Introduction

The M3 Semiconductor Analyzer is a powerful instrument that can identify easily a large number of components.

Features

- **Automatic component identification**
  - ⇒ Bipolar transistor, with or without protection diode and/or B-E shunt resistor
  - ⇒ Darlington transistors
  - ⇒ Enhancement mode MOSFETs
  - ⇒ Junction FETs
  - ⇒ Triac
  - ⇒ Thyristors
  - ⇒ Diodes
  - ⇒ Unijunction transistors
- **Automatic pinout identification for all the above components**
- **Gain measurement for bipolar transistors**
- **Test current display**
- **V_{BE}/I_B measurement**
- **Collector leakage current measurement**
- **Automatic recognition of semiconductor type for bipolar transistors (Ge/Si)**
- **Detection of Collector/Emitter diode and Base-Emitter shunt resistor**
- **Gate threshold voltage for MOSFETs**
- **Test current measurement**
- **Gate threshold, I_{DSS} and R_{DSON} for JFETs**
- **Diode forward voltage and forward current measurements**
- **Diode leakage current measurement**
- **Low power Darlington recognition with pinout identification**
- **Low power Triac and thyristor identification**
- **Unijunction transistor identification with pinout and R_{BB}/η measurement**
- **Internal short circuit detection and resistance measurement**

Analyzing component

The M3 Semiconductor Analyzer is designed to analyze out-of-circuit and un-powered components. This is necessary to avoid erroneous component detection and errors in parameters measurements. Three-terminals components can be connected in any fashion to the probes. Diodes should be connected to the left and right probes.

When the unit is powered on, the display shows the revision of the software for two seconds and the analysis begins.

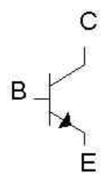
```
M3 Semiconductor
Analyzer Rev.3.0
```

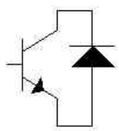
If no semiconductor is connected to the unit or if the component is not detected, the following message will be displayed:

```
No component
     *-*-*
```

When a component is detected, the first line shows the component type, and up to two parameters. The second line shows the pinout and, for some components, a supplementary parameter. For some components the analyzer shows successively different screens with different parameters. The analysis is done in real time, you just have to connect the component to the probes and the unit displays in less that one second the result of the analysis. The backlight of the unit is powered when a valid component is detected, and powered off when no component is connected. The backlight is powered off also when the component is connected for more than 30 seconds, in order to conserve battery life.

Bipolar Junction Transistors





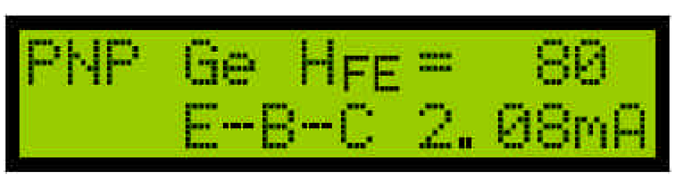
A bipolar transistor (BJT) is a semiconductor device commonly used for amplification. Physically, a bipolar transistor amplifies current, but it can be connected in circuits designed to amplify voltage or power. There are two major types of bipolar transistors, PNP and NPN. The ratio of the collector current to the base current, called current gain or H_{FE}, is on the order of 100 for most types of BJTs. Bipolar transistors can be fabricated to match with like devices much better than FETs, making them useful for high precision analog circuit design. This makes them well suited as components in op-amps and discrete transistor amplifiers where, combined in precisely-matched pairs, they form input structures called current mirrors. Some high power or high frequency BJTs have an internal diode between collector and emitter terminals.

The M3 Semiconductor Analyzer can detect two different kinds of semiconductors: Germanium or Silicon. The first type are older and are not common. The analyzer can also detect the presence of an internal diode, symbolized by the pictogram -▶|- as well as a base-emitter shunt resistor. All the parameters are displayed in three different panels. The first panel displays the H_{FE} (static current gain) of the transistor. The M3 can measure current gain in the range of 5 to 999. The current gain varies according to the operating condition of the transistor. The polarization of the transistor under test is not fixed but depends on the actual H_{FE} value. The collector test current is displayed for reference. This will be between 1.5mA and 12mA.

The unit can also detect low power Darlington transistors, but in this case the current gain is not displayed.

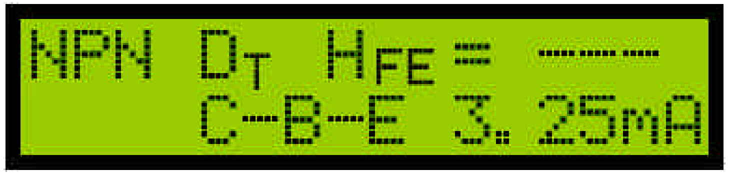
The H_{FE} value displayed can be different than the value encountered in a real world circuit with different values of collector current and collector voltage. The displayed value is very useful however for comparing transistors of a similar type for the purposes of gain matching or fault finding. The determination of the H_{FE} of high power transistors can be inaccurate. In this case a star '*' is displayed after the beta value. This is also the case when a transistor with an internal resistor is recognized.

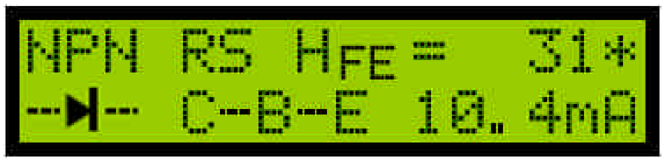
This example shows the first screen for a NPN Silicon bipolar transistor with internal protection diode.



This example shows the display when a PNP Germanium transistor is detected.

The following screen is displayed when a NPN Darlington type is detected. The current gain is not displayed.





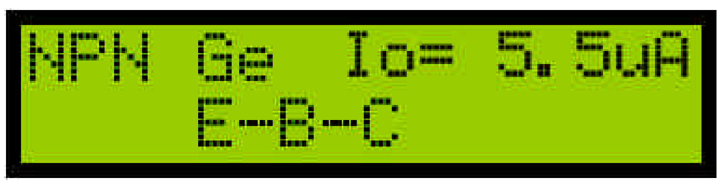
This screen shows an inaccurate H_{FE} measurement of an ESM113 transistor with internal diode and shunt resistor.

> ☞ **Please note that the M3 will determine that the transistor under test is a Germanium if the base-emitter voltage drop is between 0.1V and 0.5V. If this voltage is between 0.5V and 1V the transistor will be detected as Silicon type. Between 1V and 2V the M3 will determine that the transistor is a Darlington type.**

The second panel shows the V_{BE}/I_B measurement values.

The third and last screen shows the collector leakage current. The collector leakage current is measured when the base is connected to the emitter through a resistor of 100kΩ. The current flowing across this resistor is low compared to the current flowing into the base. Thus the current displayed is near the real I_{CEO} current measured normally with the base left open. One can determine the I_{CBO} current by dividing the I_{CEO} result by the H_{FE} value. Two automatic ranges are provided in the unit. The first range goes up to 25µA with 100nA resolution. The second range goes to 900µA with 1µA resolution.

An old Germanium AC130 transistor exhibits a collector leakage current of several µA.



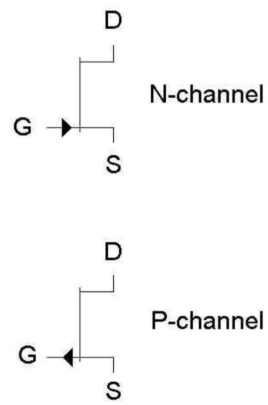
> ☞ **Please note that the unit cannot identify bipolar junction transistors with collector current above 900µA.**

Faulty semiconductors

Generally, a defective semiconductor presents one or two junctions short-circuited. In such case, the M3 would display the affected terminals and the resistance value of the short.

> ☞ **Please note that the M3 will determine a short-circuit if the measured resistance between two terminals is below 50Ω for the two current directions and if the third terminal does not influence the value. The test current for the resistance measurement is about 12mA. Accuracy of displayed resistance is ±2% ±5Ω.**

Junction FETs (JFETS)



With no gate voltage, current flows easily when a voltage is applied between the source and drain. This current is called the Saturation Current, symbolized by the I_{DSS} symbol. The current flow is modulated by applying a voltage between the gate and source terminals. N-Channel JFETs require a negative voltage on their gate with respect to their source, the more negative the voltage, the less current can flow between the drain and source. When the voltage reaches the voltage threshold of the transistor the drain current becomes zero.
With low drain-source voltage, the channel is a gate to source voltage dependant resistor (linear region). With no gate to source voltage this resistance is called R_{DSON}. Unlike MOSFETs, JFETs have no insulation layer on the gate. This means that the gate to source resistance is very high if the junction is reverse biased, but the gate current can rise if the junction is forward biased.

Unlike other semiconductor testers, the M3 has an original method which permits the determination of 3 parameters: V_{TO}, I_{DSS} and R_{DSON}.
The internal structure of JFETs is essentially symmetrical about the gate terminal, this means that the drain and source are indistinguishable by the unit. However the M3 will show the drain and source terminals according to the parameter measurements. The permutation of the drain and source terminals of the JFETs will not change the pinout displayed, but new parameters will be measured according to the new configuration. Thus one can verify the symmetry of the transistor by comparing the values for the two configurations. The three parameters are displayed successively every 5 seconds.

Threshold voltage measurement :

The threshold voltage is negative for N-channel JFETs and positive for P-channel JFETs. Maximum threshold voltage measurement is fixed to ±20V. Voltage resolution is 10mV for values up to ±9.99V and 100mV above. The example below shows the threshold voltage screen for a N-channel JFET. Note that the test current is also represented. In all screen displays relative to JFET, disregard the test current shown by the analyzer as the value doesn't physically exist during the test. All JFET parameters are mathematically determined. The accuracy of the measurement is ±100mV typical.

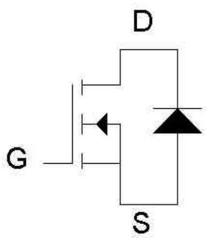
Saturation current measurement

Saturation current can be measured from 0 to 99.9mA. Resolution is 10 µA for current up to 10mA and 100µA above. With low I_{DSS} transistors (under 2 mA) the unit will show 0.00mA.

On resistance measurement

The M3 can measure R_{DSON} value from 0 to 999Ω with 1Ω resolution. With low I_{DSS} transistors the unit can show unstable values or « --- ».

Enhancement mode MOSFETs



MOSFET stands for Metal Oxide Semiconductor Field Effect Transistor. Like JFET, they are available in two main types, N-Channel and P-Channel. Most modern MOSFETs are of Enhancement Mode type, meaning that the bias of the gate-source voltage is always positive (for N-channel types). The other (very rare) type of MOSFET is the Depletion Mode type which is not recognized by the M3.

MOSFETs have an insulated gate that results in negligible gate current for both positive and negative gate-source voltages. An important feature of a MOSFET is the gate-source voltage at which conduction between the source and drain starts. Below this value the transistor is off and no current can flow across the drain to source terminals. An inherent body diode is present in all enhancement mode MOSFET.

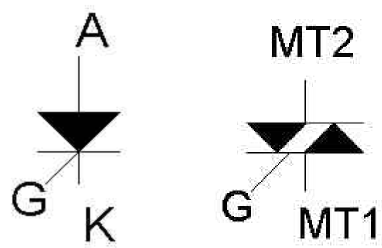
The M3 detects that drain-source conduction has started when it reaches about 2mA. The screen gives information about the type of MOSFET detected, the gate-source threshold voltage and the pinout of the transistor. Like bipolar transistors, the test current is also displayed on the second line.

Here the M3 shows the results when a BUZ11A N-Channel MOSFET is under test.

Here the M3 shows the results when a IRF9520 N-Channel MOSFET is under test.

☞ **The maximum gate current is fixed to 0.5µA. In order to obtain reliable results the instrument should be kept in a dry environment, as humidity can generate parasitic currents in the surface of the printed circuit board which can lead to erroneous detection of MOSFETs**

Thyristors (SCR) and Triacs



Thyristors are switching devices that require no control current once they are turned on. When a small control pulse of gate current is applied, the SCR conducts only in the forward direction, the same as any conventional rectifier. When that pulse is removed the thyristor continues to conduct, assuming a minimum holding current is maintained. Thyristors operate in only one quadrant (anode and gate positive). Triacs operates in 3 or 4 quadrants, the M3 tests the triac on two quadrants.

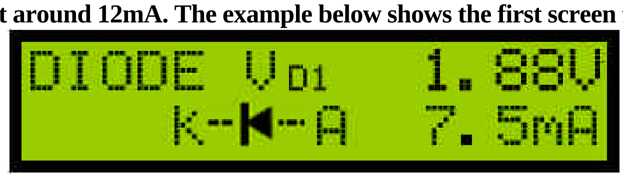
Sensitive low power thyristors (Silicon Controlled Rectifiers-SCRs) and Triacs can be easily identified and analyzed with the M3. Triac operation is very similar to that of thyristor and can be distinguish from it by the M3. Thyristor terminals are the anode, cathode and the gate. For a triac the terminals are MT1, MT2 and gate (displayed T1, T2 and G by the M3). MT1 is the terminal with which the gate current is referenced.

☞ The test currents used by the M3 are low (<12mA) to eliminate the possibility of damage to a vast range of component types. Some thyristors and triacs will not operate at low currents and these types cannot be analyzed with this instrument.

Diodes

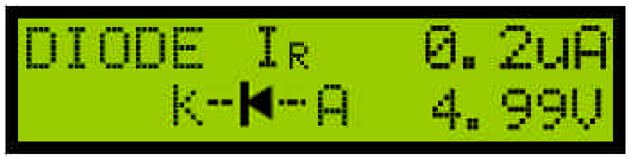
The diode (or any semiconductor junction) should be connected to the left and right test clips. The M3 runs three successive tests on the diode with the results displayed successively every 5 seconds.

The first screen gives the forward voltage, the pinout and the test current for a limiting resistor of about 400Ω, which gives a maximum current around 12mA. The example below shows the first screen for a red LED.



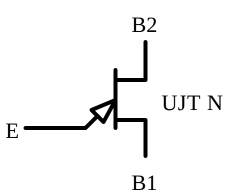
The next screen shows the same information but with a limiting resistor of 5.9kΩ, which gives a maximum current of 800µA. The same LED connected to the instrument gives lower forward voltage and current.

The last screen shows the leakage current measurement and the absolute reverse test voltage. Working junctions should not introduce any leakage current. Germanium junctions can exhibit low leakage current. The example below gives the result for a base-emitter junction of an old OC140 Germanium transistor. This test is useful in detecting bad junctions which appear correct with other tests. Some special components like photodiodes can also be checked with this test. The maximum leakage that the M3 can measure is 25µA. Above this value the display shows « --- ». Measurement resolution is 100nA.



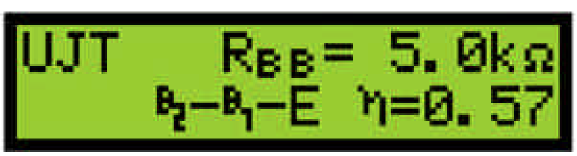
☞ **In order to obtain reliable leakage current values the instrument should be kept in a dry environment, as humidity can generates parasitic currents in the surface of the printed circuit board.**

Unijunction transistor



The unijunction transistor is more a thyristor than a transistor. It has one junction and was once referred to as a double-base diode. The UJT, unijunction transistor, does not conduct until a peak voltage, V_P, is reached. At that time the emitter conducts, resulting in a positive pulse at B1 and a negative pulse at B2. The threshold voltage V_P depends on the voltage between the bases and the Intrinsic Resistor Ratio h. When the emitter is below the threshold voltage, the B_1-B_2 channel acts as a resistor R_{BB}., generally between 5kWand 10kW.

The unit does not recognize UJT transistors with R_{BB} values under 100Ω or above 20kΩ. The M3 detects the pin-out and measures these two parameters. The η measurement takes a few seconds to stabilize.

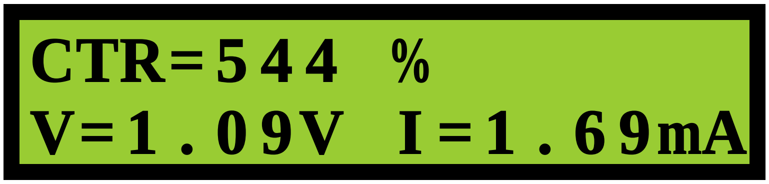


OP1 Optional Optocoupler Analyzer

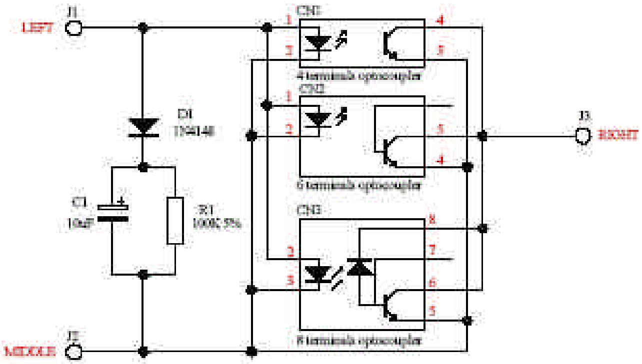
The OP1 module allows the detection and the Current Transfer Ratio measurement of most standard optocouplers. The module without any component must be connected to the M3 before power-up. When the M3 is powered on, the module is recognized by the tester and the screen shows the following message:

If no component, or a faulty component, is detected the M3 should display the following screen:

When a valid optocoupler is plugged in to its corresponding socket, the M3 would show the following screen:



The first line shows the Current Transfer Ratio. This value, expressed in %, is the ratio between the output transistor collector current and the input LED current. Measurement range is 1% to about 600%. Maximum output current is 10mA.
The second line shows the LED current and the forward voltage.



Opto-coupler test module schematic

Calibration

The purpose of the calibration is to establish the resistances of the analog switches. The measurement of these resistances is done by an automatic process. When the unit is powered on without calibration, the unit shows the following screen:

```
Cal Error
```

In this case, the unit takes default values for the internal calculations. The measurements are not accurate, and some components might not be determined.

To enter calibration mode, place a short at the W1 jumper, and short the three test terminals together. Apply power and the following screen appears:

```
Cal
Remove jumper W1
```

Remove the short at W-1 and the self-calibration starts. The unit performs three resistance measurements and displays their values. These values should be around 130Ω ?and are stored in memory. Calibration is only required once but can be performed as often as desired. Your instrument is now ready for use.

Technical Specifications

Reference temperature: 25°C

Parameter	Minimum	Typical	Maximum	Note
Peak test current across unknown	-12mA		12mA	1
Peak test voltage across unknown	-5.1V		5.1V	1
Measurable transistor gain H_{FE}	5		999	
Transistor H_{FE} accuracy		±2% ±2		
Transistor V_{BE} accuracy		±2% ±20mV		
V_{BE} for Germanium identification	0.1V		0.5V	
V_{BE} for Silicon identification	0.5V		1.0V	
V_{BE} for Darlington identification	1.0V		2.0V	
Transistor collector-emitter test current	0.2mA		12mA	
Transistor collector-emitter test current		2.0mA		2
Acceptable collector leakage		0.9mA		3
Base-emitter shunt resistor threshold		50kΩ		
MOSFET gate threshold range	0.1V		4.9V	
MOSFET gate threshold accuracy		±2% ±20mV		
MOSFET drain-source test current		2mA		4
MOSFET maximum gate current		1μA		
JFET R_{DSON} range	1Ω		999Ω	
JFET R_{DSON} accuracy		±5% ±10Ω		
JFET I_{DSS} range	0.2mA		100mA	
JFET I_{DSS} accuracy		±5% ±0.1mA		5
JFET V_{TO} range	-20V		20V	
Thyristor/Triac gate test current		10mA		
Thyristor/Triac load test current		10mA		
Diode limiting resistor #1		400Ω		
Diode limiting resistor #2		5.9kΩ		
Diode forward voltage accuracy		±2% ±20mV		

Diode leakage current range	0.0µA		25.0µA	6
UJT R_{BB} range	100Ω		20kΩ	
UJT R_{BB} accuracy		±3% ±100Ω		
UJT η range	15%		85%	
UJT η accuracy		±2%		7
Battery type	9V-LR622			
Battery voltage range	7.5V	9V	15V	
Inactivity backlight shutdown		30 secs		
Operating temperature range	0°C		50°C	

1. Between any pair of test clips.
2. H_{FE} = 100, Silicon transistor
3. Collector-emitter voltage of 4.0V
4. Actual test current depends on threshold voltage: $I_D = (5-V_{TO})/1.1k\Omega$
5. Typical accuracy.
6. Reverse voltage is 5V if I_R = 0µA, 2.5V if I_R = 25.0µA
7. V_{BB} = 5.0V