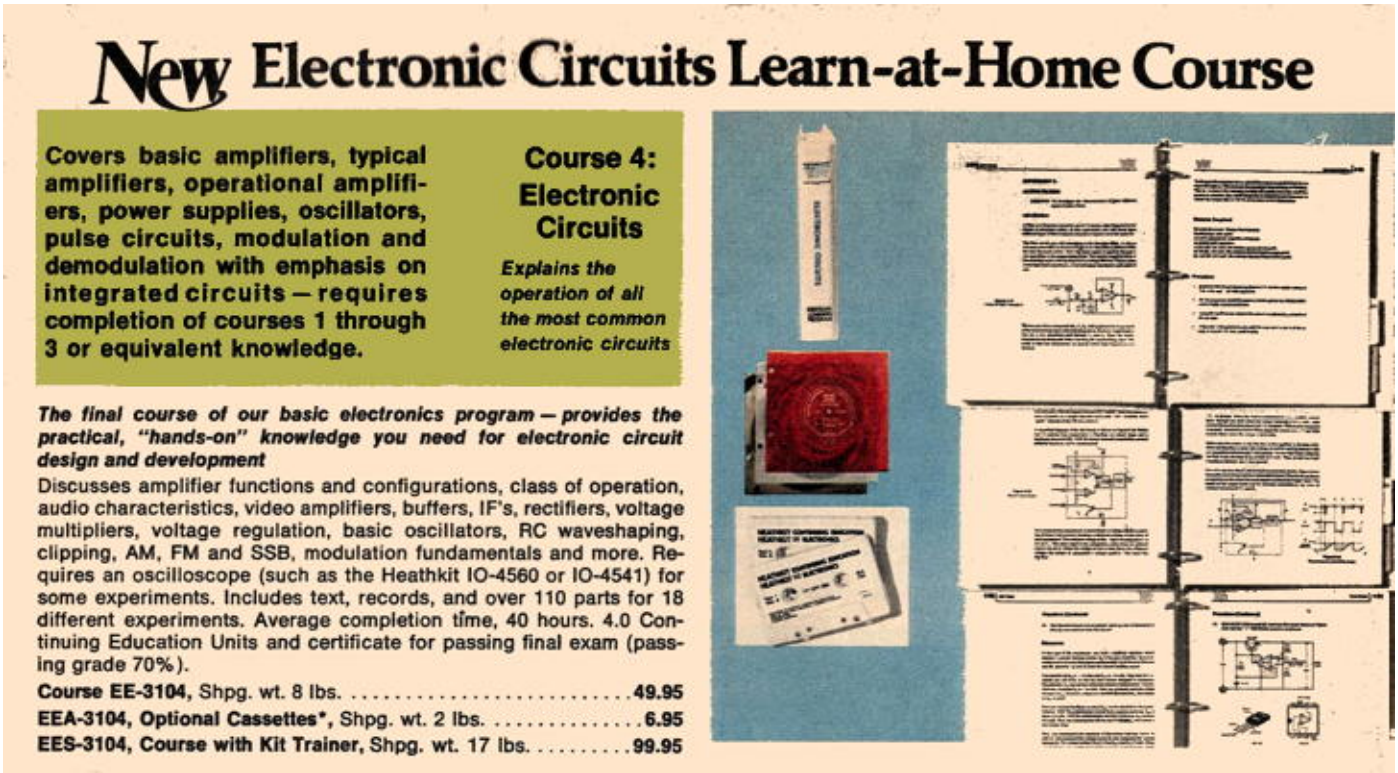


Figure 8: The fourth course (EE-3104) was introduced in the Spring 1977 catalog. Also this is the first catalog available that offered the new optional cassettes.

EE-3105-1 (Module 1): 2 Unit-Subjects: 1. Analog Meters; 2. Digital Meters; includes 27 components and parts.

EE-3105-2 (Module 2): 1 Unit Subject: 3. Oscilloscopes; includes 5 components and parts.

EE-3105-3 (Module 3): 2 Unit Subjects: 4. Frequency Measurement; 5. Frequency Generation; includes 18 components and parts.

EE-3105-4 (Module 4): 1 Unit Subject: 6. Special Measuring Instruments; includes 48 components and parts.

When the first two modules were offered, they were sold separately. Module 1 sold for $19.95, and Module 2 sold for $14.95. In the spring, when the remaining two Modules were introduced, all four could be ordered separately. Modules 3 and 4 sold for $19.95 each, or you could buy all four for $64.95, saving $9.85. By the Fall 1979 catalog, the four modules were shown only as a set at $59.95, though you likely could still buy them individually.

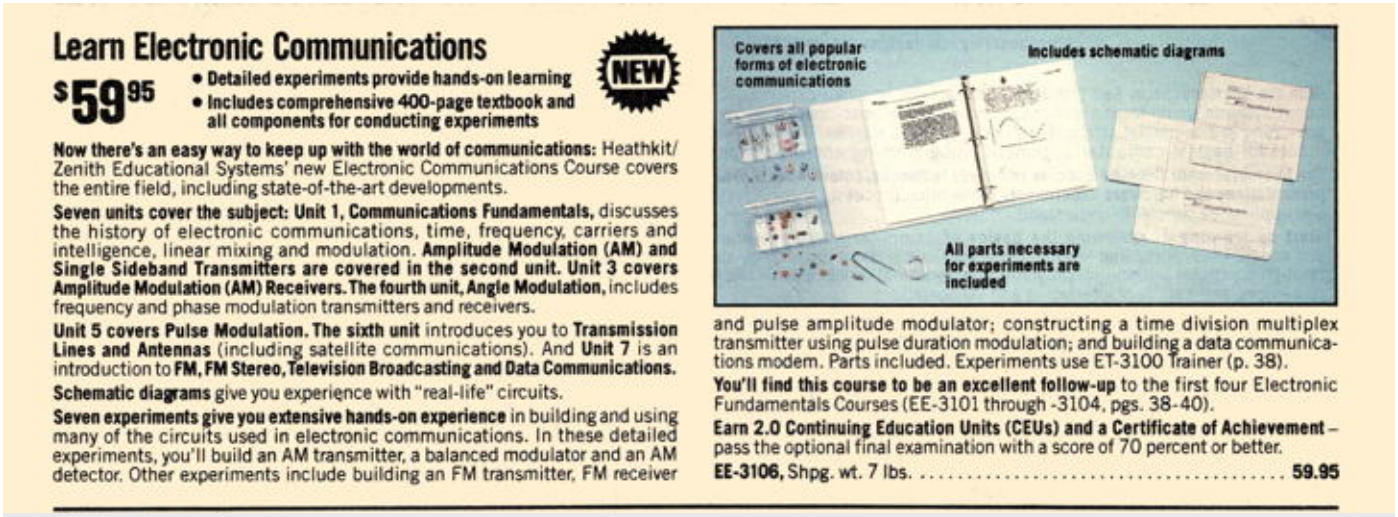
EE–3106 Electronic Communications Course:
A sixth course, covering Electronic Communications, was introduced in the 1981 Spring-Summer catalog (**Figure 9**). While the first five courses required, as a prerequisite, the preceding courses, this course required only courses 1 through 4 as a prerequisite; the 5th course was optional.

7 Unit-Subjects: 1. Communications Fundamentals; 2. Amplitude Modulation (AM) and Single Sideband Transmitters; 3. Amplitude Modulation Receivers; 4. Angle Modulation; 5. Pulse Modulation; 6. Transmission Lines and Antennas; 7. FM, FM Stereo, Television Broadcasting and Data Communications. A component and parts count is not available in the Heath advertising. This last course sold for $59.95.

These six courses make up the prime curriculum. The course manuals are shown in order in **Figure 10**.

Course Updates:
In late 1982 Heath updated the EE-3101 through EE-3105 courses, adding an 'A' suffix to their part numbers. The EE-3106 course was upgraded a year later (Christmas 1983 #863 catalog). In the summer of 1990 another upgrade ('B' suffix) was made to the EE-3101 through EE-3104. The EE-3105B was released in early 1991. The EE-3106A remained as it was. these upgrades were general refinements to the existing courses.

Additional Courses:
Heath introduced two additional courses unrelated to the prime curriculum of the ET-3100 series trainer. The first, is EE-3140 - **Electronics for the Hobbyist**. The second is EE-3100 -



Learn Electronic Communications

$59.95

NEW

- **Detailed experiments provide hands-on learning**
- **Includes comprehensive 400-page textbook and all components for conducting experiments**

Now there's an easy way to keep up with the world of communications: Heathkit/Zenith Educational Systems' new Electronic Communications Course covers the entire field, including state-of-the-art developments.

Seven units cover the subject: Unit 1, Communications Fundamentals, discusses the history of electronic communications, time, frequency, carriers and intelligence, linear mixing and modulation. **Amplitude Modulation (AM) and Single Sideband Transmitters are covered in the second unit. Unit 3 covers Amplitude Modulation (AM) Receivers. The fourth unit, Angle Modulation,** includes frequency and phase modulation transmitters and receivers.

Unit 5 covers Pulse Modulation. The sixth unit introduces you to **Transmission Lines and Antennas** (including satellite communications). And **Unit 7** is an introduction to **FM, FM Stereo, Television Broadcasting and Data Communications.**

Schematic diagrams give you experience with "real-life" circuits.

Seven experiments give you extensive hands-on experience in building and using many of the circuits used in electronic communications. In these detailed experiments, you'll build an AM transmitter, a balanced modulator and an AM detector. Other experiments include building an FM transmitter, FM receiver and pulse amplitude modulator; constructing a time division multiplex transmitter using pulse duration modulation; and building a data communications modem. Parts included. Experiments use ET-3100 Trainer (p. 38).

You'll find this course to be an excellent follow-up to the first four Electronic Fundamentals Courses (EE-3101 through -3104, pgs. 38-40).

Earn 2.0 Continuing Education Units (CEUs) and a Certificate of Achievement – pass the optional final examination with a score of 70 percent or better.

EE-3106, Shpg. wt. 7 lbs. **59.95**

Figure 9: The last of the major Courses that used the ET-3100 was introduced in the 1981 Spring-Summer catalog. Like the Test Equipment course, it doesn't appear to include audio records.

Figure 10: Gerhard - DF1DA Sent a photo of his bookshelf with his course manuals used with the ET-3100. With the magic of the computer, a few missing manuals were added to complete his shelf.

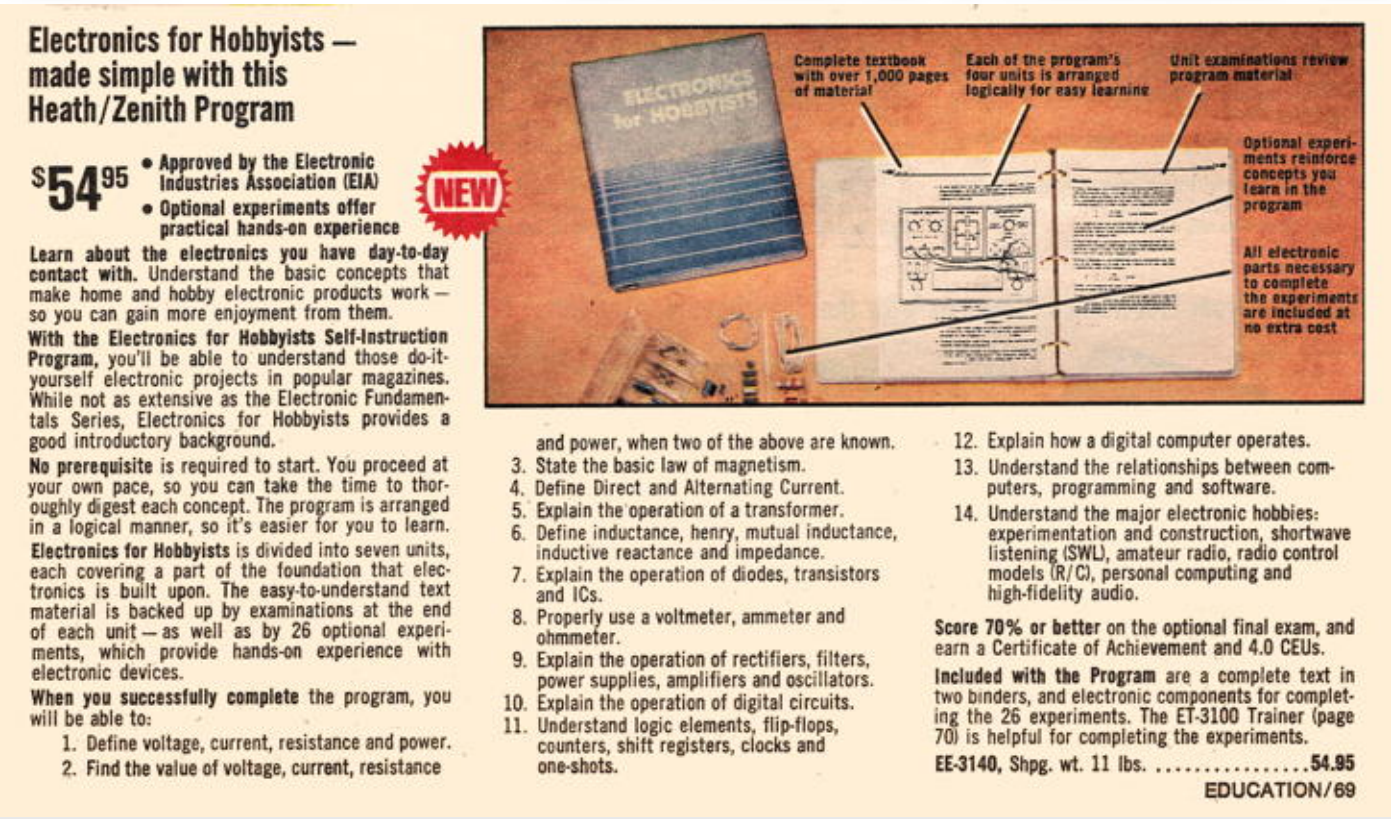
Concepts of Electricity. The following is a short discussion of each.

EE–3140 Electronics for the Hobbyist Course:
This course was introduced in the Fall 1980 (#850) catalog, selling for $59.95 (**Figure 11**). It came in two binders (over 1,000 pages) that covers seven unit subjects. It teaches a subset of the six prime curriculum courses, the areas that are most beneficial to the electronic hobbyist.

7 Unit Subjects: 1. Direct Current; 2. Alternating Current; 3. Active Devices; 4. Electronic Circuits; 5. Digital Electronics; 6. Digital Computers; 7. Survey of Electronics Hobbies. The course comes with 78 parts and components and includes 26 experiments to be performed on an ET-3100 series trainer using those parts.

This course received an 'A' upgrade in the Fall of 1987. At that time it was also renamed "**Concepts of Electronics"**. It continued to be available through Heath Educational Services after Heathkit folded.

EE–3100 Concepts of Electricity Course (Basic Electricity Course):
The Concepts of Electricity course EE-3100 was often referred to as the Basic Electricity Course in Heathkit catalogs and literature. It is a retro course designed to teach a person, unknowledgeable in the basics of electricity enough so they can move successfully to the first EE-3101 **DC Electronics** course, or perhaps to the EE-3140 **Electronics for the Hobbyist** course. This course was announced in the Winter 1981 catalog (#852) at a price of $29.95 **(Figure 12)** It came with two audio cassettes to enhance the learner's experience. This course did not use the ET-3100 series trainer until it was expanded under Heath Educational Service in 1993 as Heathkit, per se, was closing. From its introduction through the summer of 1990 the course price fluctuated between $24.95 and $29.95, and the course itself remained static.



Electronics for Hobbyists — made simple with this Heath/Zenith Program

$54.95

- Approved by the Electronic Industries Association (EIA)
- Optional experiments offer practical hands-on experience

NEW

Learn about the electronics you have day-to-day contact with. Understand the basic concepts that make home and hobby electronic products work — so you can gain more enjoyment from them.

With the Electronics for Hobbyists Self-Instruction Program, you'll be able to understand those do-it-yourself electronic projects in popular magazines. While not as extensive as the Electronic Fundamentals Series, Electronics for Hobbyists provides a good introductory background.

No prerequisite is required to start. You proceed at your own pace, so you can take the time to thoroughly digest each concept. The program is arranged in a logical manner, so it's easier for you to learn.

Electronics for Hobbyists is divided into seven units, each covering a part of the foundation that electronics is built upon. The easy-to-understand text material is backed up by examinations at the end of each unit — as well as by 26 optional experiments, which provide hands-on experience with electronic devices.

When you successfully complete the program, you will be able to:

1. Define voltage, current, resistance and power.
2. Find the value of voltage, current, resistance and power, when two of the above are known.
3. State the basic law of magnetism.
4. Define Direct and Alternating Current.
5. Explain the operation of a transformer.
6. Define inductance, henry, mutual inductance, inductive reactance and impedance.
7. Explain the operation of diodes, transistors and ICs.
8. Properly use a voltmeter, ammeter and ohmmeter.
9. Explain the operation of rectifiers, filters, power supplies, amplifiers and oscillators.
10. Explain the operation of digital circuits.
11. Understand logic elements, flip-flops, counters, shift registers, clocks and one-shots.
12. Explain how a digital computer operates.
13. Understand the relationships between computers, programming and software.
14. Understand the major electronic hobbies: experimentation and construction, shortwave listening (SWL), amateur radio, radio control models (R/C), personal computing and high-fidelity audio.

Complete textbook with over 1,000 pages of material

Each of the program's four units is arranged logically for easy learning

Unit examinations review program material

Optional experiments reinforce concepts you learn in the program

All electronic parts necessary to complete the experiments are included at no extra cost

Score 70% or better on the optional final exam, and earn a Certificate of Achievement and 4.0 CEUs.

Included with the Program are a complete text in two binders, and electronic components for completing the 26 experiments. The ET-3100 Trainer (page 70) is helpful for completing the experiments.

EE-3140, Shpg. wt. 11 lbs. 54.95

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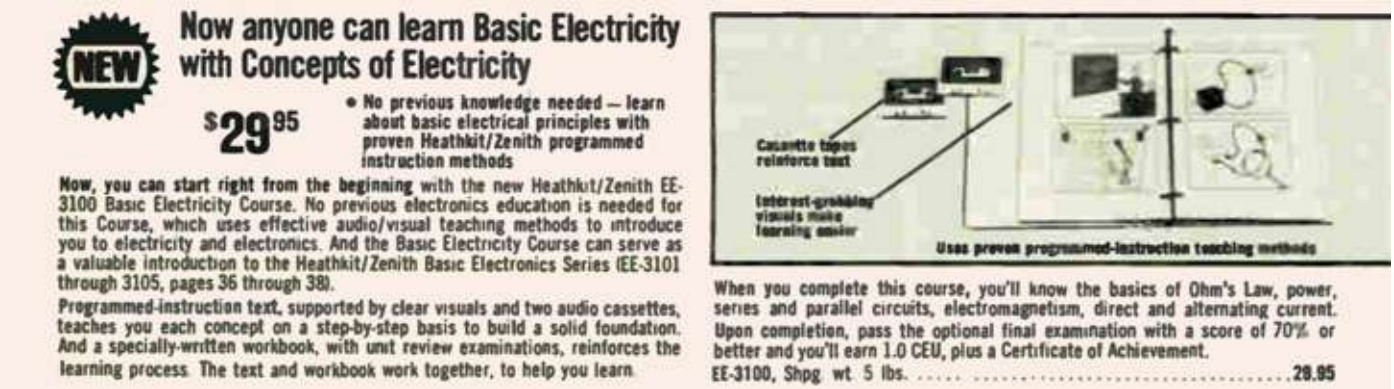
Figure 11: Ad from the Fall 1980 Catalog introducing the EE-3140 **Electronics for Hobbyists** course.

CEU Credits & Certificates of Achievements:
After completing a course you could opt to take a final exam. You would be awarded Continued Education Unit credits (CEUs) if you pass the test with a score of 70% or above, as well as a Certificate of Achievement. A total of 18½ CEUs can be earned for courses one through six: 2.0, 1.5, 3.0, 4.0, 6.0, 2.0 CEUs respectively. Additionally, satisfactorily completing the EE-3140 course would award you a Certificate of Achievement and 4.0 CEUs, and the EE-3100 would award you a Certificate of Achievement and 1.0 CEU.

Audio Video Course Support:
Heath supplied audio records with the original four courses. Later it expanded into other optional media including cassettes, cassettes with printed visual aids and finally VHS video tapes.



NEW

Now anyone can learn Basic Electricity with Concepts of Electricity

$29.95

- No previous knowledge needed — learn about basic electrical principles with proven Heathkit/Zenith programmed instruction methods

Now, you can start right from the beginning with the new Heathkit/Zenith EE-3100 Basic Electricity Course. No previous electronics education is needed for this Course, which uses effective audio/visual teaching methods to introduce you to electricity and electronics. And the Basic Electricity Course can serve as a valuable introduction to the Heathkit/Zenith Basic Electronics Series (EE-3101 through 3105, pages 36 through 38).

Programmed-instruction text, supported by clear visuals and two audio cassettes, teaches you each concept on a step-by-step basis to build a solid foundation. And a specially-written workbook, with unit review examinations, reinforces the learning process. The text and workbook work together, to help you learn.

Cassette tapes reinforce text

Interest-grabbing visuals make learning easier

Uses proven programmed-instruction teaching methods

When you complete this course, you'll know the basics of Ohm's Law, power, series and parallel circuits, electromagnetism, direct and alternating current. Upon completion, pass the optional final examination with a score of 70% or better and you'll earn 1.0 CEU, plus a Certificate of Achievement.

EE-3100, Shpg. wt. 5 lbs. 28.95

Figure 12: The Introduction of the EE-3100 **Concepts of Electricity** course from the Winter 1981 catalog. This course was often referred to as the **Basic Electricity** course.

EEA-3101, Optional Cassettes*, Shpg. wt. 2 lbs. 6.95
SAVE $9.95! EES-3101, Program with Kit Trainer.
Shpg. wt. 18 lbs. 89.95

EEA-3102, Optional Cassettes*, Shpg. wt. 2 lbs. 6.95
SAVE $9.95! EES-3102, Course with Kit Trainer,
Shpg. wt. 18 lbs. 89.95

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*Optional Cassettes duplicate material on records, but in convenient, easy-to-use cassette format.

Figure 13: Heath provided the following cassette warning.

Vinyl Records:
Courses EE-3101 through EE-3104 came with flexible vinyl 33-⅓ RPM records. These records contained audio information to enhance course learning. The other EE-3100 series courses never used records. Occasionally, in early ads, Heath would list one of their phonographs in case the user didn't already own one. The records were discontinued as part of those four courses with the introduction of the 'A' revision of each course. The vinyl records came in multiple colors, but records and record players were quickly being outdated by cassette tapes.

Cassette Tapes:
In the Spring of 1977, about 15 months after the EE-3101 DC-Electronics course was first released, Heath offered an optional set of two cassettes for each of the four courses that came with vinyl records. They contained the same material as the records, but could be played on a more modern cassette tape machine. In their advertising, Heath made it a point to be sure cassette buyers realized the material was identical to the supplied records **(Figure 13)**. Each set of two tapes originally sold for $6.95 per course.

With the exception of the **Concepts of Electricity** course, Cassette tapes were an extra-cost option. They continued to be available as EEA-3101 thru EEA-3104. No evidence exists that there were ever optional cassettes for the EE-3105, EE-3106 or EE-3140 courses. from 1977 through most of 1982 the price of the two cassette sets rose occasionally reaching $12.95.

Audio Visual Accessories:
Late in 1982 Heathkit began updating the EE-3100 series of courses, adding an 'A' suffix to their part number. At the same time they discontinued the vinyl records and replaced the optional cassettes with what they termed an optional Audio Visual Accessory for each updated course. This was an optional set of two cassettes accompanied by an illustration booklet, to 'enhance' your course experience. These A.V. Accessories were also available for the EE–3105 Test Equipment course (EEA-3105A) and eventually for the EE–3106 Electronic Communications course (EEA-3106A), neither of which earlier had optional cassettes. The optional A.V. Accessories initially sold for $19.95.

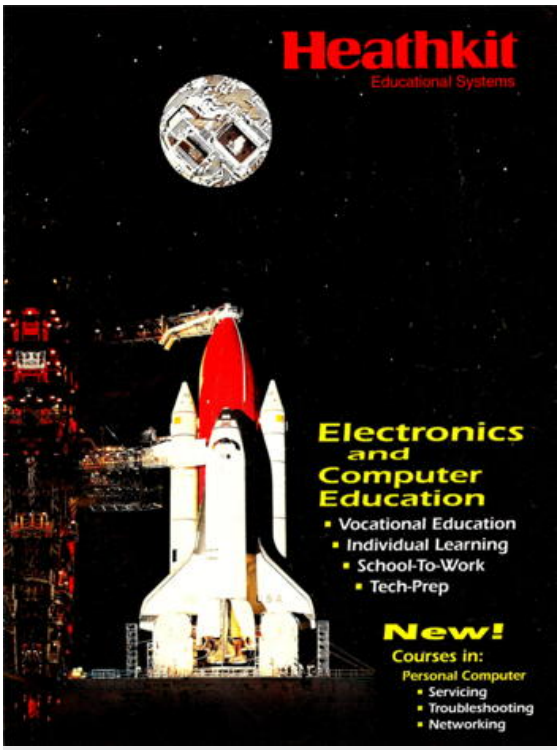


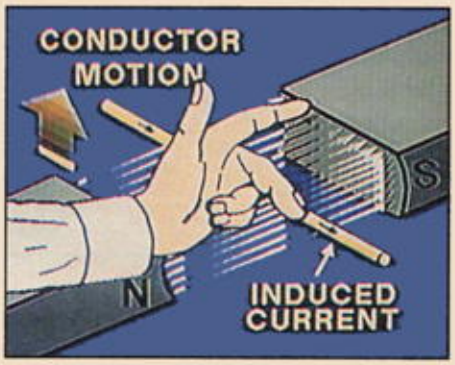
Figure 14: The 1993 Heathkit Educational Services Catalog .

VHS Video Tapes:
In the summer of 1990, Heath began offering sets of VHS tapes to support their first four courses designed for the ET-3100 trainer. (**Figure 15**). As the kit building world of Heath diminished, they continued their educational courses and when Heathkit closed, Heath Educational Services (HES) took over these courses. In the 1993 HES catalog (**Figure 14**) the only kits offered,

Home video education

EDUCATION

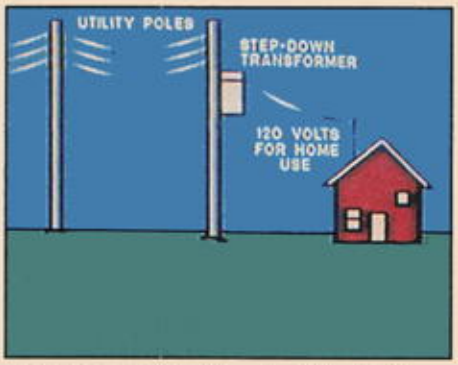
Learn electronics the easy way. These exciting, new full-color videos supplement our Basic Electronics Series courses on pages 36 and 37. We've used animation to explain key concepts and included self review questions throughout the tapes. Each VHS video lasts approximately one hour and comes with an activity-filled student workbook plus an explanation of the answer for every problem.



DC electronics

This first video in the series begins with an explanation of electron movement and carries you through the actual troubleshooting and repair of a simple electronic circuit. You're introduced to DC current and voltage, resistance, inductance, capacitance, Ohm's law, magnetism and DC electrical measurement. You'll compute current, voltage and resistive values and learn how inductors and capacitors are made and used. You'll even learn the correct use of ammeters, voltmeters and ohmmeters.

EV-3101-A (2 lbs.) $39.95



AC electronics

The AC Electronics video explains the principles of AC current and voltage, and AC electrical measurement. You're introduced to the AC applications of capacitance, inductance and transformers. Other topics shown include sinusoidal and non-sinusoidal waveform generation, waveform analysis, motors, generators and various test instrument meter movements. To fully benefit from this video presentation, you should first complete the EV-3101-A video or be familiar with the principles of DC electronics.

EV-3102-A (2 lbs.) $39.95

Figure 15: Heath introduces Home videos to support their first four basic courses in the Summer 1990 catalog (221). Shown are the EV-3101-A and the EV-3102-A videos for the DC and AC Electronic Courses. Videos EV-3103-A and EV-3104-A were also offered for the Semiconductor Devices Course and the Electronic Circuits Course.

other than some of the trainers, were two clock models, their accessories and a portable radio.

A Closer Look at the ET-3100B Circuits:

Here is a closer look at the last of the ET-3100 series trainers. While the trainers were updated twice, any of them could be used for their designed courses. With a minor exception, all controls and indicators remained the same. That exception is the changes in the pilot lamp in each version, as previously discussed. The controls and indicator, which all mount on the sloping front panel, are shown in **Table III**.

The heart of the ET-3100 trainers is the breadboarding socket that includes 480 'holes', that are arranged as 96 groups of five. Each vertical group of five is connected together. Forty-eight of the groups are in the top half of the breadboarding socket, and 48 are in the bottom half. Spacing of the 'holes' is 0.10". The spacing between the top 48 groups and bottom 48 groups is 0.3", which is standard between pin rows for many DIP integrated circuit packages. The 'holes' are designed to accept up to #20 solid wire (0.032" diameter).

The ET-3100 trainers also have 15 wire connectors each. These connectors have 4 'holes' similar to the ones in the breadboarding connector. The 4 are connected together and each is used as an output connection for the power sources and generator. They are also used for the two potentiometers available for breadboarding. these connectors are listed as Wire Connector (4-term.) in TABLE III.

Assembling the ET-3100B Trainer:

Circuit Board:

A major amount of the components mount on the main circuit board, which is also the sloping front panel of the unit. Most of the circuit components mount near the top of the board and they are covered by the upper part of the cabinet top. Assembly begins with installing small parts onto the board. Then larger parts are installed such as the two switches, five potentiometers, 15 wire connectors, and the large breadboarding socket. This is covered over 12-¼ manual pages, including 1-½ pages that are a refresher section on circuit board soldering. The circuit board is then checked and set aside.

Cabinet Assembly:

The AC wiring is done next. The 3-wire power cord is prepared, fed through a hole in the bottom of the two-part cabinet, and fastened to a relief plate using a power cord strain relief. This kit has no chassis as such. The only real chassis parts are the circuit board common and the shell of the power transformer. They are connected together and tied to the AC ground lead. All the primary wiring, with the exception of the leads to the power transformer and the power switch **SW-101** are in a small box molded inside the cabinet bottom. Inside the box **(Figure 16)** is a four-lug terminal strip (B), the fuse holder and a relief plate that holds the power cord strain relief. The AC leads to the transformer are not exposed; the switch leads, however are, so they are protected with shrink tubing to prevent accidental contact. The power transformer is installed and its primary is wired to the 4-lug terminal strip. Different terminals are used depending upon whether the unit is wired for 120 or 240 volts (See **Figure 17**).

Final Wiring:

The transformer secondary (6-leads) are connected to the circuit board. One of the twisted leads from the power switch **SW1** are connected to lug 3 of the 4-lug terminal strip; the other connects to lug 1 of the fuse holder. Green

ET-3100/A/B Sloping Front Panel Controls, Indicators, Connectors

Top Row (left side - L to R)		
Pilot Light:	Neon, NE2	(ET-3100)
	LED, Red	(ET-3100A/B)
POWER	Switch, Rocker, SPST	
Center Row (Left Box)		
POWER SUPPLY		
(Upper)		
+ **VOLTAGE**	Potentiometer 3KΩ **1 - 5 - 10 - 15**	
– VOLTAGE	Potentiometer 3KΩ **1 - 5 - 10 - 15**	
(Lower)		
POS	Wire Connector (4-term.)	
GND	Wire Connector (4-term.)	
NEG	Wire Connector (4-term.)	
Center Row (Center Box)		
LINE FREQuency		
1 (upper)	Wire Connector (4-term.)	
2 (middle)	Wire Connector (4-term.)	
3 (lower)	Wire Connector (4-term.)	
1 – 2: **15 VAC**; **2 – 3**: **15 VAC**; **1 – 3**: **30 VAC**		
Center Row (Right Box)		
GENERATOR		
(upper)		
FREQuency	Potentiometer, Dual	
	100 KΩ/100 KΩ	(ET-3100/A)
	200 KΩ/5 KΩ	(ET-3100B)
	200 Hz 1 kHz 2 kHz	
	2 kHz 10 kHz 20 kHz	
(center)		
RANGE	Switch, slide, DPDT **LOW – HIGH**	
(lower)		
SINE	Wire Connector (4-term.)	
GND	Wire Connector (4-term.)	
SQUARE	Wire Connector (4-term.)	
Bottom Row (L to R)		
1K Ω	Potentiometer 1K Ω	
1 (CCW)	Wire Connector (4-term.)	
2 (Wiper)	Wire Connector (4-term.)	
3 (CW)	Wire Connector (4-term.)	
Breadboard	2 x 48 x 5 Wire Connections	
100K Ω	Potentiometer 100K Ω	
1 (CCW)	Wire Connector (4-term.)	
2 (Wiper)	Wire Connector (4-term.)	
3 (CW)	Wire Connector (4-term.)	

TABLE III

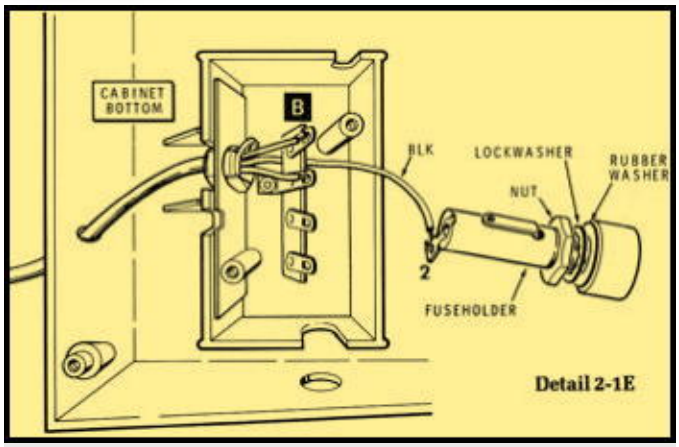


FIGURE 16: Molded box that holds the primary AC winding. Three notches are along the top edge of the box. The upper one handles the four transformer primary leads and a ground lead to the transformer case and PC board common; the left one is for the two wires going to the power switch; and the bottom one holds the fuse-holder. Note the cabinet hole for fuse access.

ground leads are run from a solder lug under a mounting screw of the transformer to lug 2 of the 4-lug terminal strip, and to the circuit board common foil. With the primary wiring complete, an insulated cover is screwed over the box opening isolating the primary wiring. The knobs are installed by carefully pressing bushings into the knob after aligning the fully CCW control with the proper knob marking. The knobs are needed to perform the test and adjustments.

Test and Adjustments:

First the Generator section is tested using a counter or an oscilloscope, if available. Next each of the two 1.2 – 15 volt power supplies are tested using a VOM or VTVM. Finally the 15 and 30 volts **LINE FREQ** outputs are checked with an AC voltmeter. Pieces of hookup wire are used to connect the wire connector blocks to the scope and meter.

Final Assembly:

The final assembly involves mounting the nameplate label to the upper section of the top chassis, mounting the circuit board, dressing and clamping some wires and joining the top and bottom cabinet halves. The Caution label,

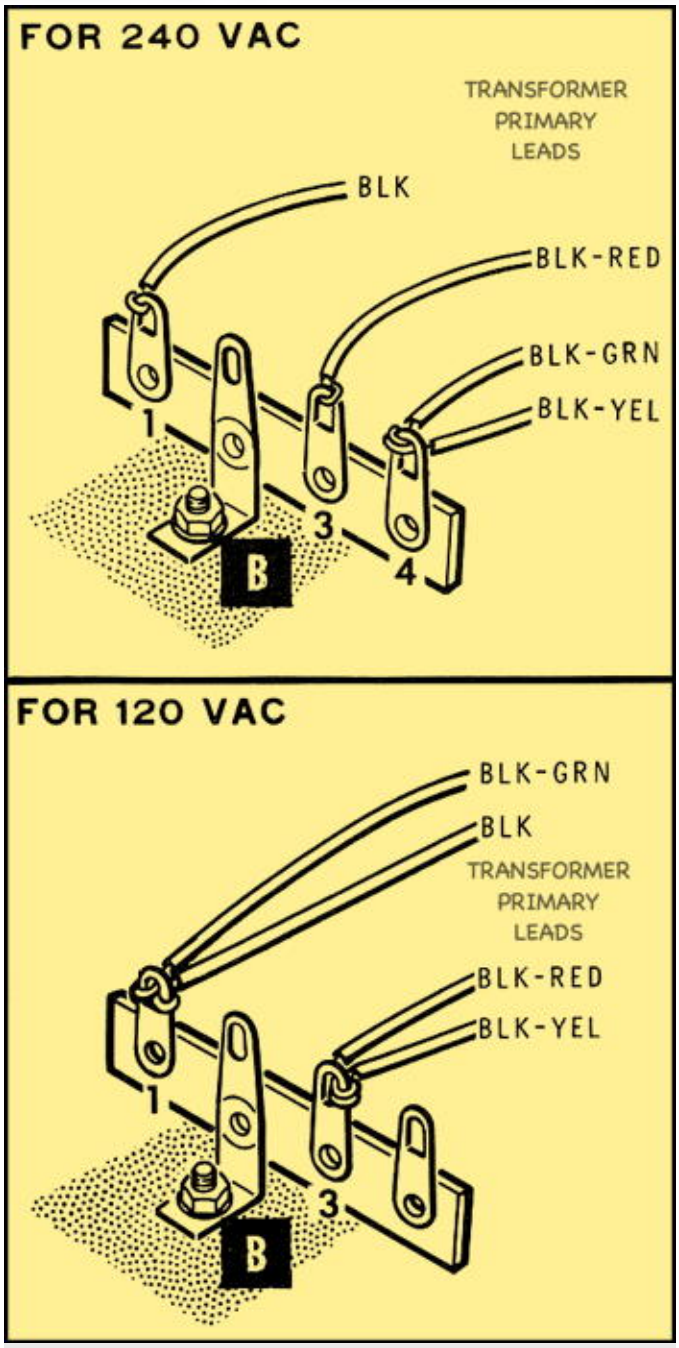


FIGURE 17: Wiring for the 4-lug terminal strip for 120 and 240 VAC power. Terminals: 1 is AC common, 2 is chassis ground (see text), 3 is AC hot after fuse and power switch, 4 is used only as a series tie-point for 240 VAC wiring.

Blue and White series label and the FCC compliance label are attached to the bottom of the cabinet, and the feet are installed. Completing the assembly.

Using the ET-3100 Trainer:
Use of the ET-3100 trainer is covered in depth in the EE-310x course material. Many of the courses can be found online. Links to the DC and AC Electronics Courses are given in the notes. They will provide good usage details.

ET-3100B Circuit Description
The trainer may be broken into four sections, the Negative DC power supply, the Positive DC power supply, the Line Freq. AC power supply and the 20 Hz to 20 kHz signal generator.

The Negative DC Power Supply:
The negative DC power supply is complementary to the positive DC supply. PNP transistors are used instead of NPN transistors. Diodes and polarized capacitors are reversed from the positive supply. It outputs regulated -15 VDC to the Generator and regulated -1.2 to -15 VDC for breadboard use. Refer to the positive power supply for circuit discussion.

The Positive DC Power Supply Circuit:
A schematic of the power supply is shown in **Figure 19**. Transformer **T101**, **D102, D104** & **C101** provide about +26 VDC. **R101** and **V101**, an LED, function as a pilot lamp circuit, indicating the power is on.

R102, ZD101, **C102** and **C103** make up a zener regulator that drops the 26 volts to a regulated 15 VDC which powers the generator circuit and also provides a stable 15 V reference voltage to **R104**, the + VOLTAGE control. The 26 VDC is also fed to **Q101** and **Q102.** These transistors are wired as a Darlington pair. (**Figure 18**) Consider them a single transistor with very high gain **(Q101/Q102)**. They are biased on by **R103** causing voltage to appear at the output. The emitter of **Q103**, the control transistor, is at the voltage selected by **R104**, and the collector is at the output voltage. As the output voltage reaches about 1.2 volts more than the voltage selected by **R104**, **Q103** begins to conduct and draws current away from the base of **Q101/Q102** controlling the output voltage. Should more current be drawn

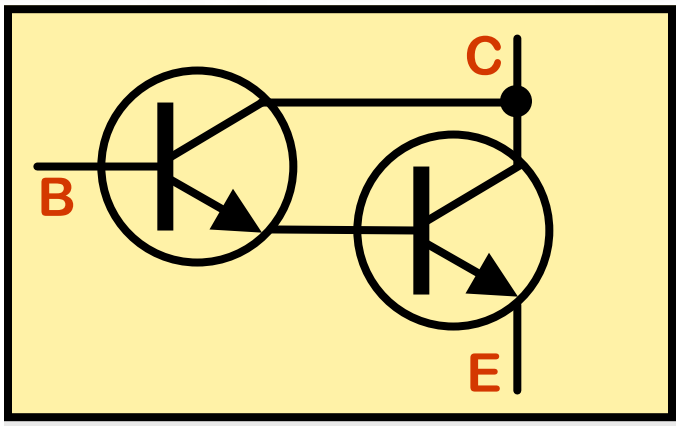


FIGURE 18: Two transistors wired as a Darlington pair. The gain is approximately the same as the two gains multiplied together. However the V_{BE} is twice single transistor.

from the supply, the output voltage will tend to drop causing **Q103** draw less current and raise the drive to **Q101/Q102** keeping the voltage steady.

Q104 and **R105** make up the current limiting circuit. **Q104** is off during normal power supply operation. However, should too much current be drawn through **R105**, the voltage drop across **R105** will turn on **Q104** which will draw current away from the base of **Q101/Q102** limiting the current to a safe level.

The 60 Hz Sine Wave Output Circuit:
The 60 Hz sine wave output are just connections to a separate 30 VCT secondary winding on the power transformer, with the center-tap grounded. These go to the three **LINE FREQ** wire connectors, #**1**, #**2** and #**3**. #**1** and #**3** are 15 VAC to #**2** which is ground. #**1** to #**3** is 30 VAC. The circuit is included in **Figure 19**.

The 20 Hz to 20 kHz Signal Generator Circuit:
The circuit of the signal generator in the ET-3100B **(Figure 20)** changed significantly from the two earlier models. It uses two LM301 op-amps instead of a single 741 op-amp. The LM301 has 8 pins. Pin-2 is the inverting input; Pin-3 is the non-inverting input, held at ground potential in this circuit; Pin-6 is the output; Pin-

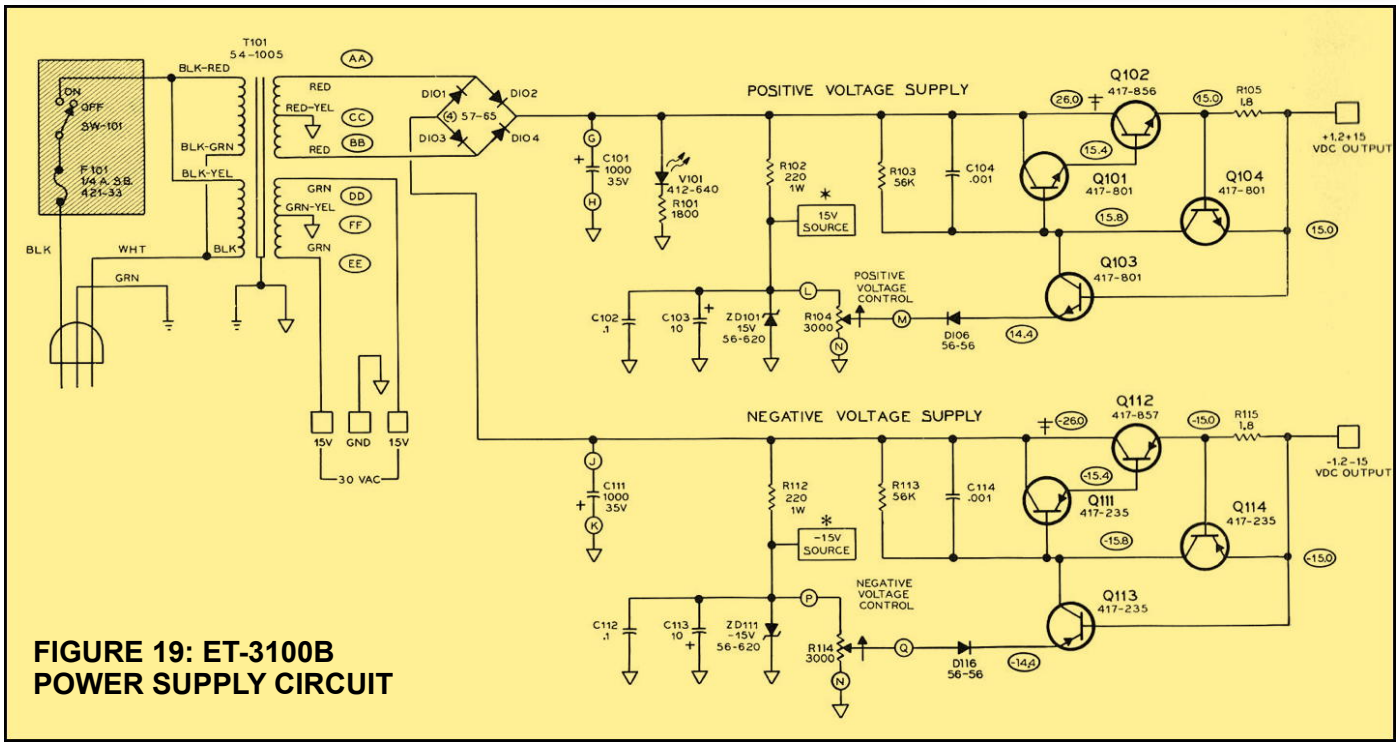


FIGURE 19: ET-3100B POWER SUPPLY CIRCUIT

4 and Pin-7 are the -15 and +15 VDC Vcc pins respectively, and pins 1, 5 and 8 are null and compensation terminals. **U1** is wired as an inverting amplifier that gets its signal from the output of **U2**. **R1** and **R2** set the gain of **U1,** and **C2** attenuates high frequencies to prevent unwanted parasitics. The output of **U1** is fed through a frequency determining network to the input of **U2** which is also an inverting amplifier. Capacitors **C3** and **C4** are used for the low range and **C5** and **C6** are used for the high range. **R8** and **FREQ** potentiometer **R9** set the frequency. Since there is positive gain and there is 180° phase shift between the input and output of **U2** the circuit will oscillate at the frequency determined by the network. The zener diodes **ZD1** and **ZD2** limit the level of output from **U1** into the network. **FREQ** control **R9** is in tandem with **R5**. As **R9** and **R5** turn in unison CW, increasing the frequency, the resistance of **R9** decreases, raising the frequency. And **R5** also decreases in resistance, raising the drive into the network to compensate for the frequency increase.

The output of **U2** is a clean sine wave and is fed via a divider consisting of **R14** and **R15** that

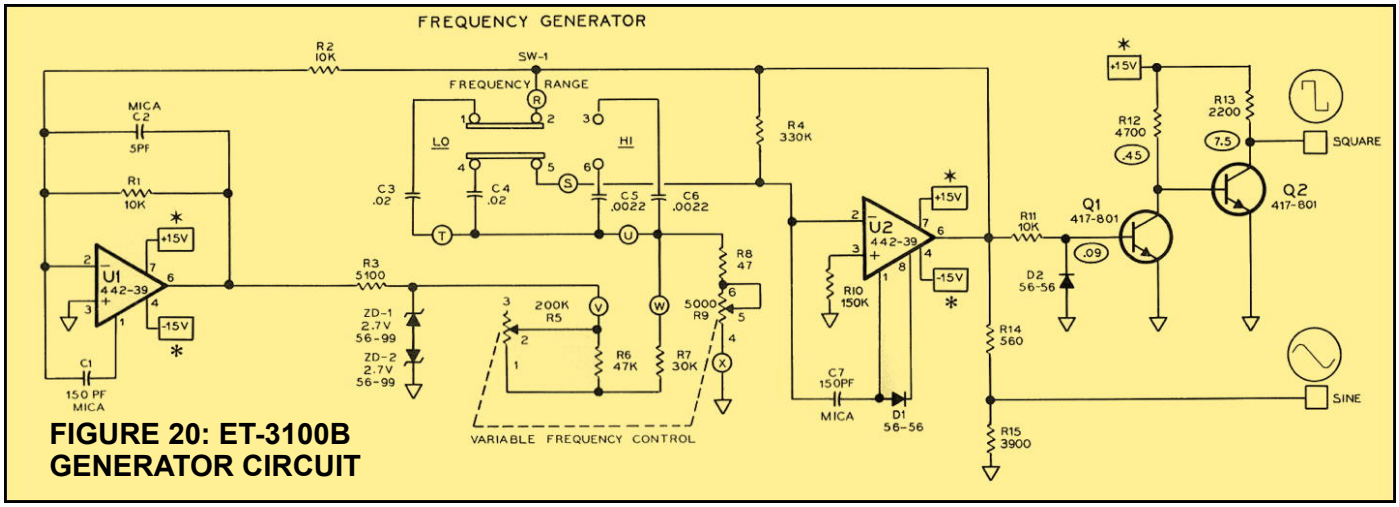


FIGURE 20: ET-3100B GENERATOR CIRCUIT

provides a nominal 1V rms, 600Ω impedance output to the **SINE** wire connector.

The output of **U2** is also fed through **R11** to **Q1**. Diode **D2** prevents the base of **Q1** from going negative. **Q1** and **Q2** are high gain amplifiers and at the output of **Q2** the sine wave has been transformed into a square wave, which is output to the **SQUARE** wire connector.

On **U1** and **U2** Pin 5 is not used. It allows the addition of a null trim pot if nulling is critical. Pins 1 and 8 are for internal amplifier compensation. Heath used 150 pf for **C1** and **C7**. They also used diode **D1** to increase the bandwidth of **U2**. Details on compensation are given on the LM301 data sheet[6].

ET-3100 Conclusion:
My first impression, viewing the ET-3100, was very positive. One weakness, I thought, was that the breadboard could have been larger. All the experiments easily fit on it. Yet, I wondered about using it later on, on other projects? Of course it could be used with an easily available separate breadboard.

Browsing through the first three course manuals, it was obvious that a lot of thought and study went into their preparation. When first looking at the extra parts in the ET-3100 box. (that I later figured out were the parts for the DC Electronics course) The parts included two envelopes of resistors. In one, that was marked "RESISTORS FOR EXPERIMENT 5", I found a standard carbon ½ watt 20% resistor, with the most unusual markings: brown black violet, 100

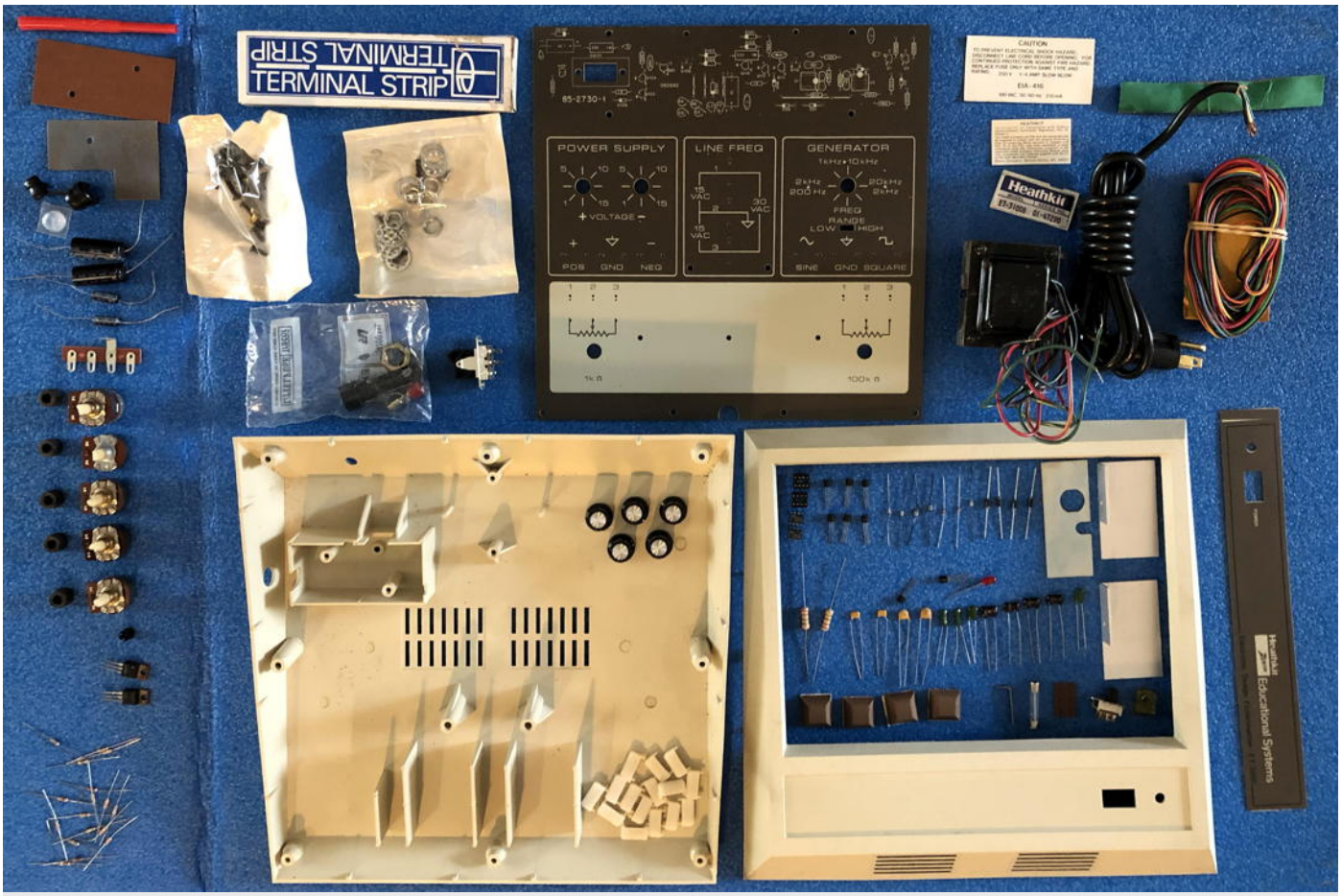


Figure 21: The components that make up the ET-3100B are laid out for display.

Note 7 Meg Ω (Heath part #1-139). The highest value standard carbon ½ watt resistor I'd ever seen before was 22 Meg Ω. Looking, a little further, I found one an order of magnitude higher in value, a 1,000 Meg Ω (1 giga Ω) carbon ½ watt 20% resistor marked brown black gray (Heath part #1-141)[7]. I was curious what they would be used for in the course? Experiment #5 involves resistor color-code familiarization, just removing a resistor from the envelope noting the size and reading the color code to determine the values of that resistor (wattage, ohms, and tolerance).

Note 8 If you'd like to see the course manuals for the DC and AC Electronics they are available online[8].

Heath continued to develop new courses, some with specific trainers, and some that didn't require a trainer. Even after Heath stopped selling kits, their Educational Division continued for a few more years.

Comments:

As usual, I had a lot of help preparing this article. Steve Gladstein - N8FH provided hard-to-find information on the 'A' version, including the schematic and parts list. Gerhard Wagner - DF1DA provided a lot of insight as well as the photo of the course manuals. Chuck Penson - WA7ZZE, author of those excellent Heathkit books, filled in a lot of details including sending copies of pages from his vast Heathkit catalog collection. A lot of support also came from Santos e Silva of Portugal; he is very knowledgeable about Heathkits. One could say this is an international effort!

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

Thanks - AF6C

Notes:

1. See HotM #124: https://www.w6ze.org/Heathkit/Heathkit_124_EUW18.pdf
2. The catalog is available here (See pages 62 - 65) https://www.worldradiohistory.com/Archive-Catalogs/Heathkit-Catalogs/Heathkit-Christmas-1975.pdf
3. https://www.w6ze.org/Heathkit/ET3100/index.html
4. The Tranter video is available here: https://www.youtube.com/watch?v=X9haztHTCsg
5. These are the values given in a Heath *Parts Master File*. The plus to minus value of 52 volts would not be possible. No doubler circuit is used.
6. The data sheet for the LM-301 can be found here: https://www.ti.com/lit/ds/symlink/lm101a-n.pdf
7. In later releases of the DC Course the 1,000 MegΩ resistor was replaced with a 10 MegΩ resistor, Heath part #6-106.
8. The first four course manuals are available online at: https://archive.org. Search for 'Heathkit EE-310n' where n is 1, 2, 3, 4 for the four courses. (Select 'meta' for search type when asked.)

To be honest, I got so much support and new information after the article was published in *'RF'* that the revised article was extended from 13 to 17 pages. Added was more information on optional AV tools that became available during he lifetime of the ET-3100 series Trainer. Also Gerhard guided me to the Concept of Electricity course (EE-3100) which was added, along with the Electronics for Hobbyists course (EE-3140) which was discovered during the rewrite.

Be sure to checkout the Heathkit Specification section I've added to the website. It currently has 164 data spec. sheets in 14 categories. There are still more to add, mostly audio/HiFi but scanning schematics that are 34" x 22" is a challenge!:

https://www.w6ze.org/Heathkit/HeathSpecSheetsIndex.html

73, from AF6C