

## Self Calibration Module with Output Control [SCM-BP]

- **Accurate & Stable Voltage Reference**
- **Outputs Set by Precision Resistors**  
Output voltage from  $\pm 247\text{mV}$  to  $\pm 98\text{V}$   
10k $\Omega$  & 10M $\Omega$  Current Conversion  
Banana jack DMM connections  
Calibration cable assures 10M $\Omega$  integrity
- **Minimal Temperature Effects**  
Ground reference inverting amplifier  
Isothermal cover for sensitive parts  
Temperature measurement  
Separate output stage
- **Provides Traceability to Standards Lab**  
System accuracy set by external DMM  
Helps satisfy ISO900X requirements
- **Eliminates Manual Calibrations**  
Self-calibration finds gain corrections  
Internal DMM finds offset corrections

Transfer Uncertainties After SCal is Run		
Cardinal Voltage(V)	24 Hr, $\pm 1\text{C}^\circ$ (% of Value)	30 days, $\pm 5\text{C}^\circ$ (% of Value)
0.25	0.003	0.01
0.50	0.002	
1.00		
2.50		
5.00		
10.0		
25.0		
50.0		
100		
Cardinal Resistance ( $\Omega$ )	24 Hr, $\pm 1\text{C}^\circ$ (% of Value)	30 days, $\pm 5\text{C}^\circ$ (% of Value)
10k	0.002	0.01
10M	0.004	0.02

### Traceability to Standards Lab

Reedholm self calibration modules (SCM, P/N 11038 and SCM-BP, 11106) provide easy, cost-effective methods for making Reedholm instrumentation agree with a company's standards lab. Using a software utility called SCal, an external DMM is brought to the system to make a small set of DC and resistance measurement standards that are input to a text data file. That file is subsequently used by another package called self-calibration to determine the gain correction factors that make the internal DMM exactly match the standards lab DMM. After also measuring current and voltage offsets, the internal DMM is then used to calibrate every DC instrument in the system for gain and offset correction factors. As a result of those measurements, every DC value, forced or measured, in a Reedholm system is directly traced to the standards lab DMM.

### Automatic Calibration of Instruments

Running self-calibration also eliminates the need to do manual calibration. All potentiometers are "set and forget" adjustments with an SCM or SCM-BP.

### Stability After Running SCal

Use of precision resistors and instrument grade amplifiers results in generation of very stable voltages. Likewise, the precision resistors used by the internal DMM to convert SCM voltages to current are stable beyond the 16-bit instrumentation resolution for the first 24 hours after SCal is run. Furthermore, not running SCal for a month does not impact accuracy appreciably.

Current calibrations are based on the SCM voltages plus the 10M $\Omega$  resistor up to 10 $\mu\text{A}$ , and the 10k $\Omega$  resistor to 5A, albeit with considerable extrapolation. Calculation of instrumentation accuracies is determined using support note [SN-115](#).

### Assuring Manufacturing Quality

The SCM provides a straightforward way to prove system accuracy and repeatability, so it fits well with quality assurance standards such as ISO9000 and its successors.

In addition to providing assurance of modules being within calibration, offset and gain correction factor outputs of the self-calibration software can be tracked using statistical process control (SPC) techniques. In this way, modules that might be drifting can be identified and repaired before they cause problems in production or development.

## Changes from Previous SCM

The new SCM-BP and the original SCM provide traceability and automatic calibration, but the new SCM-BP is more stable as a result of design improvements. In addition, temperature measurement and multiplexing of the outputs to a single set of banana jack receptacles.

## Consolidated Outputs

Relays were added to multiplex the external measurement outputs to a set of banana jacks that permit direct connection to an external DMM without having to move the leads to various test points. Doing this makes it simple to connect the SCM-BP output to banana jack connections. It also minimizes voltage offset errors due to thermal emf's when test leads are heated through handling.

## Replaced Power Op Amp

The older SCM forced voltage with a power op amp used in many Reedholm instruments. It combines desirable JFET input stage performance of low input current and low voltage TCR with the ability to deliver  $\pm 100V$ . However, it warms up considerably during operation, so even its good TCR ( $\pm 5\mu V/C^\circ$ ) can be wasted. In addition, the op amp produces shot-noise of  $20\mu V$ . Since the amplifier buffers output voltage regardless of level, that much shot noise combined with uncertainty due to temperature can easily be  $\pm 50\mu V$ , or  $\pm 200ppm$  of  $247mV$ .

The new design uses a JFET input op amp whose operating condition is independent of output voltage, has lower TCR ( $\pm 2\mu V/C^\circ$ ), no shot-noise to speak of, and drives a MOSFET output stage to  $\pm 100V$ . With this approach, low level uncertainty is no greater than at higher voltages.

## Eliminated 10M $\Omega$ Leakage Paths

Layout of the older SCM did not minimize current leakage effects when measuring the  $10M\Omega$  resistor that transforms voltage to current for the  $100nA$ ,  $1\mu A$ , and  $10\mu A$  ranges.

In the new design, the node relay is moved to right outside a shielded section of the module and guard land patterns are used up to the node relay. All connections to the  $10M\Omega$  resistor are made with Teflon wiring to Teflon standoffs or device-to-device connections. This assures that relay leakage resistance of  $>10^{12}\Omega$  is the limiting factor in accuracy of the  $10M\Omega$  resistor, so maximum error contributed by the SCM-BP is  $<10ppm$ .

## Thermal Isolation

All critical analog components are put under an aluminum shield. In addition, an extensive ground plane underneath the shield helps create an isothermal environment. Active heating/cooling is not needed. Temperature stability of the SCM-BP is excellent after SCal is run and the SelfCal.dat data file is populated with measurements from the external calibration DMM. Temporary heating from other instruments does not last long enough to change the SCM-BP temperature.

## Temperature Measurement

While temperature control is not provided, temperature sensing capability was added. Software extracts temperature from two voltage/current measurements on a diode connected transistor. The emitter is connected to the ground plane under the heat/electrostatic shield, and thus indicates temperature of the critical components. A "set and forget" potentiometer is used in conjunction with the software to set temperature during production to match that of a test station digital thermometer. Measured temperature is placed in the SelfCal.dat and SelfCal.ini files.

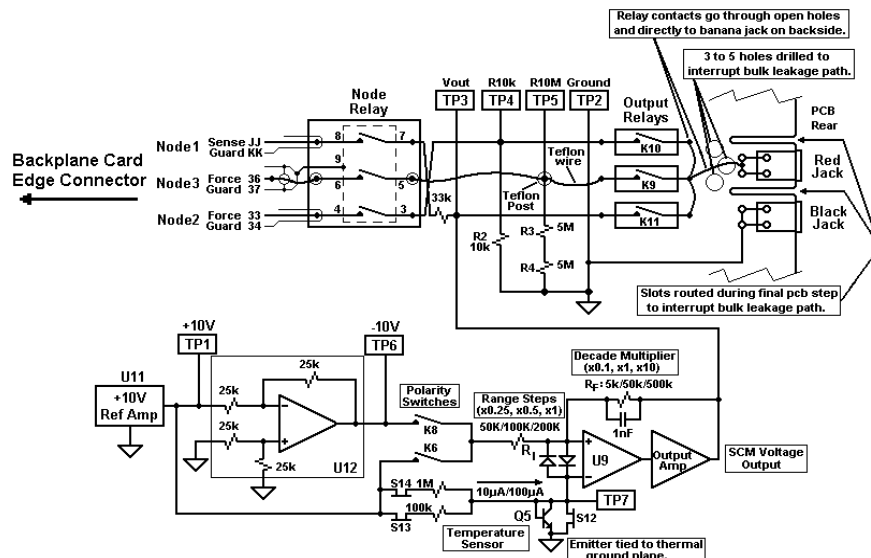


Figure 1 - Simplified Schematic of SCM with Output Control

## Measuring the Self Calibration Module

The RDS DOS SCal utility program is used to measure the cardinal SCM or SCM-BP outputs with an external precision digital multimeter and put those measurements into the SCal data file. Figure 1 shows the multimeter connected to test points on the SCM front edge using the SelfCal Test Lead Set, RI P/N 16360. Figure 2 is a screen capture of the data output that can also be sent to a printer.

This special lead set avoids inaccuracies that would otherwise be introduced by thermally generated voltages, series resistance, and external noise pickup. Most importantly, the lead set avoids the leakage resistance associated with common lead sets when measuring the precision 10MΩ resistor on the SCM and SCM-BP. Support note SN-116, SelfCal Test Lead Set, goes into more detail on why the lead set needs to be used.

After measurements are taken and input, the results are displayed for review before being stored and used to correct module outputs and measurements. Figure 2 is an example output of the voltage and resistance measurements used to essentially transfer accuracy of the external meter to the SCM. Note that the nominal measured voltages outputs are less than the range values. That was done deliberately so that corrections could be made on each current and voltage without causing an over range condition.

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Self Cal Module S/N --->[06011103]   Date ----->[Mar 18, 2011]
Operator ----->[MAT]               Time ----->[2: 48: 48 PM]
Tester ID ----->[RI-40W2]          Date ----->[Mar 20, 2011]
Prior SCal Temperature --->[24.79]
Measured Temperature --->[25.29]

VOLTAGES ENTERED:
Range      Positive      Negative
-----
250mV      246.27mV      -247.93mV
500mV      493.25mV      -494.91mV
1V         987.32mV      -988.95mV
2.5V       2.4698V       -2.4715V
5V         4.9405V       -4.9422V
10V        9.8819V       -9.8834V
25V        24.699V       -24.714V
50V        49.406V       -49.421V
100V       98.818V       -98.832V

RESISTANCES ENTERED:
Range      Actual
-----
10K        10.0008k
10M        10.0061M

Overwrite SelfCal.DAT (Y/N)? N
  
```

Figure 2 - SCal Output Screen

## Performing System Calibration

Self-calibration software determines gain and offset errors relative to those expected from the SCal data file. Correction factors are generated and displayed for each module. Operator approval is required before they are stored in the SelfCal.ini file and then used for correction. The RDS DOS self-calibration software output is shown in figure 3 for a DMM-16. Of all the modules, DMM's produce the richest set of calibration data because they have the most ranges.

During operation, the self-calibration software forces the SCM and the module being calibrated to voltages and currents ~1% below full-scale range points. DMM#1 is calibrated first. If there is a DMM#2 in the system, it is calibrated next. Afterwards, the calibrated DMM#1 is used to calibrate the VFIF and VF modules. Finally, correction factors are generated for those optional instruments capable of dc calibration.

Range	DMM #1 (DMM16)		Test Limits	
	Gain Factor	Offset	Gain Factor	Offset
250mV	999.975m	-283.205u	1.0 ±0.0006	200u
500mV	1.00003	-291.55u	1.0 ±0.0006	250u
1V	1.00001	-301.904u	1.0 ±0.0006	300u
2.5V	1.00002	-340.194u	1.0 ±0.0006	500u
5V	1.00005	-395.535u	1.0 ±0.0006	1m
10V	1.00003	-510.714u	1.0 ±0.0006	2m
25V	999.988m	-2.74776m	1.0 ±0.0006	5m
50V	1.00002	-3.42857m	1.0 ±0.0006	10m
100V	999.973m	-4.83035m	1.0 ±0.0006	20m
100nA	999.047n	8.72424p	1.0 ±0.0040	200p
1uA	999.91n	-60.4868p	1.0 ±0.0030	400p
10uA	999.816n	-776.623p	1.0 ±0.0010	2n
100uA	1.00001	-8.58347n	1.0 ±0.0010	20n
1mA	1.00023	-75.625n	1.0 ±0.0010	200n
10mA	1.00005	-773.214n	1.0 ±0.0010	2u
100mA	1.00058	-6.63392u	1.0 ±0.0030	20u
1A	999.876m	-73.8392u	1.0 ±0.0030	200u

Pausing - Press <Enter>

Figure 3 – Self-Calibration DMM Output Screen