Heathkit of the Month #75:
by Bob Eckweiler, AF6C

ELECTRONIC TEST EQUIPMENT

Heathkit IT-121
FET/TRANSISTOR TESTER (Part I)

Introduction:
In the main 1959 Heathkit catalog I could only find one kit that used transistors - the 6-transistor DF-1 Radio Direction Finder. Just two years later, the 1961 catalog had more than a dozen kits that used transistors, including a new DF-3 Radio Direction Finder. Interestingly, none of these kits were in the audio - stereo area. With the growth of transistorized Heath - kits it didn't take Heathkit long to start manufacturing test equipment for testing transistors.

Between 1961 and the demise of Heathkit as we knew it, Heathkit offered four different transistor testers. All were sold under more than one model number as styling changed, but little, if any, changes were made to the circuits.

The first transistor tester - The IT-10 - was listed as "New through Heath research" in the May 1961 catalog. Later that year the IM-30, a much more advanced laboratory transistor tester, was offered. In 1968 the portable IT-18, with a capability between the IT-10 and the IM-30, and housed in a portable plastic case, was introduced. In 1972 the IT-121 began production. It replaced a later version of the IM-30, though the two sold concurrently for more than a year. The IT-121 (Figure 1) will be the focus instrument of this article. Table I shows some history for the four models and their successors.

IT-10, IT-27 and IT-3127 Testers:
These three units are simple and inexpensive; they perform only the rudimentary evaluation of forward conductance and reverse leakage of

Figure 1: Heathkit IT-121
FET / Transistor Tester

a diode, and collector to emitter leakage (I_{CEO}[1]) and gain of a transistor. They also test for open and shorted diodes and transistors. Power is provided by two "C" batteries. The unit is 3-1/8" H x 3-1/8" W x3-3/4" D and weighs 12 oz. The IT-10 is shown in figure 2; the IT-27 and IT-3127 appear physically and electrically identical with new color and styling. The three units are not designed for in-circuit testing.

The IT-10 (Figure 2) has three slide switches. The first selects NPN or PNP polarity and forward or reverse diode current measurement. This switch simply reverses the battery and meter polarity. The second switch selects high or low current. The low position is also used for diode testing. In the low position the meter reads 3 mA full scale and the transistor base current is set to about 30 µA, while in the high position full scale current is around 200 mA and transistor base current is set to about 1.4 mA. The third switch selects testing for either leakage or gain. In the leakage position the transistor base is left unconnected, and in the gain position the selected current is applied to the transistor's base.

A transistor short is indicated by full scale meter deflection in the leakage position, and an

[1] Notes begin on page 8

MODEL	FIRST YEAR	LAST YEAR	INTRO PRICE	HIGH PRICE	POWER SOURCE	METER	COMMENTS
IT-10	1961	1967	$6.95	$6.95	2-C Batteries	0 - 3 MA	Simple transistor & diode tester
IT-27	1967	1978	$6.95	$11.95	2-C Batteries	0 - 3 MA	Restyled IT-10
IT-3127	1978	1981	$12.95	$12.95	2-C Batteries	0 - 3 MA	Restyled IT-27
IM-30	1961	1967	$54.88	$54.88	7-D Batteries	± 10 µA	Lab transistor & diode tester
IM-36	1967	1974	$60.00	$67.50	7-D Batteries	± 10 µA	Restyled IM-30
IT-18	1968	1979	$24.95	$32.95	1-D Battery	0 - 200 µA	Portable transistor & diode tester
IT-3118	1978	1979	$34.95	$34.95	1-D Battery	0 - 200 µA	Restyled IT-18, New blue molded case
IT-121	1972	1977	$59.95	$62.95	2-D Batteries	0 - 100 µA	Transistor, FET, UJT, SCR, Triac & diode tester
IT-3120	1977	1989	$54.95	$99.95	2-D Batteries	0 - 100 µA	Restyled IT-121
				TABLE I			Info from available factory catalogs

open is indicated by no meter deflection in the gain position.

IT-18 and IT-3118 Testers:

The IT-18 is a less rudimentary transistor tester utilizing a calibrated meter and capable of making quantitative measurements. It also does rudimentary in-circuit testing of transistors and diodes. It is powered by a single "D" battery, measures 8-1/2" W x 4-1/8" H x 7-1/8" D, and weighs 2-1/4 pounds.

Out-of-circuit transistor measurements are I_{ceo} and I_{cbo}[2] leakage up to 5 mA, and DC beta[3] from 2 to 1,000 in two ranges: 2 to 100 and 20 to 1,000. Diode testing indicates the diode is open, shorted or good whether in or out of a circuit.

The IT-18 has a large 4-1/2" 100µA meter that is easy to read. The 0 - 5 mA leakage scale is nonlinear and expanded at the low end so you can read leakage as small as 5 µA. 1 mA is at center scale with 5 mA full-scale.

The IT-18 has a meter and six controls on the front panel. The large meter takes up over half the area, and there are three rows of controls to

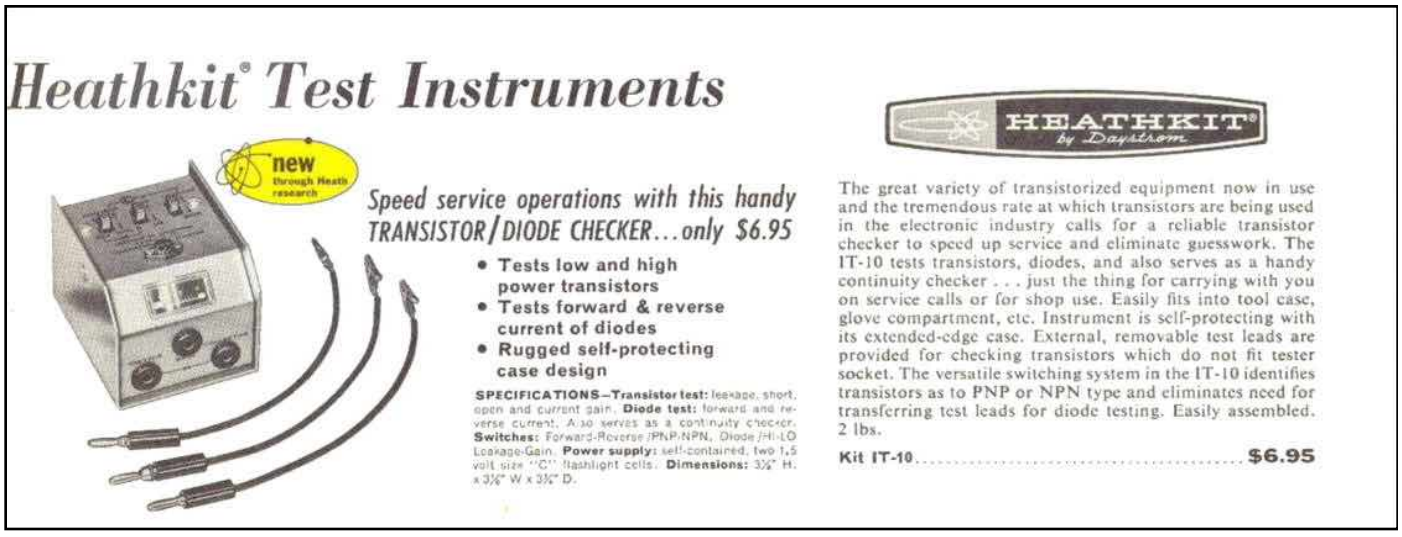

Figure 2: Heathkit IT-10 Transistor Tester (From: May 1961 Heathkit Catalog)

Figure 3: Heathkit IT-18 Transistor Tester

its right. The top row (L to R) contains the **BETA CAL** pot and the **NPN - OFF - PNP** power and polarity switch. As with the IT-10 this switch reverses the power and meter polarity. In the OFF position it also shorts the meter to provide dynamic damping protection, important for portable instruments. The second row has the **BETA X1 - X10**, range switch, the **Iceo - Icbo** function switch and a socket for the transistor under test. (Leads are also available for connection to a transistor in circuit or one that won't fit the socket). The final row contains the **CAL - TEST** rocker switch.

The IT-18 originally came in a black plastic case. The case was replaced with a brown molded case partway through its production. This is the same type brown molded case that deteriorated to plastic fragments on my ID-29 (see HOM #73). The later IT-3118 sports the newer blue inject molded case that seems to be less prone to disintegration over time. The IT-18 case measures 9-3/8"W x 5-3/8"H x 9"D (including handle) and weighs 2-1/4 lbs.

IM-30 and IM-36 Transistor Testers: The IM-30 (Figure 4) and restyled IM-36 are more advanced laboratory style transistor testers than the units already discussed. They are designed for out-of-circuit transistor testing and may be set up for quick GO - NO GO testing, and matching, of batches of transistors once the desired parameters are set on the front panel. The IM-30 performs Base Current, Collector Current, Collector Voltage, Gain (both DC Beta and DC Alpha[4]), Leak Voltage, Transistor Leakage (both Iceo and Icbo) and Short tests. Diodes can be checked for leakage and forward current characteristics. AC operating conditions can also be determined by testing at different bias points. The sensitive ±10 µA meter allows accurate quantitative measurements that facilitate calculations of both AC and DC current gain, transconductance, base and collector resistance. The IM-30 is powered by seven (7) "D" batteries. A voltage

Figure 4: Heathkit IM-30 Laboratory Transistor Tester

up to 9V is available internally (in 1.5V steps) for collector voltage and leak voltage tests, or an external voltage source may be used for tests up to 50 and 150 volts respectively. The IM-30 measures 10-3/4W x 5-1/2"H x 10-1/4 D and weights 8 lbs.

To go into greater detail on this tester is beyond the scope of this article. Perhaps if there is interest the IM-30 and IM-36 may be given its own article in the future.

IT-121 & IT-3120 FET / Transistor Testers:
Between the IT-18 and the IM-30 capability sits the Heathkit IT-121 and it's restyled IT-3120. The IT-121 not only tests diodes and transistors, it incorporates the necessary circuitry to test FETs (Field Effect Transistors) SCRs (Silicon-Controlled Rectifiers), Triacs and UJTs (Unijunction Transistors). Let's delve more deeply into this handy piece of test equipment. The focus will be on the IT-121, everything also pertains to the IT-3120.

The IT-121 comes in a cabinet with a sloping front that measures 9-9/16 W x 5-1/4 H x 8-5/8 D. A large 4-1/2" meter reads Gm and beta directly, as well as leakage. It is powered by 2 internal "D" cell batteries. These batteries have to provide up to one amp of current during certain tests. The batteries remain serviceable down to a voltage of 0.9V while under load.

HEATHKIT IT-121 FET/TRANSISTOR TESTER

Top Panel (Left to Right):

FET Socket (Pins CW from top):
Source - Gate1- Gate2 - Drain

Banana Jack (Green) - Gate2

Banana Jack (Red) - Source, Emitter, Anode

Banana Jack (White) - Gate1, Base

Banana Jack (Black) - Drain, Collector, Cathode

Transistor Socket (Pins CW from top):
Base - Collector - none - Emitter

Sloping Panel (Left to Right):

Row 1:

Meter (Five scales):
BETA: ∞ down to **1**
BETA: **CAL x1**, **CAL x5**, **CAL x10**
FET Gm x1000: ∞ down to **0: µmhos x 1000**
LEAKAGE: 0 to **100**
BAT. OK

Potentiometer (multi-turn):
SET Gm = 0 (top), **SET BETA =** ∞ (bottom)

Potentiometer (single-turn) with pull switch:
BETA CAL
PULL TO EXTEND RANGE

Row 2:

Meter (continued)

RANGE: 5-Push button switch group (L to R):
(Interlocked - only one sw. is in a time)
100µA (remainder blank) - top
100µA, **1 mA**, **10 mA**, **100 ma**, **1 A** - bottom

Row 3:

FUNCTION: 6-Push button switch group (L to R):
(Interlocked - so only one may be activate a time)
Gm=0, **Gm**, **GATE 1**, **GATE 2**, **Igss**, **Idss** - top
BETA=∞, **BETA CAL**, **BETA**, **Icbo**, **Ices**, **Iceo** - bot.

MODE: 5-Push button switch group (L to R):
ON (**IN**), **OFF** (**OUT**) (independent).
BAT. TEST, **TRANS**istor, **FET**, (Interlocked)
P CHAN./PNP (in), **N CHAN./NPN**) (out) (independent)

TABLE II - IT-121 Panel Controls

Fresh batteries will pin the meter when the battery test switch is pressed; this can be a bit disheartening, but it is mentioned in the manual which claims it will not damage the meter.

Table II shows lists the layout of the controls and switches for the IT-121. The switches are organized in three banks, the **RANGE** bank, **FUNCTION** bank and **MODE** bank. The RANGE and FUNCTION banks are each interlocked so only one switch may be in at a time as are the middle three MODE switches. The **ON - OFF** and **NPN - PNP** MODE switches operate independently.

IT-121 Tests:
The IT-121 tests can perform the following tests: For general germanium or silicon bipolar junction transistors, including power transistors, the IT-121 measures Beta, I_{ceo}, I_{ces}[5] and I_{cbo}. For FETs it measures G_m[6], I_{gss}[7] and I_{dss}[8]. For UJTs three leakage tests may be performed, I_{eb_2s}[9], $I_{b_2b_1s}$[10] and I_{b_2es}[11]. These tests are performed out-of-circuit only. SCRs and Triacs may be tested for function and operation both in and out-of-circuit.

Checking the IT-121 Batteries:
Prior to testing any device, the batteries should be checked. First, turn the IT-121 on by pressing the ON - OFF (MODE) switch. This switch alternates between ON (in) and OFF (out) with each press. Next, be sure the NPN - PNP switch is out (NPN), and press the BAT TEST (MODE) switch. The meter should read above the **BAT. OK** mark on the face of the meter (Figure 5). This tests one of the "D" batteries. To test the other battery, press in the NPN - PNP switch and again check the meter scale. Press the **TRANS** (MODE) switch to release the BAT. TEST switch. Do not leave the tester in the BAT. TEST any longer than necessary as it will shorten battery life. Turn the IT-121 off by releasing the ON - OFF switch and also return the NPN - PNP switch to the NPN position (out).

Testing a Typical Bipolar Transistor:
With the ON - OFF switch OFF (out), connect the three transistor leads to the red (**E**) white (**B**) and black (**C**) banana jack leads, or insert the transistor in the right-hand socket. Be sure the leads are correct by checking the transistor data sheet or using the illustrations of standard lead positions in the Heathkit manual. If testing in-circuit, connect the test leads to convenient points on the circuit.

Now press in the **TRANS** (MODE) switch and the **BETA = ∞** (FUNCTION) switch. Select a collector current depending on the transistor type (See Table III) and press the appropriate current switch (RANGE).

CLASS	APPLICATION	CURRENT CAPABILITY
SIGNAL	AUDIO, RF, IF	1 mA - 10 mA
INTERMEDIATE POWER	AUDIO, SWITCHING	10 mA - 100 mA
POWER	AUDIO, REGULATOR, OUTPUT	100 mA - 1 A

TABLE III: From the Heathkit IT-121 Manual

Next press ON and using the **SET BETA = ∞** control adjust the meter needle until it aligns with the ∞ mark at the left of the **BETA** scale (top). If this step cannot be performed the transistor may be defective or improperly connected. Once set, check that the **BETA CAL** control is pushed in and turned fully counter-clockwise, then press the **BETA CAL** (FUNCTION) switch; this releases the BETA = ∞ switch. Rotate the BETA CAL control to move the meter needle. If the meter goes off-scale or doesn't respond, it indicates either a bad transistor, improper connection, or the NPN - PNP switch may be improperly set. Move the control until the meter needle corresponds with one of the three CAL marks on the BETA meter scale (**CAL X10**, **CAL X5** or **CAL X1**). Generally use x10 first. If you are testing a power transistor and you cannot set the CAL, pull out on the BETA CAL control. This extends the control's range, but only for power transistors.

To measure beta, press the **BETA** (FUNCTION) switch and read the beta on the BETA scale on the meter. Multiply this number by 10, 5 or 1, depending on the calibration mark used.

Leakage testing requires the transistor be out-of-circuit. Generally germanium transistors will show significant leakage that increases with higher temperature. Low power silicon transistors will show no, or almost no, leakage and any significant leakage can be a sign the transistor is bad. To test for leakage Press the **Icbo** (FUNCTION) switch, then set the RANGE to 100 µA and read the leakage directly on the meter's 0 - 100 leakage scale (bottom). Likewise press the **Ices** and **Iceo** switches to measure their leakage. Iceo should always be the largest leakage and Icbo should always be the smallest leakage of the three measurements.

Figure 5: IT-121 Meter scales

Testing an FET Transistor:

The IT-121 will test both junction FET and MOS-FET transistors. With the power switch OFF (out) Select **FET** (MODE), set the **N CHAN - P CHAN** switch to the proper type of FET and select the **Gm = 0** (FUNCTION) switch. Press the ON switch and use the **SET Gm = 0** control to set the meter needle over 0 (full-scale) on the **Gm** scale (red). Now press the Gm (FUNCTION) switch and read the Gm on the red scale. Remember to multiply the scale reading by 1000. If the meter reads 0 or ∞ the FET is bad. Now press the **GATE 1** switch (FUNCTION). The Gm should decrease. If it does not change, or if it increases, the FET is either bad, the connections are improper or the **N CHAN - P CHAN** switch is in the wrong position. If the FET being tested has two gates, press the **GATE 2** switch. The Gm should again decrease. if this is not the case then the FET is bad.

To test the FET for leakage the FET must be out-of-circuit. To test for Igss press the **Igss** (FUNCTION) switch. The meter switch should be in the 100 µA (RANGE) position. This leakage is in the nano ampere range so you should see no movement of the meter. To measure Idss first set the meter switch to 10 mA (RANGE) position, then press the **Idss** (FUNCTION) switch. You should see a reading of somewhere between 100µA and 10 mA depending on the FET. You can check that this reading is in the ballpark on the FET's data sheet.

Testing a Diode:

With the power off, connect the diode's cathode lead to the black (C) banana jack and the anode lead to the red (E) banana jack of the IT-121. Press the TRANS (MODE) switch, press the 100 µA (RANGE) switch, Press the Iceo (FUNCTION) switch, and put the NPN - PNP switch in the NPN position (out). Now press

the ON switch (in) and read the reverse diode leakage directly on the LEAKAGE scale.

To check the forward conduction of the diode move the NPN - PNP switch to the PNP position (in). Select a test current using the RANGE switch. Do not exceed the current rating of the diode. (Typically 1 mA or 10 mA for a signal diode and 100 mA or 1 A for a rectifier diode). If the diode has good forward conductance the meter should read above 80 on the LEAKAGE scale.

Testing a UJT Transistor:

The FET functions of the IT-121 are used to test unijunction transistors. A UJT typically has three leads, two are bases and one is the emitter, and must be tested out-of-circuit. With the power off, the UJT is connected as follows:

UJT Emitter to the G1 banana jack (white)

UJT Base 1 to the S banana jack (red)

UJT Base 2 to the D banana jack (black)

Press in the FET (MODE) switch, the Igss (FUNCTION) switch and the 100 µA (RANGE) switch. Determine the polarity of the UJT under test from the data sheet (P-channel UJTs are rare) and set the N CHAN - P CHAN switch appropriately. Now press the ON switch and read I_{eb_2s} leakage current which should be less than 1 µA.

Next press the 1 mA (RANGE) switch and the Idss (FUNCTION) switch. The meter now reads the $I_{b_2b_1s}$ current. It should be nominally between 150 µA and 400 µA. From this value you may calculate Rbb, the resistance between base 1 and base 2, knowing the battery voltage (1.5 V):

$$Rbb = 1.5V / I_{b_2b_1s}$$

Next, press the 100 mA (RANGE) switch and reverse the N CHAN - P CHAN switch. The meter reads the emitter current I_{b_2es} on the leakage scale. It should be nominally between 15 and 50 mA.

Testing a Silicon Controlled Rectifier (SCR):

The transistor functions of the IT-121 are used to test SCRs. An SCR typically has three leads, the anode, cathode and gate; and may be tested in-circuit or out-of-circuit. With the power off, the SCR is connected as follows:

SCR Cathode to the C banana jack (black)

SCR Anode to the E banana jack (red)

SCR Gate to the B banana jack (white)

Press in the TRANS (MODE) switch, the 1 A (RANGE) switch and the Iceo (FUNCTION) switch. Set the NPN - PNP switch to PNP (in).

Next press the ON switch, press the Ices switch (FUNCTION) and then press the Iceo switch (FUNCTION). The SCR should now be turned on and the meter should read 50 or greater on the LEAKAGE scale. Momentarily disconnect the cathode lead from the black banana jack and then reconnect it. This should turn the SCR off. The meter should now read less than 5 on the LEAKAGE scale.

Testing a Triac:

The transistor functions of the IT-121 are used to test Triacs. A Triac is a dual polarity device, and typically has three connections, the anode (often referred to as “hot”), cathode (often referred to as “common”) and gate; and may be tested in-circuit or out-of-circuit. With the power off, the Triac is connected as follows:

Triac Cathode to the C banana jack (black)

Triac Anode (hot) to the E banana jack (red)

Triac Gate to the B banana jack (white)

Press in the TRANS (MODE) switch, the 1 A (RANGE) switch and the Iceo (FUNCTION) switch. Set the NPN - PNP switch to NPN (out).

Press the ON switch (in).

Press the Ices switch (FUNCTION) and then press the Iceo switch (FUNCTION). The Triac should now be turned on and the meter should read 50 or greater on the LEAKAGE scale. Momentarily disconnect the cathode lead from the black banana jack and then reconnect it. This should turn the Triac off. The meter should now read less than 5 on the LEAKAGE scale.

To test the other polarity of the Triac set the NPN - PNP switch to PNP (in), and then repeat the previous paragraph.

When finished testing be sure to remove the device from the tester and check that the ON - OFF switch is in the OFF position (out). This will insure long battery life.

What the IT-121 Cannot Test:

Probably the weakest feature of this instrument is the low test voltage it uses (± 1.5 VDC); this is also a safety feature as it prevents damage when doing in-circuit testing. Due to the low voltage, zener diodes can be checked for leakage but not for their regulating voltage; usually if a zener diode passes the leakage test it is operating properly. High-voltage diodes, SCRs and Triacs that have a forward voltage drop greater than 1.5 volts cannot be tested; neither can Darlington transistors that have a Vbe drop greater than 1.5 volts. SCRs, Triacs and UJTs that require trigger voltages greater than 1.5 volts also cannot be tested. Generally these devices can be checked by measurement.

Next Article - In Part II…

...we will examine the circuitry used in each of the tests and perhaps briefly cover a little of the theory behind the semiconductors that can be tested.

73, from AF6C

Notes:

1. **Iceo** is the current that flows between the collector and emitter with the base is open.
2. **Icbo** is the current that flows between the collector and base with the emitter is open.
3. **DC Beta** (β) is the ratio of the collector current to an applied base current. It is the DC current gain.
4. **DC Alpha** (α) is the collector current divided by the emitter current. It is always less than one and is related to the DC beta by **α = β/(β+1)**.
5. **Ices** is the current that flows between the collector and emitter with the base is shorted to the emitter.
6. **Gm** (transconductance) is a measurement of how a change in FET gate voltage affects drain current. It is usually expressed in μmhos.
7. **Igss** is the FET current that flows between the gate and the source with the source shorted to the drain.
8. **Idss** is the FET current that flows between the drain and the source with the gate shorted to the source.
9. **Ieb$_2$s** is the leakage current between the emitter and base 2 with base 1 shorted to base 2 of a UJT.
10. **Ib$_2$b$_1$s** is the forward current through base 2 and base 1 with the emitter shorted to base 1 of a UJT.
11. **Ib$_2$es** is the emitter current that flows between base 2 and the emitter with base 1 shorted to the emitter of a UJT
12. A schematic of the IT-3120 (IT-121) may be found at: http://www.w6ze.org/Heathkit/Sch/IT3120_Sch.jpg

Remember if you come across any old Heathkit Manuals or Catalogs that you do not need, please pass them along to for my research.

Thanks - AF6C

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