



Electrical Transport Option (ETO)

Available for PPMS® (P605), VersaLab™ (V605), and DynaCool™ (D605)

The **Electrical Transport Option (ETO)** represents the next generation electrical characterization option for the PPMS family of instruments (PPMS, VersaLab, and DynaCool). The primary operating mode of this 2-channel measurement system uses an AC current excitation and digital lock-in voltage detection to perform 4-wire measurements of electrical resistance or Hall effect in samples of resistance up to several mega-ohms. However, there are 3 major new capabilities which ETO adds to our electrical characterization suite:

- 1) *high impedance mode*: the stimulus-response circuit can operate as an AC voltage source and a nano-ammeter, thus allowing for 2-wire measurements of sample resistance up to 5 giga-ohms.
- 2) *AC+DC source*: the current source can superimpose a DC bias current I_{bias} on an AC signal, making it possible to use the lock-in to study differential resistance dV/dI versus I_{bias} . In high impedance mode, the excitation is an AC+DC voltage and the resulting current is detected so the measurement becomes dI/dV versus V_{bias} .
- 3) *two sources and meters*: there are two distinct sources and detection circuits which allow the 2 channels to operate truly independently. This is critical for applications such as measurements of resistance in the P850 Dilution Refrigerator where excitations should not be cycled on and off.

The measurement modes provided by ETO are as follows:

- Resistance (2- or 4-wire): in 4-wire mode the Hall resistance can also be measured
- I-V curve tracing (2- or 4-wire)
- Differential resistance dV/dI vs. I_{bias} (4-wire) and dI/dV vs. V_{bias} (2-wire)

Specifications

Preamp Specifications:

Noise

High Gain Amp: 1 nV/rtHz @ 100 Hz (typical):
(300X) 2 nV/rtHz (maximum)

Programmable Gain Amp: 30 nV/rtHz (typical)
(1X, 10X, 100X)

Voltage Input Range

± 4.5 Volts at 1X gain

Current Input Range (for 2-wire high impedance mode)

± 250 nA

Common Mode Rejection

-100 dB @ 100 Hz

Current Source Specifications:

Current Range

10 nA to 100 mA continuous operation

When using either the P850 Dilution Refrigerator System or the P825 Helium-3 System, the current is limited to <20 mA to protect system wiring. Consult Quantum Design for specific information on recommended maximum excitation settings at low temperatures on the P850 and P825 systems.

Frequency Range

DC, and 0.1Hz to 200 Hz AC
(Below 1µA Range 0.1Hz to 25Hz)

Resistance Specifications:

Absolute Accuracy

0.1% (typical for R < 200 kOhms)

0.2% (max for R < 200 kOhms)

Relative Sensitivity

± 10 nOhms RMS (typical)

Resistivity Range

up to 10 MOhms in 4-wire mode (typical)

2 MOhms to 5 GOhms in 2-wire mode (typical)

System Requirements:

The ETO is a CAN-based option. For proper operation on the PPMS it requires the Model 1000 Modular Control System, which is included with the P525 VSM or ordered separately.

ETO is compatible with P850/D850 Dilution Refrigerator, P825/D825 Helium-3 Refrigerator, and P310A/D310A/V310A Horizontal Rotator.

System Incompatibilities:

The ETO is not designed to be used with the P670 Thermal Transport Option (TTO), which requires the P600 ACT.

