DynAmp

RECTIFIER MONITORING SYSTEM

MODEL RCEM

PORTABLE CURRENT TRANSDUCER VERSION

Installation, Operation and Service Manual

Manual Item No. 043526

Rev. J

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While all information presented is believed to be reliable and in accordance with accepted engineering practices, DynAmp makes no warranties as to the completeness of the information.

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Hazard Warning!



GENERAL

All installation, maintenance and service must be performed by qualified technicians who are familiar with the warnings and instructions of this manual.

Disconnect power to the system before servicing or replacing fuses.

Use of the equipment in a manner not specified by the manufacturer can impair the protection provided within.

DynAmp does not assume liability for the customer's failure to comply with the rules and requirements provided in this manual.



HAZARDOUS VOLTAGE

This equipment is designed to be connected to hazardous electric voltages. Ignoring the installation precautions and warnings can result in severe personal injury or equipment damage.

To avoid the risk of electrical shock or fire, the safety instructions and guidelines in this manual must be followed. The electrical specifications must not be exceeded and the unit must be installed according to directions provided.



INSTALLATION

This equipment is intended for indoor use only. It should be mounted in a well-ventilated area, away from high heat, dust, and corrosive atmosphere. The ambient temperature must not exceed 55°C.

For mounting considerations that fall outside the recommended specifications provided in this manual, the factory should be contacted for approval.

The laptop computer must be located well away from magnetic fields. Failure to comply may result in damage to the computer.

This unit is rated for installation category III, 300V and pollution degree 2.

Symbol Identification:

General definitions of safety symbols used on equipment and manual.



Caution/Warning: Refer to accompanying documents for instructions.

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Revision Page

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all	NEW		01/01
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several	B	Added Safety Section, added 240 channel text, added USB Extender text, revised specification table, added 240 channel connection tables, revised drawing list table, and added ANSI Circuit 52	03/03
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several	J	ECO-3277 – Update manual: Replace Personal DAQ/56 with Measurement Computing USB-2533	08/12

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1. SAFETY

1.1 OVERVIEW

This equipment is designed to be connected to hazardous electric voltages. Ignoring the installation precautions and warnings can result in severe personal injury or equipment damage. The following are general guidelines that should be followed when installing, operating and servicing the RCEM.

- Qualified technicians who are familiar with the warnings and instructions of this manual must perform all installation, maintenance and service.
- Always follow all local and plant safety procedures.
- The equipment covers should remain closed at all times during operation to ensure safety of personnel. Only authorized personnel or technicians should be allowed to open and service the equipment.
- Cover #3 (PC Board Cover) may be removed if the operator needs access to the diode waveform connectors. Use caution whenever the cover is removed.
- Only qualified technicians should perform Service. If use of an oscilloscope becomes necessary during operation or servicing, either the scope must be floating or ungrounded, or differential probe(s) must be used. The equipment is isolated from the mains via the power transformers. If a grounded scope is used, a hazardous condition is created since current will flow through the probe to ground.
- Replace fuses with correct type, size and value. Refer to the servicing instructions or spare parts list for more information on replacement fuses. Do not bypass the fuses or modify the electronics. Disconnect power to the system before replacing fuses. Failure to follow these instructions will result in intermittent operation and premature failure and will void the warranty.
- The equipment is not intrinsically safe. Do not place in explosive atmospheres.
- The Current Transducers are double insulated to protect the operator from possible hazardous voltage potentials of the rectifier. The transducers are also protected from heat by a protective sheath.
- Make sure the transducer cables and interconnection cables are kept well away from hazardous voltage potentials and heat sources inside the rectifier.
- Keep the electronics enclosure as far as possible away from the hazardous voltage potentials of the rectifier.
- Use of the equipment in a manner not specified by the manufacturer can impair the protection provided.

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2. HANDLING AND STORAGE

DynAmp products are engineered and manufactured for use in industrial environments. However, they contain sensitive electronic and mechanical components which may be damaged and fail if not handled and stored properly. All products must be handled and stored with the same care as any precision measurement instrument. Severe bumps or jolts may damage internal parts and cause malfunction or premature failure. DynAmp products are designed and assembled with conformal coating, shock mounting, and environmental seals, when appropriate or when specified. However, this protection requires that the product must be properly installed and operational before the protection is fully functional. Therefore, adequate protection from humidity, shock, and temperature must be provided during handling and storage prior to installation.

The handling and storage of equipment must be sufficient to meet the storage temperature and humidity specifications of the product and to prevent any condensation or contact with water or any other liquid. The storage location and container or crate must provide adequate protection from precipitation (rain, snow, ice) and direct water contact. Adequate shelter must be provided to prevent the accumulation of precipitation (rain, snow, ice) and water which can lead to the deterioration or failure of shipping containers or crates and cause water ingress. Storage in coastal or industrial areas subject to salt-laden or corrosive air or areas of wind-driven sand or other abrasive dust must be adequate to prevent the deterioration or failure of shipping containers or crates and cause ingress. Frequent inspection of storage areas and storage containers or crates is required to ensure proper storage conditions are being maintained.

If the shipping container or crate is opened and/or the equipment is removed for inspection prior to installation, the equipment must be repackaged in the original undamaged container or crate in the same manner as it was shipped to prevent environmental damage or placed in a storage location that meets the required environmental and storage conditions.

General product storage temperature and humidity requirements:

Storage Temperature:	-40 to 70°C
	-40 to 158°F
Storage Humidity:	85%, non-condensing

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3. PRODUCT DESCRIPTION

3.1 GENERAL

The DynAmp RECTIFIER MONITORING SYSTEM Model RCEM is designed for isolated measurement of device currents in multiple path power rectifiers.

Model RCEM is a monitoring system composed of a 120 Channel Data Acquisition Unit, a laptop computer, Current Transducers, and the interconnection cables

A 240 Channel RCEM is also available. This system consists of two 120 Channel Data Acquisition Units, a laptop computer, Current Transducers, and interconnection cables.

3.2 DEFINITIONS

The following terms are used extensively in this manual:

Channel	Individual Flexible Current Transducer and associated electronic circuitry
DAU	Abbreviation for Data Acquisition Unit; rectifier monitoring system active electronics hardware
Device	Rectifier semiconductor device (such as a diode or thyristor).
Current Transducer	DynAmp, LLC Current Transducer
I/O	Input/Output device.
Laptop Computer	Portable computer used to display the rectifier data locally
Leg	Group of rectifier devices connected in parallel. Symbolically referred to as **R** or **S** in ANSI circuit diagrams
Multiplexer Address	The binary address which selects one of six integrator card leg output signals.
USB	Universal Serial Bus
RCEM	DynAmp, LLC Rectifier Condition Evaluation Monitor
RMS	root mean square – Effective value of a waveform

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3.3 DATA ACQUISITION UNIT

The Data Acquisition Unit contains the following elements:

1. Analog Card Rack containing:
   a. Backplane
   b. Reset Sync Cards
   c. Integrator Cards
2. Measurement Computing USB-2533 – USB Data Acquisition Board
3. USB Extender Receiver
4. Digital Interface Module

3.4 LAPTOP COMPUTER

The laptop computer is connected to the Data Acquisition Unit via the USB Extender Sender and RJ-45 cable. The laptop computer provides a means of displaying the rectifier data. It also allows access to the internal test signal generator. The data is displayed on a spreadsheet program and individual leg bar graphs.

3.5 FLEXIBLE CURRENT TRANSDUCERS

The DynAmp Flexible Current Transducers provide the input signals to the Data Acquisition Unit. The Current Transducers are mounted around each diode current path in the rectifier. The Current Transducers have an aperture of 8.3 inches (210 mm). A fiberglass sheath protects the Current Transducer from abrasion.

3.6 MAGNETIC FIELD STATEMENT

The magnetic field from a high current DC bus may damage or destroy the laptop computer hard disk drive. To avoid damage, **the laptop should be kept as far from the DC bus as practicable.** This warning applies at all times.

The destructive effect of a magnetic field on a hard disk drive depends on the orientation of the laptop computer within the field, and the degree of magnetic shielding provided by the hard disk enclosure. Laptop computer and hard disk manufacturers do not provide specifications for maximum magnetic field outside the hard disk enclosure.

It is difficult to accurately specify a maximum safe Gauss level for laptop computer disk drives. Our best estimate is a maximum ambient magnetic field strength of 25 to 50 Gauss for safe laptop computer operation.

This manual provides recommended guidelines for use of the rectifier monitoring system. It is the sole responsibility of the customer to assure safety of equipment and personnel when using this product.

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4. PRODUCT SPECIFICATIONS

The specifications for the Rectifier Condition Evaluation Monitor are listed in Table 4.1.

Table 4.1
Rectifier Condition Evaluation Monitor Specifications

Physical		
Dimensions		Comments:
Data Acquisition Unit	22”W x 23”H x 13.75”D (559 x 584 x 349) mm	
Current Transducer	Length (Open) 24 in. (610 mm) I.D. (Closed) 8.3 in. (210 mm) O.D. (Closed) 7.0 in. (178 mm)	Standard Size (other sizes are available)
Transducer Minimum Bending Radius	1.50 in. (38 mm)	
Transducer cable length	4.5 ft. (1.37 m)	
Weight		
Data Acquisition Unit	55 lbs. (20.5 kg)	
Current Transducer	0.4 lbs. (0.15 kg)	
Interconnection Cables		
Leg Cable Length	33 ft (10 m)	Data Acquisition Unit(s) to Flexible Current Transducers
USB Cable Length	15 ft (5 m)	Computer to USB Extender Sender
Serial Data Cable Length (Type Category 5E)	150 ft (45.7 m)	USB Extender Sender to Data Acquisition Unit
USB Cable Length	15 ft (5 m)	Data Acquisition Unit #1 to Data Acquisition Unit #2 (240 Channel Systems)

Environmental		
Temperature		Comments:
Data Acquisition Unit	0°C to 50°C	
Current Transducer	-20°C to +100°C	
Leg Cables	-20°C to +105°C	
Humidity		
Data Acquisition Unit	85% RH non-condensing	
Current Transducer	85% RH non-condensing	

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Table 4.1
Rectifier Condition Evaluation Monitor Specifications (Continued)

Electrical		
AC Supply		Comments:
Voltage	100 – 240 Vac	Automatic Selection
Frequency	50/60 Hz	
Basic Accuracy	5%	
Measuring Range		
Current Transducer	0…2000A	Standard Scaling (other scale factors are available)
Data Acquisition Unit	10 to 100%	
Output		
Analog Output	1V/1kA	Waveform Connectors
Serial Data	Data Port (Type RJ-45)	Laptop Computer

Safety		
Isolation		Comments:
Current Transducer	5550 VAC, 1 Minute @ 60 Hz	
Data Acquisition Unit Output to line	Installation Category III @ 300 Volts	

Other		
Visual Indicators		Comments:
Data Acquisition Unit	+24V LED MUX A0 – MUX A2 LEDs TEST MODE LED TEST A0 – TEST A1 LEDs	
USB-2533 Update Rate	6 seconds for 120 channels	

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5. TECHNICAL DESCRIPTION

5.1 GENERAL

The Data Acquisition Unit(s) (DAU) contains one analog card rack with backplane, reset sync cards, and integrator cards. The Data Acquisition Unit also contains the USB-2533 USB Data Acquisition Board, USB Extender Receiver, and three power supplies. The USB-2533 accepts a maximum of 120 device data channels. The Data Acquisition Unit #2 in a 240 Channel system does not contain an USB Extender Receiver.

5.2 BASIC THEORY OF OPERATION

Each current transducer is associated with the measurement channel for a specific rectifier element. The signal from each current transducer is conducted to the DAU via an individual 2-conductor cable and a wire pair within the interconnection cable.

The output from a current transducer is a voltage waveform corresponding to the instantaneous change of current in the rectifier device associated with that current transducer. Integrating the output signal of the current transducer returns it to the current waveform being conducted by the rectifier device. The current waveform is converted to a DC voltage proportional to the RMS value of the integrated signal.

The analog card rack contains multiplexer circuits to switch the DC voltage signals into the twenty analog input channels located in the USB-2533. The digital I/O in the USB-2533 controls the multiplexer. The multiplexing scheme can be described as a 6-leg by 20-channel matrix. One of six integrator channels ("legs") is addressed on all 20 integrator cards.

5.3 ANALOG CARD RACK

The analog card rack contains the following elements: one backplane, two reset sync cards, and twenty integrator cards. See Figure 5.1.

DAU DATA I/O CONNECTOR VARIATIONS		
DAU VERSION	DATA PORT	USB PORT
120 CHANNEL	INSTALLED	N/A
240 CHANNEL DAU #1	INSTALLED	USB “A”
240 CHANNEL DAU #2	N/A	USB “B”

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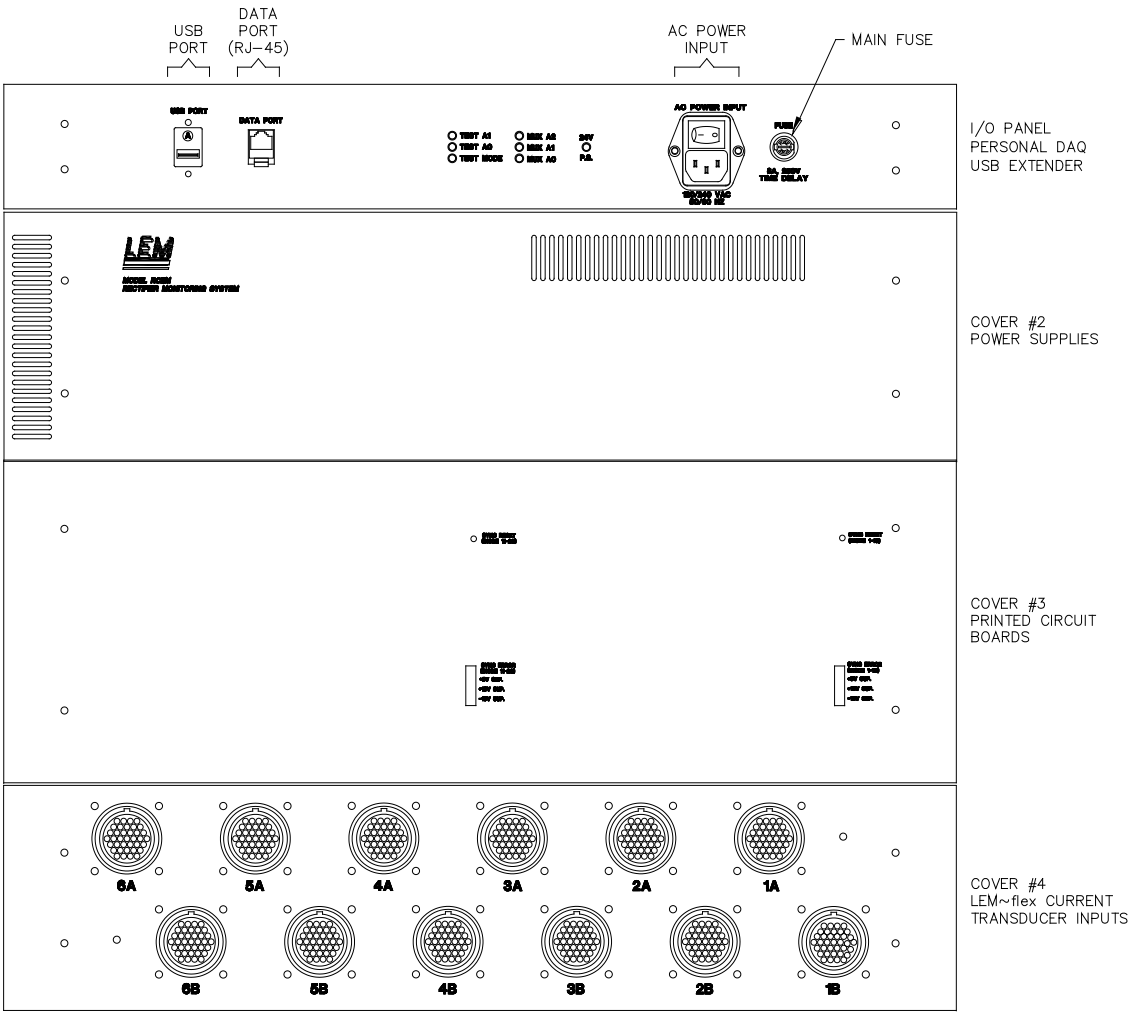


Figure 5.1
Analog Card Rack

5.4 BACKPLANE

The digital interface circuits to/from the USB-2533 are located on the Data Acquisition Unit backplane. The backplane also contains the reset sync cards connectors, the integrator card connectors, the signal input connectors from the current transducers, and the power circuits.

The backplane also contains the ac zero-crossing detector circuit. This circuit supplies the ac zero-crossing timing pulse to the reset sync pulse generator and the test signal generator circuits located on the Reset Sync Cards.

5.5 POWER CIRCUITS

The power circuits in the Data Acquisition Unit consist of the ac power input circuit, the regulated quad output power supply, the +12V power supply, the + 5V power supply, and the dc power input circuits.

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The ac power input circuit contains varistors used to clamp transient voltages and a filter module to reduce line-transmitted noise. The fuses are used to protect the power supply and the ac zero-crossing detector.

The regulated power supply has 4 output voltages. They are +5VDC, ±15VDC, and +24VDC. The regulated voltages all have a common ground circuit. The power supply is mounted on card rack side panel. This power supply may be accessed by removing Cover #2.

The power supply outputs are connected to the backplane. LC filters located on the backplane filter the regulated voltages. The +24VDC is connected to the digital interface module as well as powering the rectifier/test relays on the integrator cards.

The isolated +12V and the +5V power supplies are also mounted on the card rack side panel. The +12V power supply is used to power the USB-2533 while the +5V power supply provides power to the USB Extender Receiver. All three power supplies have a universal ac power input circuit rated at 100-240VAC, 50/60Hz.

5.6 ANALOG INPUT CONNECTORS

There are twenty analog input connectors located to the bottom edge of the backplane. The current transducers are connected to these connectors via twelve circular connectors located on the analog input panel. The backplane connects the current transducer output signals to the integrator inputs. Each integrator card has an associated 12-position input connector.

5.7 INTEGRATOR CARDS

Each integrator card provides electronic circuitry for six channels. Each integrator includes the following:

- rectifier/test DPDT relays
- active integrator circuits
- RMS-to-dc converters
- (1) 6-to-1 analog multiplexer

The circuits found on each integrator card are discussed below.

1. Rectifier/Test DPDT Relay.

   Each of the test signal DPDT relays is used to switch the input source for two integrator circuits. The normally closed relay contacts connect the integrator inputs to the current transducer signals. Energizing the ganged relay coils selects the test signal as the input source for all integrator circuits. A digital I/O channel in the USB-2533 controls the relays.

2. Active Integrator Circuits.

   Each integrator card contains six active integrator circuits. Each integrator circuit uses a CMOS analog switch to reset the integrating capacitor. CMOS digital buffers buffer the integrator reset pulses.

   Integrator resets are synchronized to the ac line supplying power to the DAU. Reset synchronization is established by the Reset Sync Cards during its initialization sequence upon power-up. A “RCEM RESET” command from the spreadsheet program

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will also cause the integrator resets to synchronize to the ac line.

To work properly, each integrator must be reset when the associated rectifier device is not conducting current during the commutation cycle. In a full-wave, three leg rectifier, the reset pulse will occur at a different instant for each integrator on the integrator card. The six integrator channels on each integrator card are referred to as Leg 1, Leg 2, Leg 3, Leg 4, Leg 5, and Leg 6.

The integrator circuit outputs are scaled to 1V/1kA. The output of each integrator circuit is available at the 12-position waveform output connector located on the top edge of each integrator card. The integrator circuit outputs are also connected to the pc board edge connector. The reset sync cards to generate the reset pulses use these outputs. The final connection is to the RMS-to-dc converters. This is the output signal path.

3. RMS-TO-DC Converter.

   The RMS-to-dc converters are used to convert the device current waveform to a dc voltage. The outputs of the RMS-to-dc converters are connected to the 6-to-1 multiplexer.

4. 6-to-1 Analog Multiplexer Circuit.

   The multiplexer used is an eight input, one output CMOS analog multiplexer. Inputs S1 through S6 are connected to the six RMS-to-dc converter outputs. Inputs S7 and S8 are not used. The output of the 6-to-1 multiplexer is connected to a non-inverting amplifier with a gain of 5. This output is routed to the USB-2533 via the backplane and a wiring harness.

5.8 RESET SYNC CARDS

This circuit generates the reset pulses required to control the analog integrator circuits. The device waveform signal from the integrator card are applied to comparators. The outputs of the comparators are connected to a microcontroller. The microcontroller uses the outputs from the comparators to generate the reset signals.

The first Reset Sync Card generates the reset signals for the first ten Integrator Cards while the second Reset Sync Card generates the resets for the second group of ten Integrator Cards. The reset signals are available on connectors P23 and P24 located on the backplane. See Figure 5.2 for the Reset Pulse Connector Location and Figure 5.3 for Reset Pulse Signal Location.

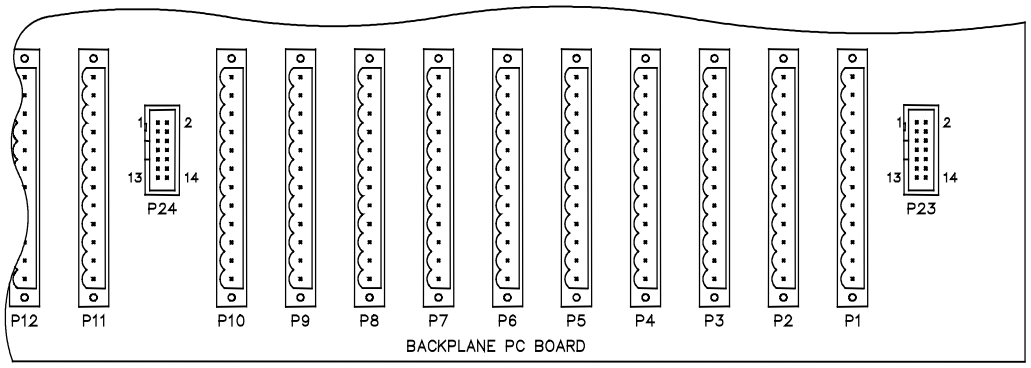


Figure 5.2
Reset Pulse Connector Location

	PIN NO.		
Reset Pulse 1	1	2	Common
Reset Pulse 2	3	4	Common
Reset Pulse 3	5	6	Common
Reset Pulse 4	7	8	Common
Reset Pulse 5	9	10	Common
Reset Pulse 6	11	12	Common
Zero-crossing	13	14	Common

Notes:
1) P23: Channels 1 – 10
2) P24: Channels 11 – 20

Figure 5.3
Reset Pulse Signal Location

5.9 TEST SIGNAL GENERATOR

The reset sync card also contains the test signal generator. A second microcontroller is used to generate the test pattern. This microcontroller also uses the ac zero-crossing circuit to generate the pattern. The timing signals from the microcontroller are connected to the signal generator consisting of op amps U11 and U14, analog switch U9, and a reference voltage produced by U12. The test signal waveform for the 571A test signal is shown in Figure 5.4.

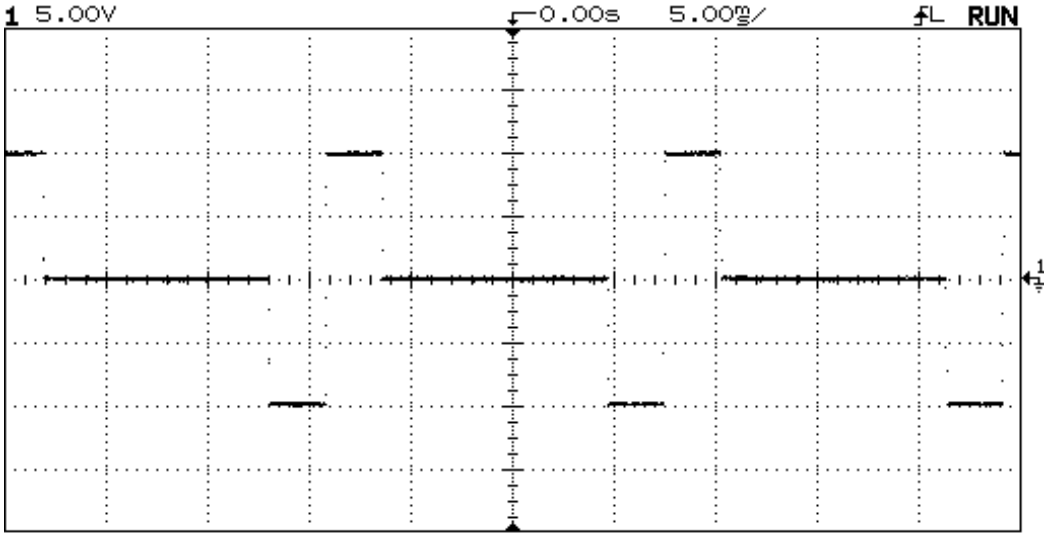


Figure 5.4
571A Test Signal Waveform

5.10 MEASUREMENT COMPUTING USB-2533

The USB-2533 is a self-contained USB Data Acquisition Board with twenty analog input channels and 16 digital I/O channels. The USB-2533 is located on the top end panel of the Data Acquisition Unit. See Figure 5.5. The USB-2533 is powered by an isolated +12V power supply.

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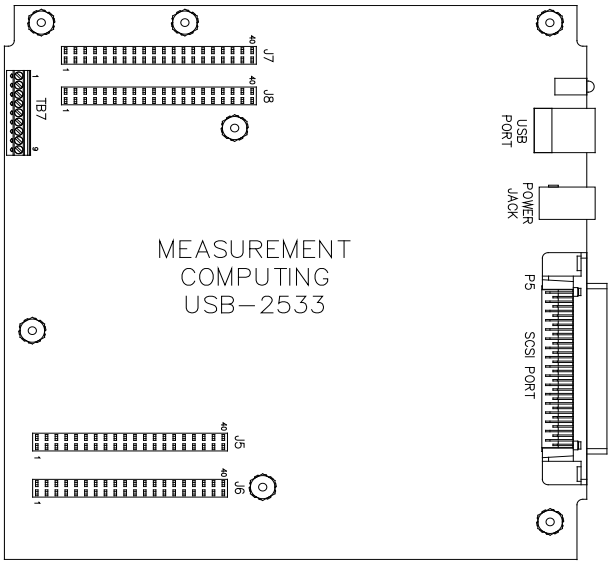


Figure 5.5
Measurement Computing USB-2533

5.11 USB EXTENDER RECEIVER

The USB specification severely limits the distance of an USB peripheral from the computer. The USB Extender allows that distance to be increased to a maximum distance of about 300 feet. The USB Extender Receiver is located near the USB-2533 on the top end panel of the Data Acquisition Unit. See Figure 5.6. The receiver is powered by an isolated +5V power supply.

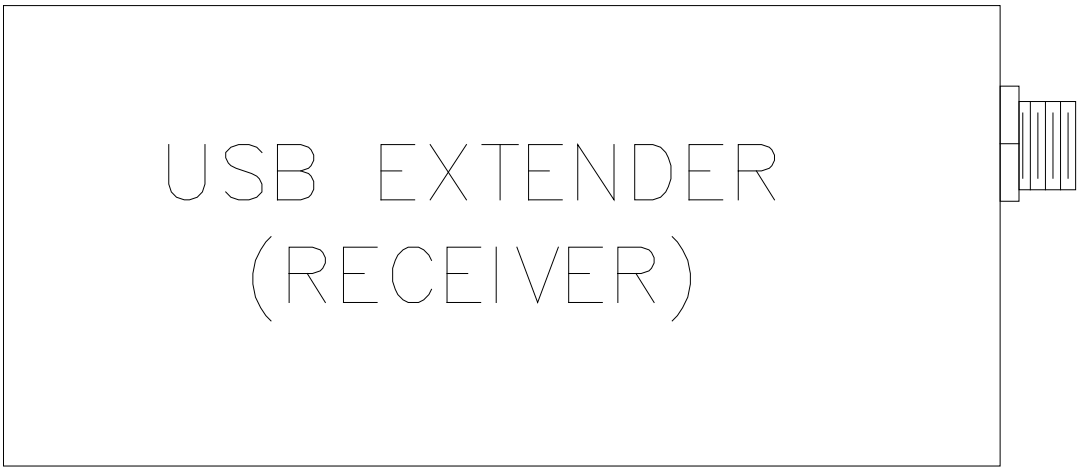


Figure 5.6
USB Extender Receiver

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5.12 DIGITAL INTERFACE MODULE

The digital interface module connects the 5V digital outputs of the USB-2533 to the 24V digital inputs required by the backplane. This module consists of an input terminal strip, an interface integrated circuit, and an output terminal strip. The module is located adjacent to the USB-2533 Data Acquisition Board. See Figure 5.7.

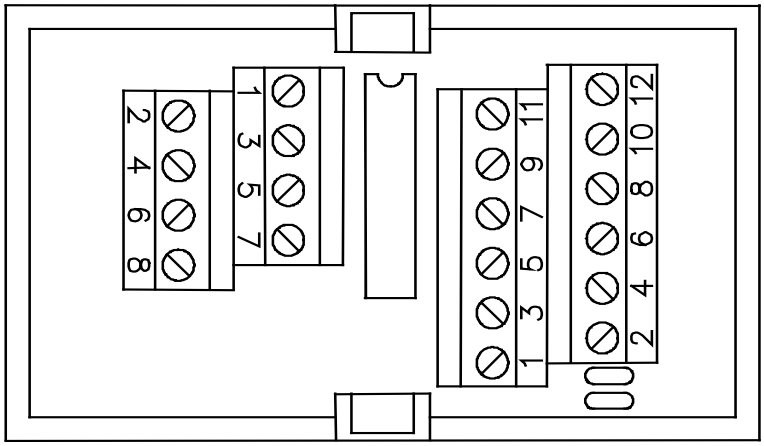


Figure 5.7
Digital Interface Module

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6. PREPARATION FOR USE

6.1 SYSTEM CHECKOUT AND PREPARATION

IMPORTANT
Make a system checkout when the equipment is received. When unpacking or handling the current transducer assemblies, treat them very gently; do not handle in such a manner as to place strain on the current transducers. The current transducers should ALWAYS be treated as delicate measurement instruments.

6.2 RECTIFIER SHUTDOWN

WARNING
Disconnect the input side of the rectifier from the AC power supply and disconnect the output side of the rectifier from the load, or use your approved disconnect procedure to ensure that no AC input is present and that cell-effect voltages from the electrochemical process are not present during installation of current transducers.

6.3 TRANSDUCER MOUNTING AND CONNECTION CONSIDERATIONS

Once the rectifier has been safely taken off line, a current transducer may be safely placed around each device (or related fuse or pigtail as circumstances dictate).

6.4 INSTALLATION INSTRUCTIONS

Make sure the current transducers and their output cables are clean before installing them in the rectifier. If the current transducers and cables are not clean, the contaminants on them may provide a conductive path for a high-voltage breakdown. This section describes how to check for such paths.

The DynAmp Current Transducers are factory calibrated to DynAmp, LLC's Current Transducer standard circuit. Since all Current Transducers are electrically identical, any Current Transducer may be used for any diode or thyristor. However, it is critical that each current transducer be connected to the proper RCEM channel. Incorrect correlation of current transducers during this process will result in confusing measurement data.

TO INSTALL CURRENT TRANSDUCERS IN A RECTIFIER:

A. Place current transducers on device paths in the proper direction (conventional plus-to-minus current flowing in the same direction as the polarity arrow). Proper Current Transducer mounting is shown in Figure 6.1. The RCEM will not sync the reset pulse to the diode waveforms if the transducers are reversed.

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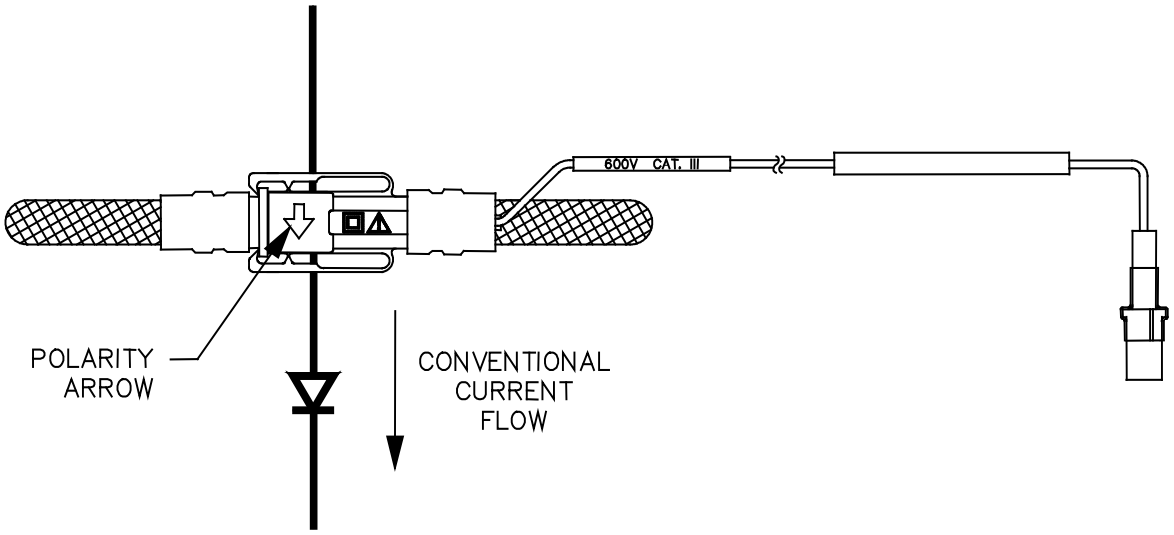


Figure 6.1
Current Transducer Installation Detail

B. To install the Current Transducer, squeeze the latch and separate the ends. Then encircle the conductor and snap the ends together.

CAUTION
The Flexible Current Transducer must be installed with the interconnection cable on the outside of the loop when the latch is engaged. The polarity arrow, the double insulation, and the warning symbols will all be on the outside of the loop. Also, do not exceed the minimum bending radius of the Current Transducer when installing the transducer around the conductor. Exceeding the bending radius will degrade the measurement accuracy

C. Connect each current transducer cable to the mating half of extension cable (refer to the enclosed interconnection drawings). Table 6.1 through Table 6.7 summarizes the connections for various rectifier configurations on 120 channel systems and 240 channel systems. The cable connectors are keyed for proper polarity.

D. Connect the Data Acquisition Unit(s) to the appropriate ac power.

E. Turn ON the Data Acquisition Unit(s) using the power switch located on the I/O Panel.

F. Put the rectifier back on-line and bring it up to load.

The RCEM may be tested, using its built-in test signal generator, during rectifier testing. Use the procedure in Appendix B.9 whenever the RCEM measurements indicate a problem in a rectifier, *before taking the rectifier off-line*. Use caution when disconnecting the current transducer cables, since hazardous voltages may exist when the current transducers are installed on live rectifier circuits.

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Table 6.1
Current Transducer Connections, 6-Leg Rectifier (20 Diodes Max.)

Leg 1		Leg 2		Leg 3	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1A-1	1	2A-1	1	3A-1
↓	↓	↓	↓	↓	↓
10	1A-10	10	2A-10	10	3A-10
11	1B-1	11	2B-1	11	3B-1
↓	↓	↓	↓	↓	↓
20	1B-10	20	2B-10	20	3B-10
Leg 4		Leg 5		Leg 6	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4A-1	1	5A-1	1	6A-1
↓	↓	↓	↓	↓	↓
10	4A-10	10	5A-10	10	6A-10
11	4B-1	11	5B-1	11	6B-1
↓	↓	↓	↓	↓	↓
20	4B-10	20	5B-10	20	6B-10

Notes: 1) This chart applies to a 120 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connect to Data Acquisition Unit connectors 1A through 6B

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Table 6.2
Current Transducer Connections, 6-Leg Rectifier (40 Diodes Max.)

Leg 1		Leg 2		Leg 3	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1A-1	1	2A-1	1	3A-1
↓	↓	↓	↓	↓	↓
10	1A-10	10	2A-10	10	3A-10
11	1B-1	11	2B-1	11	3B-1
↓	↓	↓	↓	↓	↓
20	1B-10	20	2B-10	20	3B-10
21	1C-1	21	2C-1	21	3C-1
↓	↓	↓	↓	↓	↓
30	1C-10	30	2C-10	30	3C-10
31	1D-1	31	2D-1	31	3D-1
↓	↓	↓	↓	↓	↓
40	1D-10	40	2D-10	40	3D-10
Leg 4		Leg 5		Leg 6	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4A-1	1	5A-1	1	6A-1
↓	↓	↓	↓	↓	↓
10	4A-10	10	5A-10	10	6A-10
11	4B-1	11	5B-1	11	6B-1
↓	↓	↓	↓	↓	↓
20	4B-10	20	5B-10	20	6B-10
21	4C-1	21	5C-1	21	6C-1
↓	↓	↓	↓	↓	↓
30	4C-10	30	5C-10	30	6C-10
31	4D-1	31	5D-1	31	6D-1
↓	↓	↓	↓	↓	↓
40	4D-10	40	5D-10	40	6D-10

Notes:
1) This chart applies to a 240 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connect to Data Acquisition Unit #1 connectors 1A through 6B
4) Cables 1C through 6D connect to Data Acquisition Unit #2 connectors 1A through 6B

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Table 6.3
Current Transducer Connections, Parallel 6-Leg Rectifier (10 Diodes Max)

Leg 1A		Leg 2A		Leg 3A	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	1A-1 ↓ 1A-10	1 ↓ 10	2A-1 ↓ 2A-10	1 ↓ 10	3A-1 ↓ 3A-10
Leg 4A		Leg 5A		Leg 6A	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	4A-1 ↓ 4A-10	1 ↓ 10	5A-1 ↓ 5A-10	1 ↓ 10	6A-1 ↓ 6A-10
Leg 1B		Leg 2B		Leg 3B	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	1B-1 ↓ 1B-10	1 ↓ 10	2B-1 ↓ 2B-10	1 ↓ 10	3B-1 ↓ 3B-10
Leg 4B		Leg 5B		Leg 6B	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	4B-1 ↓ 4B-10	1 ↓ 10	5B-1 ↓ 5B-10	1 ↓ 10	6B-1 ↓ 6B-10

Notes: 1) This chart applies to a 120 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connect to Data Acquisition Unit connectors 1A through 6B

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Table 6.4
Current Transducer Connections, Parallel 6-Leg Rectifier (20 Diodes Max)

Leg 1A		Leg 2A		Leg 3A	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1A-1	1	2A-1	1	3A-1
↓	↓	↓	↓	↓	↓
10	1A-10	10	2A-10	10	3A-10
11	1B-1	11	2B-1	11	3B-1
↓	↓	↓	↓	↓	↓
20	1B-10	20	2B-10	20	3B-10
Leg 4A		Leg 5A		Leg 6A	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4A-1	1	5A-1	1	6A-1
↓	↓	↓	↓	↓	↓
10	4A-10	10	5A-10	10	6A-10
11	4B-1	11	5B-1	11	6B-1
↓	↓	↓	↓	↓	↓
20	4B-10	20	5B-10	20	6B-10
Leg 1B		Leg 2B		Leg 3B	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1C-1	1	2C-1	1	3C-1
↓	↓	↓	↓	↓	↓
10	1C-10	10	2C-10	10	3C-10
11	1D-1	11	2D-1	11	3D-1
↓	↓	↓	↓	↓	↓
20	1D-10	20	2D-10	20	3D-10
Leg 4B		Leg 5B		Leg 6B	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4C-1	1	5C-1	1	6C-1
↓	↓	↓	↓	↓	↓
10	4C-10	10	5C-10	10	6C-10
11	4D-1	11	5D-1	11	6D-1
↓	↓	↓	↓	↓	↓
20	4D-10	20	5D-10	20	6D-10

Notes:
1) This chart applies to a 240 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connect to Data Acquisition Unit #1 connectors 1A through 6B
4) Cables 1C through 6D connect to Data Acquisition Unit #2 connectors 1A through 6B

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Table 6.5
Current Transducer Connections, 12-Leg Rectifier (10 Diodes Max.)

Leg 1		Leg 2		Leg 3	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	1A-1 ↓ 1A-10	1 ↓ 10	2A-1 ↓ 2A-10	1 ↓ 10	3A-1 ↓ 3A-10
Leg 4		Leg 5		Leg 6	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	4A-1 ↓ 4A-10	1 ↓ 10	5A-1 ↓ 5A-10	1 ↓ 10	6A-1 ↓ 6A-10
Leg 7		Leg 8		Leg 9	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	1B-1 ↓ 1B-10	1 ↓ 10	2B-1 ↓ 2B-10	1 ↓ 10	3B-1 ↓ 3B-10
Leg 10		Leg 11		Leg 12	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1 ↓ 10	4B-1 ↓ 4B-10	1 ↓ 10	5B-1 ↓ 5B-10	1 ↓ 10	6B-1 ↓ 6B-10

Notes: 1) This chart applies to a 120 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connects to Data Acquisition Unit connectors 1A through 6B

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Table 6.6
Current Transducer Connections, 12-Leg Rectifier (20 Diodes Max.)

Leg 1		Leg 2		Leg 3	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1A-1	1	2A-1	1	3A-1
↓	↓	↓	↓	↓	↓
10	1A-10	10	2A-10	10	3A-10
11	1B-1	11	2B-1	11	3B-1
↓	↓	↓	↓	↓	↓
20	1B-10	20	2B-10	20	3B-10
Leg 4		Leg 5		Leg 6	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4A-1	1	5A-1	1	6A-1
↓	↓	↓	↓	↓	↓
10	4A-10	10	5A-10	10	6A-10
11	4B-1	11	5B-1	11	6B-1
↓	↓	↓	↓	↓	↓
20	4B-10	20	5B-10	20	6B-10
Leg 7		Leg 8		Leg 9	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1C-1	1	2C-1	1	3C-1
↓	↓	↓	↓	↓	↓
10	1C-10	10	2C-10	10	3C-10
11	1D-1	11	2D-1	11	3D-1
↓	↓	↓	↓	↓	↓
20	1D-10	20	2D-10	20	3D-10
Leg 10		Leg 11		Leg 12	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	4C-1	1	5C-1	1	6C-1
↓	↓	↓	↓	↓	↓
10	4C-10	10	5C-10	10	6C-10
11	4D-1	11	5D-1	11	6D-1
↓	↓	↓	↓	↓	↓
20	4D-10	20	5D-10	20	6D-10

Notes:
1) This chart applies to a 240 Channel RCEM
2) 1A-1 = Leg cable “1A”, Current Transducer connector “1”
3) Cables 1A through 6B connects to Data Acquisition Unit #1 connectors 1A through 6B
4) Cables 1C through 6D connects to Data Acquisition Unit #2 connectors 1A through 6B

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Table 6.7
Current Transducer Connections, 1-Leg of a Multi-Leg Rectifier

Leg "n"		Leg "n"		Leg "n"	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
1	1A-1	6	2A-1	11	3A-1
2	1A-2	7	2A-2	12	3A-2
3	1A-3	8	2A-3	13	3A-3
4	1A-4	9	2A-4	14	3A-4
5	1A-5	10	2A-5	15	3A-5
Leg "n"		Leg "n"		Leg "n"	
Diode No.	Cable No.	Diode No.	Cable No.	Diode No.	Cable No.
16	4A-1	21	5A-1	26	6A-1
17	4A-2	22	5A-2	27	6A-2
18	4A-3	23	5A-3	28	6A-3
19	4A-4	24	5A-4	29	6A-4
20	4A-5	25	5A-5	30	6A-5

Notes:
1) Rectifier must have at least 3 legs
2) This table shows connections for 30 diodes/leg
3) 1A-1 = Leg cable "1A", Current Transducer connector "1"
4) Cables 1A through 6A connects to Data Acquisition Unit connectors 1A through 6A

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7. MAINTENANCE AND TROUBLESHOOTING

7.1 CALIBRATION INTERVALS

DynAmp does not specify required intervals of calibration for its products.

The end user of the product is responsible for identifying the appropriate interval between calibrations. The intervals should be determined based on the following factors:

- Requirements of a Quality Management System
- Accuracy and permissible limits of errors
- Purpose and usage
- Experience with similar products
- Manufacturer's recommendations
- Stability of the product
- Past history
- Other characteristics of the product

Reference: "ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories" and Laboratory Accreditation Bureau "Guidance for Documenting and Implementing ISO/IEC 17025:2005 and Laboratory Guidance."

As a guideline, DynAmp recommends a 24-month interval of calibration for all permanently installed products and a 12-month interval of calibration for all products used in portable applications.

7.2 GENERAL

IMPORTANT
The RCEM electronics will not operate until the communications link is established with the laptop computer.

This section contains some specialized tests of the electronics and current transducers of the RCEM, as well as some preventive maintenance procedures. The output of the built-in signal generator provides a test signal for testing the overall operation of the RCEM as well as its accuracy.

7.3 VERIFYING PROPER OPERATION

Data acquired from the test signal generator should be within ±1.5% of the selected test signal level. If data acquired from the test signal generator is within specified accuracy, the problem is not likely to be a DAU hardware problem. If data acquired from the test signal generator is not within specified accuracy, continue with the steps in this section.

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7.4 FUSE REPLACEMENT

Replace DAU fuse(s) with the specified type and current rating. The main fuse is located on the I/O Panel. The ac zero-crossing fuse is located on the end of the analog card rack.

1. Disconnect power to the system before servicing or replacing fuses.
2. Turn the DAU power switch off.
3. Remove the fuseholder cap. You may use the blade of a small screwdriver, if desired.
4. Remove the blown fuse from the fuse clip and replace with new fuse. Be sure to insert the replacement fuse in the proper location for the appropriate line voltage.

7.5 STATIC PRECAUTIONS WHEN SERVICING

Servicing should be performed by qualified personnel only, following procedures described herein.

If troubleshooting indicates a need to replace a component on a printed circuit board or to replace the entire board, measures to prevent electrostatic discharge (ESD) damage must be taken, as follows:

A.) ALWAYS wear a wrist strap connected to ground through a 1-megohm resistor when working on printed circuit boards.

B.) Use a soldering iron with a grounded tip.

C.) Use a non-static generating de-soldering pump (metallic) or solder removal braid.

D.) Transport static sensitive components in static shielding bags or rails. A new printed circuit board should be treated as a static sensitive device. The fact that a part is installed on a board does not make the part static safe.

E.) If possible, perform printed circuit board maintenance at a workstation that has a conductive covering that is grounded through a 1-megohm resistor. If a conductive tabletop cover is not available, a clean steel or aluminum tabletop is an excellent substitute.

F.) Keep plastic, vinyl, Styrofoam and other non-conductive materials away from printed circuit boards. They are good static generators that do not give up their charge easily.

G.) Return goods to DynAmp, LLC in static safe packaging. This will limit further component damage from ESD.

CAUTION
Do not touch any printed circuit board unless you are wearing a grounded wrist strap, as circuit damage may occur.

7.6 VERIFYING PROPER INTEGRATOR RESET SYNCHRONIZATION

One possible source of incorrect device data is improper integrator reset synchronization. Check any suspect channels with an oscilloscope. The waveform should look similar to Figure 7.1.

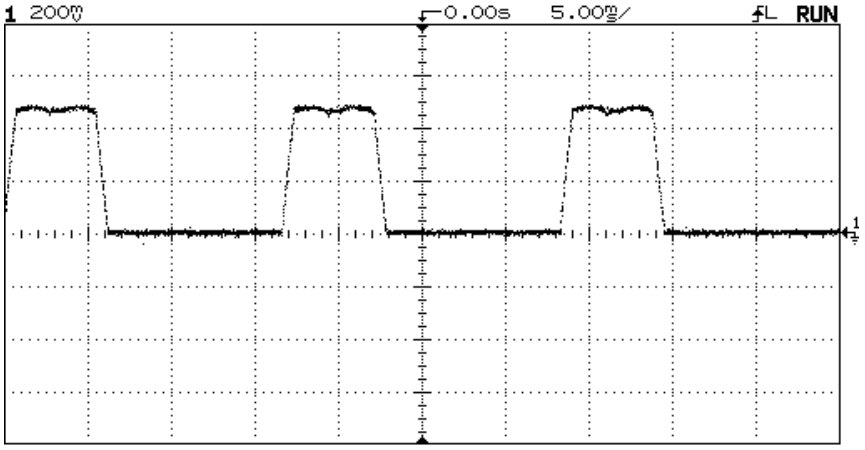


Figure 7.1
Device Current Waveform

The device current waveforms should be present anytime the rectifier is ON. Proper integrator reset synchronization is indicated by 0 volts when rectifier device is **not** conducting during the commutation cycle. That is, the device current "humps" should rise from, and return to a level of zero volts (no dc offset voltage present).

If a dc offset voltage is present in the device current waveform, the integrators are not being reset at the proper time. In this case, check the suspect integrator card as follows:

1. Make sure that all integrator cards are properly seated in the card rack.
2. Connect the oscilloscope to the questionable waveform test points. See Figure 7.3.
3. With the laptop computer connected to the USB-2533, click on the “RCEM RESET” button on the spreadsheet.
4. If the problem persists, remove the integrator card, and substitute a known good integrator card. Be sure to observe static precautions.
5. Repeat steps 3 through 4.

7.7 ADJUSTING THE SIGNAL GENERATOR

To adjust the signal generator, refer to Figure 7.2 and proceed as follows:

A.) Connect a DMM between TP1 (+) and TP2 (COM). Place switch **SW2 Position 2** in the **MANUAL** position (switch lever down).

B.) Place switch **SW2 Position 1** in the **V-** position (switch lever down).

C.) Adjust potentiometer **R54** for a reading of -10.000 Vdc.

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D.) Place switch **SW2 Position 1** in the **V+** position (switch lever up).

E.) Adjust potentiometer **R55** for a reading of +10.000 Vdc.

F.) Place switch **SW2 Position 2** in the **AUTO** position (switch lever up).

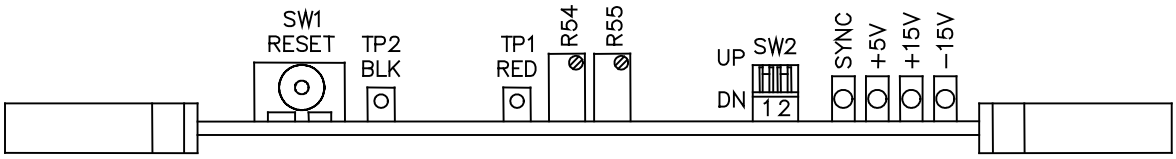


Figure 7.2
Reset Sync PC Board

7.8 ADJUSTING THE INTEGRATOR PC BOARDS

To adjust the Integrator PC Boards, refer to Figure 7.3 and proceed as follows:

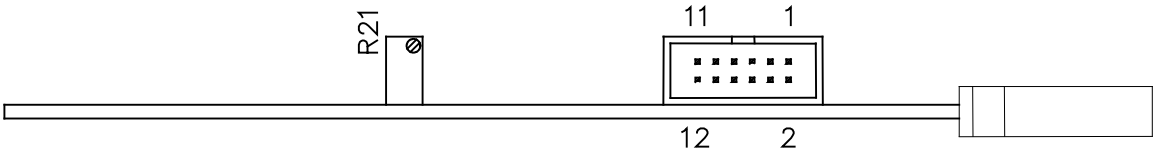


Figure 7.3
Integrator PC Board

1. Adjust the signal generator as described in the proceeding section. The accuracy of the Integrator PC Boards depends on the accuracy of the signal generator.
2. Activate the “Calibrate Worksheet” as described in Appendix B.13.
3. Adjust potentiometer R21 on the first Integrator PC Board while watching the average of Diode 1 on the “Calibrate Worksheet”. Adjust the potentiometer for a reading of 571 amps, ±1 amp.
4. Repeat for Integrator PC Boards 2 through 20 (“Calibrate Worksheet”, Diodes 2 through 20).

7.9 TRANSDUCER TESTING (CONTINUITY METHOD)

The current transducer continuity test (described below) is made when the RCEM is first installed and will also prove useful in troubleshooting. The dielectric test, paragraph 7.9, is another useful preventive maintenance and diagnostic tool.

1. Make sure that the rectifier system in which the current transducers are connected is off-line (not powered).
2. Disconnect the input connectors “1A” through “6B” on the I/O Panel of the DAU. Measure the continuity of each current transducer with a DMM.

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CURRENT TRANSDUCER	PINS
1	16 & 13
2	10 & 4
3	17 & 8
4	23 & 9
5	24 & 14
6	29 & 15
7	34 & 21
8	30 & 22
9	17 & 18
10	19 & 20

2. Replace any defective current transducer(s) and repeat the test.

7.10 TRANSDUCER DIELECTRIC TESTING - WINDINGS TO SURFACE

Dielectric withstand-voltage tests of the current transducers can be useful in preventive maintenance and troubleshooting of the RCEM.

WARNING

DANGER HIGH VOLTAGE exists while performing Hi-pot tests. Hi-pot tests should be performed by qualified trained personnel only. Refer to test equipment users guide for equipment operating instructions.

CAUTION

1. H-ipot testing produces ozone gas through electrolysis that in high concentrated levels (0.12 PPM) can be toxic as a strong irritant through inhalation. The presence of high concentrated levels of ozone gas will be noticeable by a strong pungent odor.
2. All Hi-pot tests should be performed in an open area with air movement to disperse ozone gas. The use of a portable fan may be necessary to disperse concentrated levels of ozone gas.
3. All Hi-pot testing should be halted if a high level of ozone gas is suspected until the Safety Director has reviewed the application.

Place current transducer in test ground plane (metal container containing loose hardware). Submerge current transducer below loose hardware. Use metallic hardware, preferably ball bearings (no sharp edges). Keep the output cable outside the test ground plane. See Figure 7.4 for a typical Hi-Pot test setup.

Short current transducer connector pins 1 and 2 together. Connect Hi-pot between connector pins and metal container. Gradually apply 5550 Vac for the Flexible Current Transducer and maintain for 1 minute.

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As the high-voltage source, we suggest the use of a commercial high-potential tester such as the Junior Hy-Pot from Associated Research, Inc. (8221 N. Kimball Ave., Skokie, IL). Connect the test apparatus to the ac terminals of the tester and set the tester's AC/DC switch to the AC position.

Note that the tester has two neon lamp indicators - BREAKDOWN and LEAKAGE. Once the connections are made, slowly increase the voltage output of the tester and look for an indication from the lamps. It should be possible to run the voltage up to 5550 Vac for the Current Transducer without breakdown occurring. If a LEAKAGE indication is obtained before this point, it may be necessary to adjust the threshold of the tester's leakage test circuit (by means of a potentiometer on the tester). (Leakage is caused by capacitive effects.) A breakdown will be indicated by the tester's BREAKDOWN lamp.

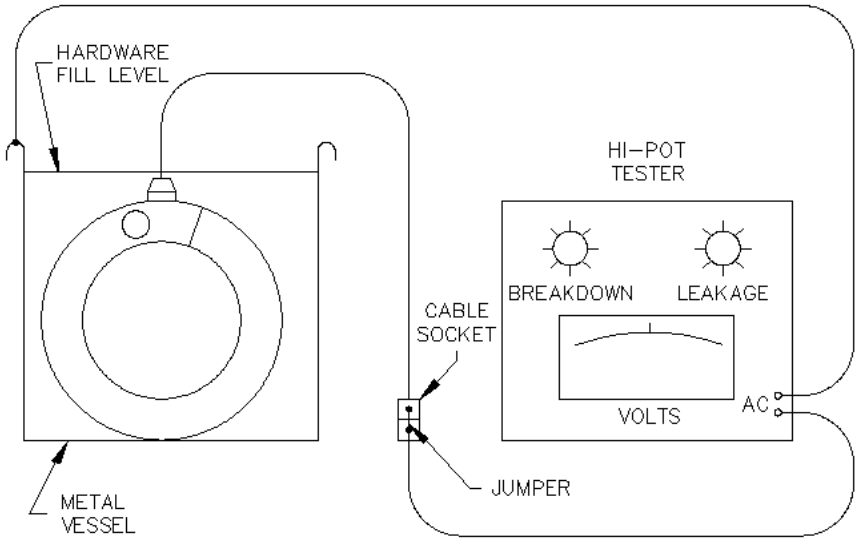


Figure 7.4
Hi-Pot Test Setup

7.11 CONNECTOR CONTAMINATION (INTEGRATOR CARDS)

In the process of daily operation or during vibration in shipment, the DAU integrator card connectors may get contaminated. This may also happen from airborne contaminants that may enter the DAU from normal factory use. This action may cause abnormal operation of the RCEM.

NOTE
ADHERE TO ALL STATIC PROTECTION WARNINGS IN 7.5 “Static Precautions When Servicing” !

The cure for this symptom is simple. Turn off the DAU using the power switch. Remove the protective cover on the DAU analog card rack. This is done by removing four screws.

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Remove the integrator cards from the DAU. Clean the connector pins on the integrator cards and the connectors inside the DAU. Suitable solvent would be isopropyl alcohol (99% pure, no glycerin added), trichlorethylene, or any other DynAmp, LLC approved connector cleaner. Reinstall all integrator cards in the appropriate slots. Reinstall the front cover and reapply ac to the unit.

7.12 RESET SYNC ERROR OR INCORRECT DATA

If a Reset Sync error occurs, this means that the DAU is not synchronized to the rectifier. Incorrect data will result if the DAU is not properly synchronized. When the DAU is turned on, it automatically goes through its synchronization routine. In order for the DAU to synchronize properly, the rectifier needs to be conducting current when the DAU is powered up. The value of this current should be approximately 100 amps per device or greater. If the DAU is powered up and the rectifier is not in the above stated condition, the DAU may not establish correct reset pulse locations. The DAU will automatically adjust the reset pulse locations when the rectifier is conducting adequate current. However, all reset pulses may not be in the optimum location. A scanner reset will assure optimum reset pulse location.

The “RCEM RESET” command button will also cause the Data Acquisition Unit to synchronize to the rectifier. This may be accomplished by turning the DAU power off then on, or by clicking on the “RCEM RESET” command button located on the laptop computer spreadsheet.

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8. MAINTENANCE AND SPARE PARTS

8.1 SPARE PARTS ORDERS - ROUTINE OR EMERGENCY

Requests for spare parts, either in an emergency or for a routine order, should be directed to "Inside Sales" at DynAmp, LLC during normal hours, if possible, or via any method shown above for off-hours. When contacting us, please present as much information as possible - the related equipment Model Number and Serial Number; the required part name and its DynAmp, LLC item number (and other identifying or vendor number(s); and your time needs. An approved Purchase Order Number should be given with your order.

8.2 SPARE PARTS

The following table lists recommended quantities of spare parts for the RCEM. As spares are used, replacements should be ordered to insure continuous operation of the equipment.

Disconnect power to the system before servicing or replacing fuses.

Table 8.1
Spare Parts List

DESCRIPTION	ITEM NO.	QUAN
Fuses, 0.125A, 250V, MDA-1/8 (5 per box)	3529	1 box
Fuses, 3A, 250V, MDA-3 (5 per box)	12591	1 box
Transducer, RS5-610-1.5-M-R *	41273	5
PCB Assembly, RCEM Reset Sync	44521	1
Cable Assembly, BNC Male-to-Male 5 Ft	42814	2
Adapter, BNC Female to 0.025 x 0.025 Socket	42815	2
PCB Assembly, RCEM Integrator LF 2kA **	43346	2

* - Transducer size may vary; consult DynAmp, LLC for correct item number.

** - RCEM Integrator scaling may vary; consult DynAmp, LLC for correct item number.

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8.3 SERVICE ASSISTANCE

For further assistance, contact DynAmp Customer Support at:

Americas:

Telephone: +1 614.871.6900 Fax: +1 614.871.6910

8:00 AM to 5:00 PM USA Eastern Time

From first Sunday in November to second Sunday in March – 13:00 GMT to 22:00 GMT

From second Sunday in March to first Sunday in November – 12:00 GMT to 21:00 GMT

Europe:

Telephone: +41 22.706.1446 Fax: +41 22.706.1311

8:30 AM to 5:00 PM Central European Time

From last Sunday in October to last Sunday in March – 7:30 GMT to 16:00 GMT

From last Sunday in March to last Sunday in October – 6:30 GMT to 15:00 GMT

After Hours Critical Service Emergency:

Telephone: +1 614.871.6906

5:00 PM to 8:00 AM USA Eastern Time

From first Sunday in November to second Sunday in March – 22:00 GMT to 13:00 GMT

From second Sunday in March to first Sunday in November – 21:00 GMT to 12:00 GMT

Central e-mail:

help@dynamp.com

DynAmp web:

www.dynamp.com

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9. DRAWING LIST

9.1 REQUIRED DRAWINGS

The drawings in table 9.1 are to be considered as part of (although not necessarily included in) this manual. Drawings should be kept with the manual at all times.

Table 9.1
Drawing List

DRAWING TITLE	NUMBER
Outline and Mounting: Transducer RS5-610-1.5-M-R	02B107818
PCB Assembly: RCEM Backplane	26D108297
PCB Assembly: RCEM Reset Sync	26B108301
PCB Assembly: RCEM Reset Sync	26B108791
PCB Assembly: RCEM Integrator Low Range	26C108485
PCB Assembly: RCEM Integrator High Range	26B109214
PCB Assembly: RCEM Digital Interface 5V/24V	26B108487
Outline: RCEM DAU 120 Channel	02D108644
Outline: RCEM DAU 240 Channel	02D108707
Interconnection Diagram: RCEM System 120 Channel	02D108645
Interconnection Diagram: RCEM System 240 Channel	02D108705
Schematic: RCEM 120 Channel DAU	05B108701
Schematic: RCEM 120 Channel DAU #2	05B108702

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APPENDIX A:
ANSI RECTIFIER CIRCUITS

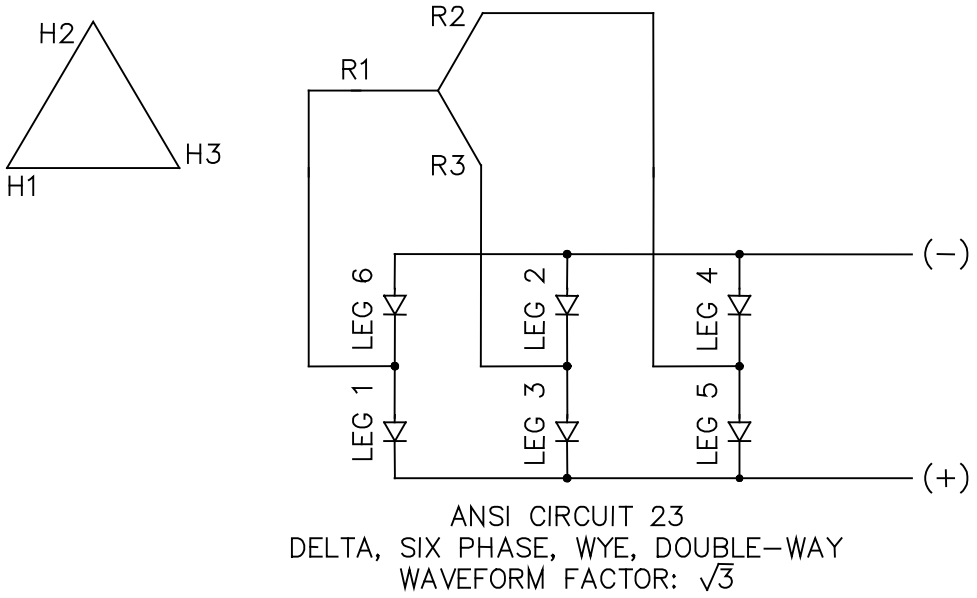


Figure A.1
ANSI Rectifier Circuit 23

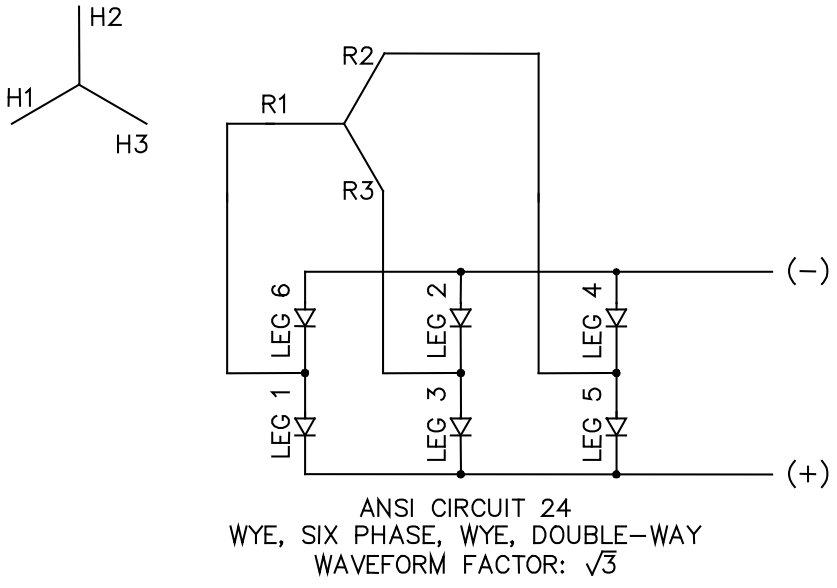


Figure A.2
ANSI Rectifier Circuit 24

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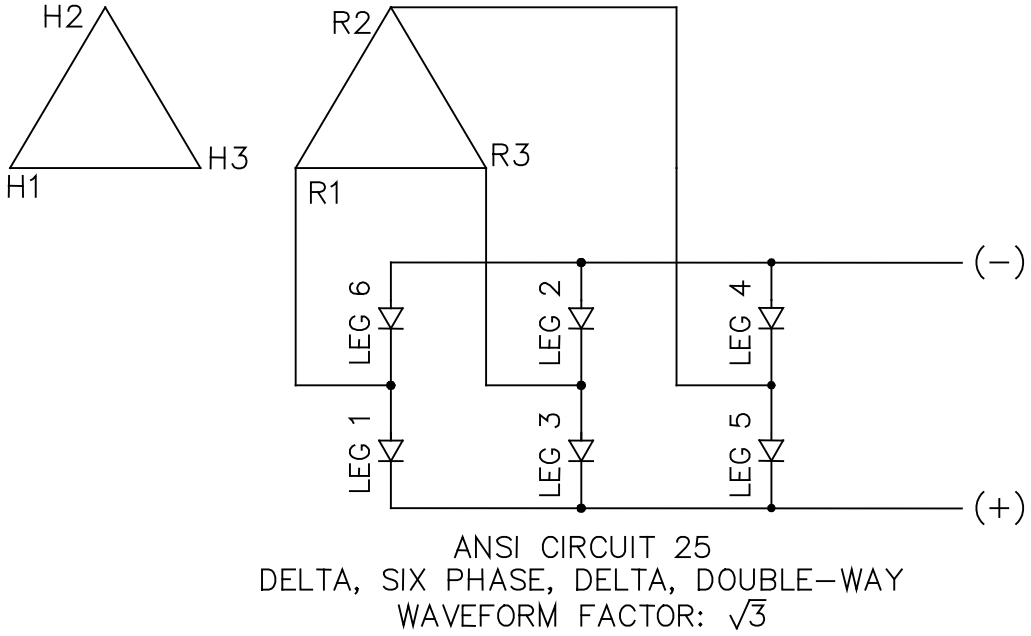


Figure A.3
ANSI Rectifier Circuit 25

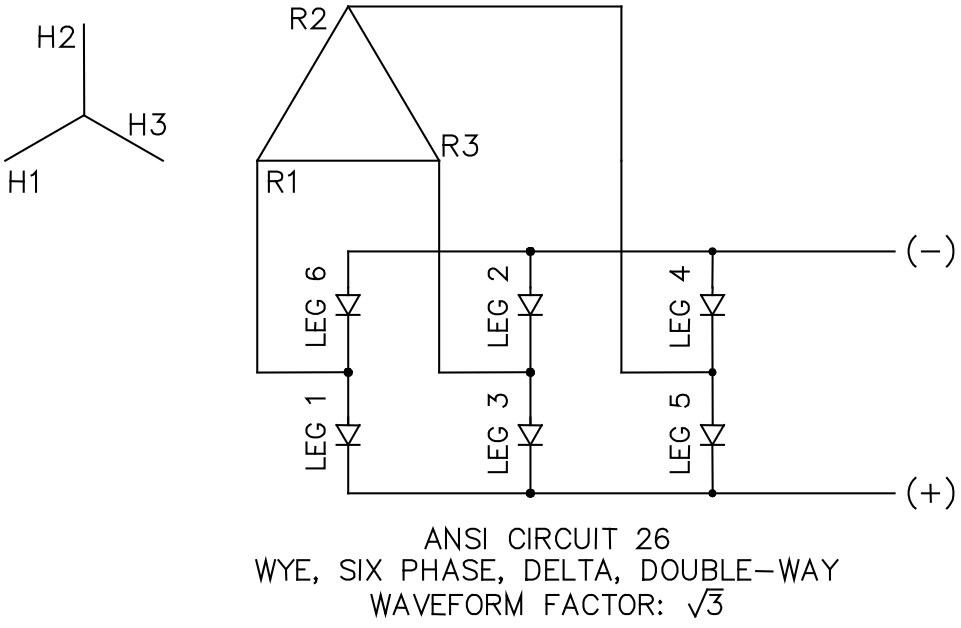


Figure A.4
ANSI Rectifier Circuit 26

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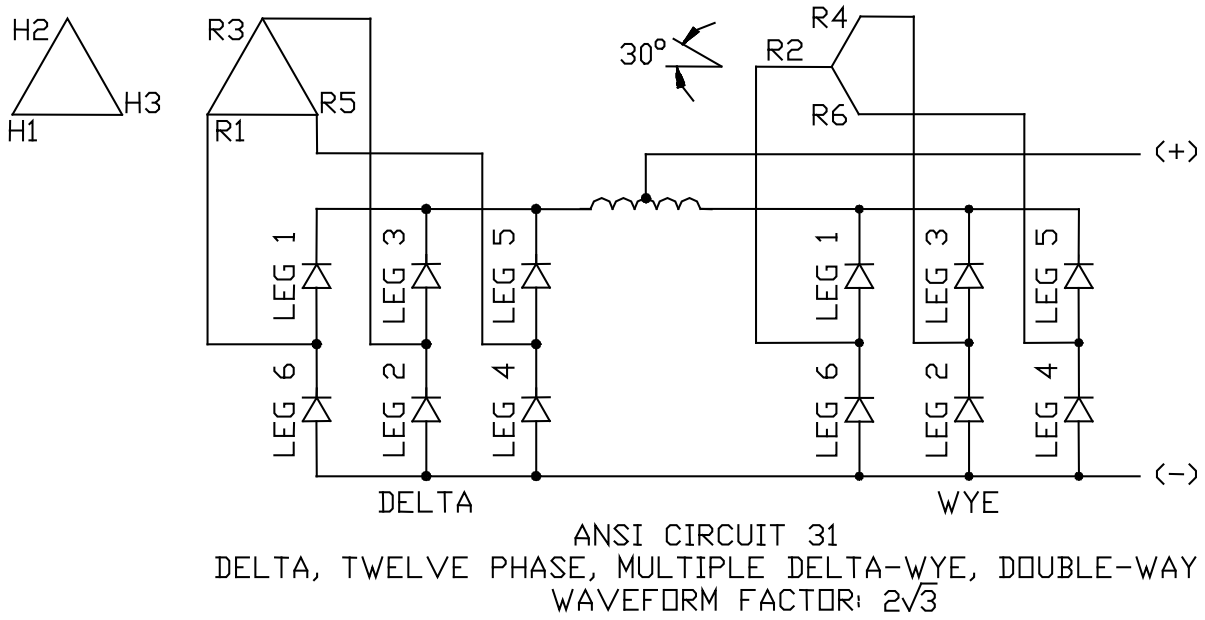


Figure A.5
ANSI Rectifier Circuit 31

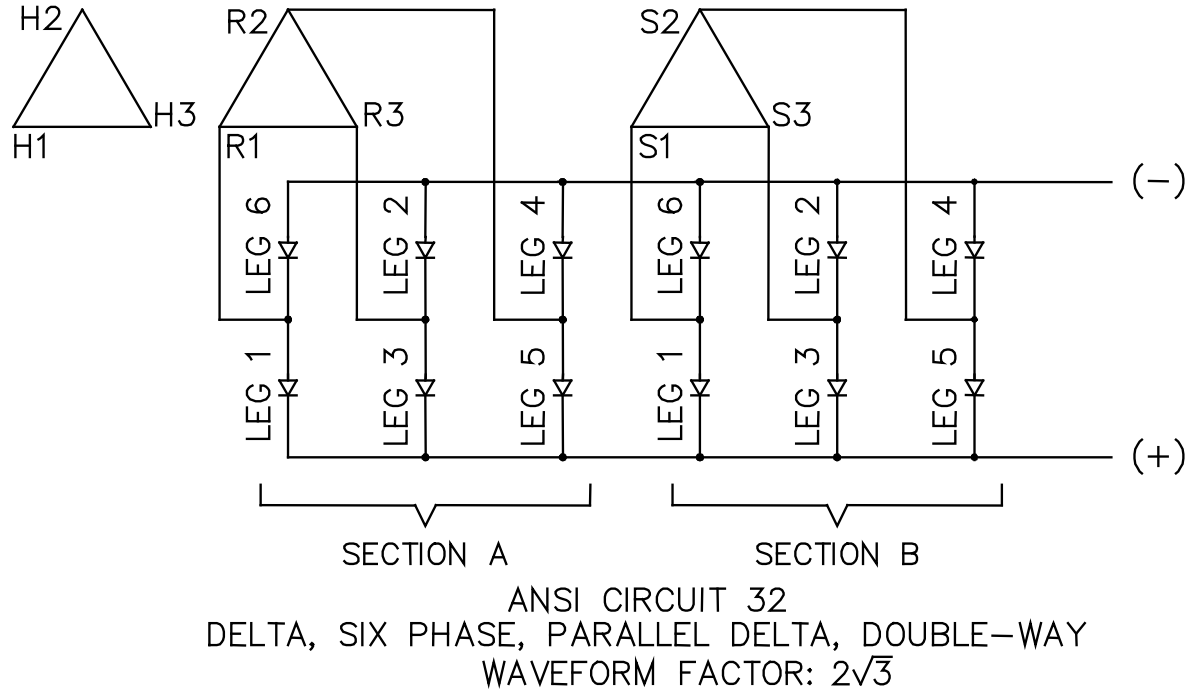
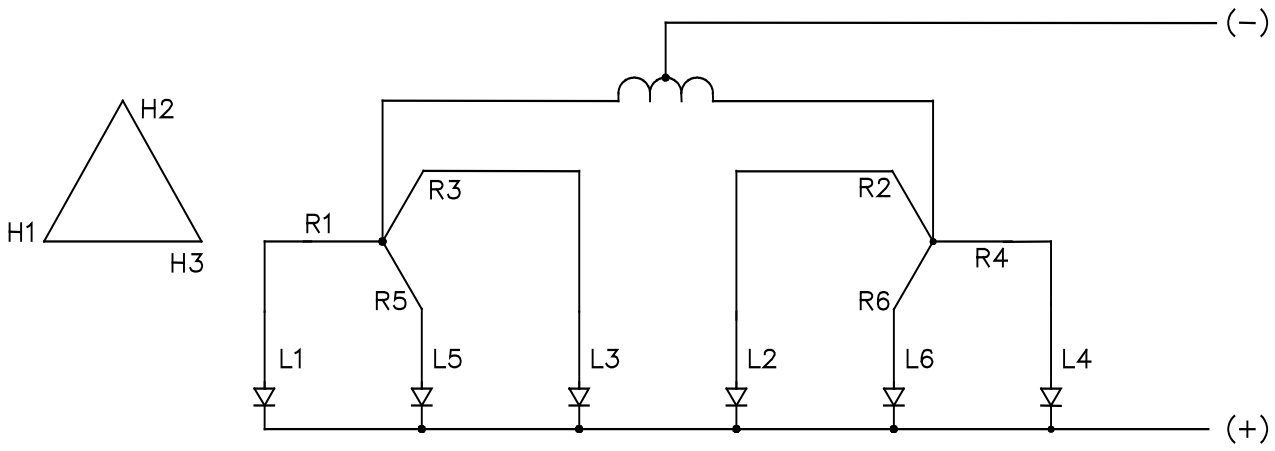


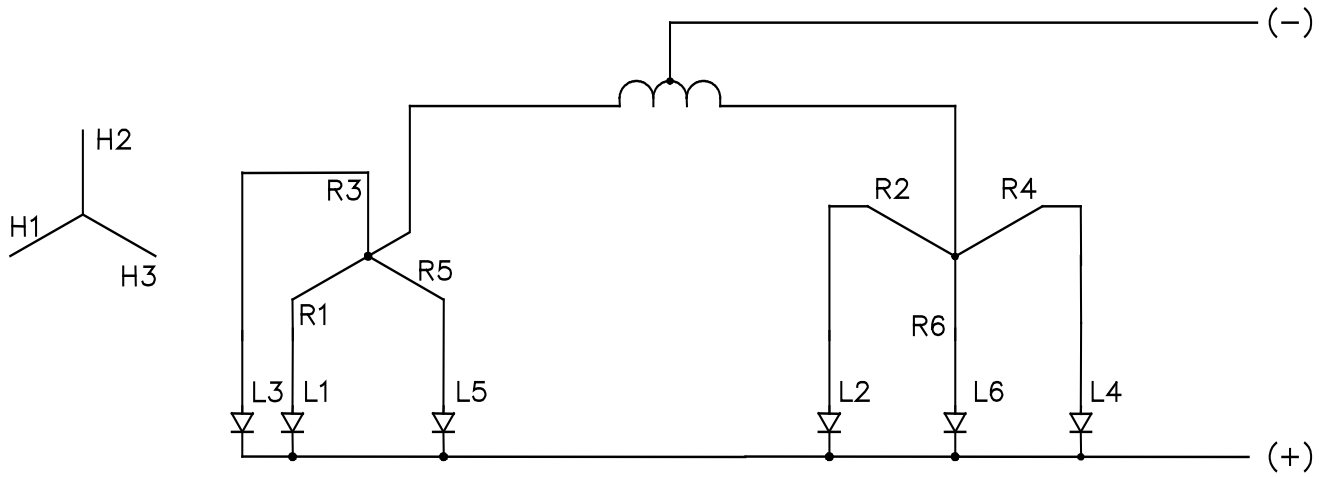
Figure A.6
ANSI Rectifier Circuit 32

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ANSI CIRCUIT 45
DELTA, SIX PHASE, DOUBLE WYE
WAVEFORM FACTOR: $2\sqrt{3}$

Figure A.7
ANSI Rectifier Circuit 45



ANSI CIRCUIT 46
WYE, SIX PHASE, DOUBLE WYE
WAVEFORM FACTOR: $2\sqrt{3}$

Figure A.8
ANSI Rectifier Circuit 46

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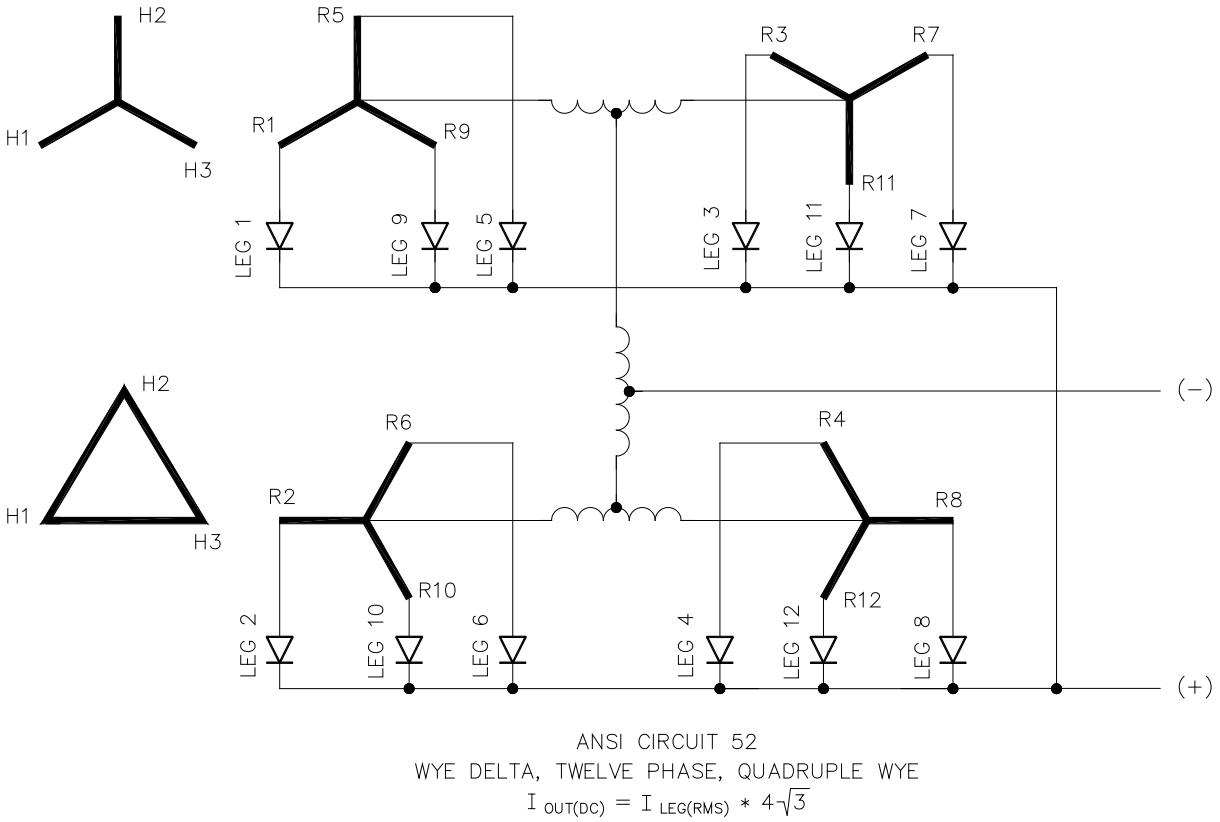


Figure A.9
ANSI Rectifier Circuit 52

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APPENDIX B: SOFTWARE

B.1 PROVIDED SOFTWARE

All software and drivers associated with this product are supplied on CD-ROMs. The contents of the DynAmp, LLC CD-ROM are as follows:

DynAmp spreadsheet(s)

A copy of this manual “043526x.pdf” (x = manual revision)

Applicable manuals / addendums

The USB-2533 software is supplied on the manufacturer’s CD-ROM.

The software is already installed on the laptop computer supplied with the product. However, in case of a problem, please follow the instructions below for reinstalling the software. Note that the provided software will operate on Windows XP (32-Bit or 64-Bit) and above.

B.2 MINIMUM REQUIREMENTS FOR LAPTOP COMPUTER

The following is a list of the minimum requirements for the laptop computer:

1. Windows XP operating system.
2. Microsoft Office 2007.
3. USB 2.0 High-power Compliant Port
4. CD-ROM Drive
5. Universal AC Adapter with an IEC 60320 International Standardized Appliance Connector

Note: All power saving modes of operation must be disabled.

B.3 SOFTWARE INSTALLATION

Place Measurement Computing CD-ROM in the drive and using “Windows Explorer”, double click on “Run” application icon. Continue with the installation by accepting all the default values.

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B.4 STARTING THE DATA ACQUISITION PROGRAM

NOTES
The current waveforms through the diodes must be stable to the mains or sync errors will occur. The USB cable(s) should be connected to the RCEM and the computer.

CAUTION
Keep the computer as far as possible away from magnetic fields or damage to the computer hard drive may occur.

Use the following procedure to start the data acquisition program:

1. The DAU power should be on.
2. Connect the USB cable(s) between the RCEM and the computer.
3. Turn the laptop computer power ON. Allow the computer to boot to the desktop screen.
4. Click on the Measurement Computing “Instacal” icon located on the desktop. The software should auto detect the UBS-2533(s) Data Acquisition PC Board(s).
5. For each USB-2533 PCB(s) detected, click on the “Configure” icon, then select the “64 Single Ended” analog input option.
6. Click on the RCEM spreadsheet icon. Allow the spreadsheet to load. All LEDs (except +24V) should turn off.
7. The RCEM Data Acquisition program is now ready to run.

B.5 SPREADSHEET DESCRIPTION

A customized Excel spreadsheet is provided for interfacing with the USB-2533 from the laptop computer. The spreadsheet allows the monitoring of the diode currents, and provides visual indicators of all the alarm conditions. It also allows the RCEM system to be operated in test mode to assist in troubleshooting problems with the system.

The “Display” worksheet’s general layouts are shown in Figures B.1, B.3, B.5, and B.7. The following list is a description of the individual fields on the worksheet:

1. UNIT NUMBER: This is the identification number of the rectifier under test.
2. RECTIFIER CURRENT: The calculated dc current output of the rectifier. (Average leg total current times the waveform factor)
3. DIODE: The diode number. There is a maximum of 20 diodes in each rectifier leg.

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4. CURRENT: Indicates diode current in rms amperes.
5. % DEV: The percent deviation of the diode current from the average leg current.
6. TOTAL: The sum of the leg diode currents in rms amperes.
7. AVERAGE: The average of the leg diode currents in rms amperes.
8. DATE: The date of the last rectifier data acquisition.
9. TIME: The time of the last rectifier data acquisition.
10. HI: The percentage (%) above the average of the leg diode currents that will cause high diode currents to be flagged. The cell containing the high diode current will change to a red background color.
11. LO: The percentage (%) below the average of the leg diode currents that will cause low diode currents to be flagged. The cell containing the low diode current will change to a blue background color.
12. WAVEFORM FACTOR: Worksheet cell containing the value used to calculate the "Rectifier Current". See Appendix A for the correct waveform factor to use. This value varies with the ANSI rectifier circuit number.
13. ANSI RECTIFIER CIRCUIT: Worksheet cell containing the active ANSI Rectifier Circuit number.
14. LEVEL: Worksheet cell containing the checkback value of the active test signal level. "OFF" will be displayed when the "TEST MODE" is not active.
15. ACQUIRE DATA: Command button used to initiate a rectifier data acquisition. One data set will be acquired each time the button is actuated. The worksheet will be updated to the data acquired.
16. RCEM RESET: Command button used to reset the microcontrollers on the Reset Sync PC Boards. This will cause the integrator reset pulses to synchronize to the diode current waveforms.
17. TEST MODE: Toggle button (click on / click off) used to switch the data source to the internal test signal generator. Radio buttons selects the test signal level.
18. SCAN: Toggle button (click on / click off) used to control the SCAN mode of operation. Data sets will be continuously acquired and displayed at a scan rate of approximately 6 seconds.
19. DEVICES/LEG: Command button used to enter the number of rectifying devices/leg.
20. ANSI RECTIFIER CIRCUIT: Selection box used to select the appropriate ANSI Rectifier Circuit Number.

B.6 PROGRAMMING THE NUMBER OF DEVICES / LEG

Use the following procedure to program the number or devices/leg:

1. Click on the "DEVICES/LEG" command button.

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2. Enter the number of devices/leg into the Input Box.
3. Click on the Input Box “Ok” button. The “Display” and “Calibrate” worksheets will be configured to the number of devices/leg entered.
4. Click on the Input Box “Cancel” button to exit the command without changing the number of devices/leg.

B.7 SELECTING THE ANSI RECTIFIER CIRCUIT NUMBER

Use the following procedure to select the ANSI Rectifier Circuit Number:

1. Click on the desired ANSI Rectifier Circuit Number checkbox.
2. The “Waveform Factor:” cell will update to the waveform factor for the selected ANSI Rectifier Circuit.
3. The “ANSI Rectifier Circuit:” cell will display the selected ANSI Rectifier Circuit Number.

B.8 ACQUIRING A RECTIFIER DATA SET

Use the following procedure to setup and acquire the rectifier data:

1. Enter the rectifier unit number in the “Unit Number:” field.
2. Enter the waveform factor in the “Waveform Factor:” field. See Appendix A for the correct waveform factor to use. This value varies with the ANSI rectifier circuit number but regardless of the waveform factor used, the diode currents will be correct.
3. Click on the “ACQUIRE DATA” command button to acquire or refresh the rectifier data.

B.9 ACTIVATING THE TEST MODE OF OPERATION

Use the following procedure to activate the test mode of operation:

1. Click on the desired test level radio button.
2. Click on the “TEST MODE” command button. If you are near the DAU, you should hear the test signal relays energize.
3. Check the “Level:” field to confirm the correct test signal level.
4. Acquire the test data by clicking the “ACQUIRE DATA” command button or start the “SCAN” mode to view the test data.
5. Click on the “TEST MODE” command button to leave the test mode of operation. The “Level:” field will change to “OFF” to indicate “TEST MODE” is not active.

B.10 THE SCAN MODE OF OPERATION

Use the following procedures to setup and start the rectifier data scan.

1. Enter the rectifier unit number in the “Unit Number” field.

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2. See Appendix A for the correct waveform factor to use. This value varies with the ANSI rectifier circuit number but regardless of the waveform factor used, the diode currents will be correct.
3. Click on the SCAN toggle button click on / click off). Data will be acquired and displayed continuously at the scan rate.
4. Click on the SCAN toggle button to exit the SCAN mode of operation.

CAUTION
Do not turn RCEM DAU power off when SCAN mode is active. The computer may lose communications with the RCEM DAU. See "*Recovering from DAQ Errors*" below to correct problem.

B.11 VIEWING THE DIODE CURRENT BAR GRAPHS

See Figure B.9 for a typical diode current bar graph. Use the following procedure to view the diode current bar graphs:

1. Start the SCAN mode of operation.
2. Click on the selected leg worksheet tab.
3. Click on the "Display" worksheet tab to switch back to the "Display" screen.

B.12 RECOVERING FROM DAQ ERRORS

Use the following procedure to recover from the error:

1. Disconnect the USB cable. All LEDs except the "24V P.S." LED should turn off.
2. Exit from the Excel spreadsheet.
3. Reconnect the USB cable.
4. Restart Excel spreadsheet

B.13 CALIBRATE WORKSHEET

A special worksheet is provided for use in calibrating the RCEM. See Figures B.2, B.4, B.6, and B.8. The diode data are displayed in rows and the legs in columns. Each row corresponds to an Integrator PC Board. The average of the diode currents in each row is calculated and displayed. Use the following procedure to activate the Calibrate Worksheet:

1. Click on the Calibrate worksheet tab.
2. Click on the "Calibrate" toggle button (click on / click off) to start data acquisition.
3. Calibrate the Integrator PC Boards according to the manual section titled "Adjusting the Integrator PC Boards".

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4. Click on the “Calibrate” toggle button to end the Calibrate mode of operation.
5. Click on the “Display” worksheet tab to return to the Display screen.

B.14 PRECAUTIONS

In order to ensure proper operation, please follow the following precautions:

1. The spreadsheet should normally be left in protected mode to avoid accidentally overwriting equations and links. Cells that allow user input are highlighted in yellow. No other cells should be modified to ensure proper operation.
2. A virus protection feature in Excel allows disabling all macros from being executed automatically. However, in order for the provided spreadsheet to operate properly, macros must be enabled.
3. When entering new values in the spreadsheet, such as Lo alarm value, the entry operation into the cell must be completed by pressing the “Return” or “Enter” keys before the new values can be updated.

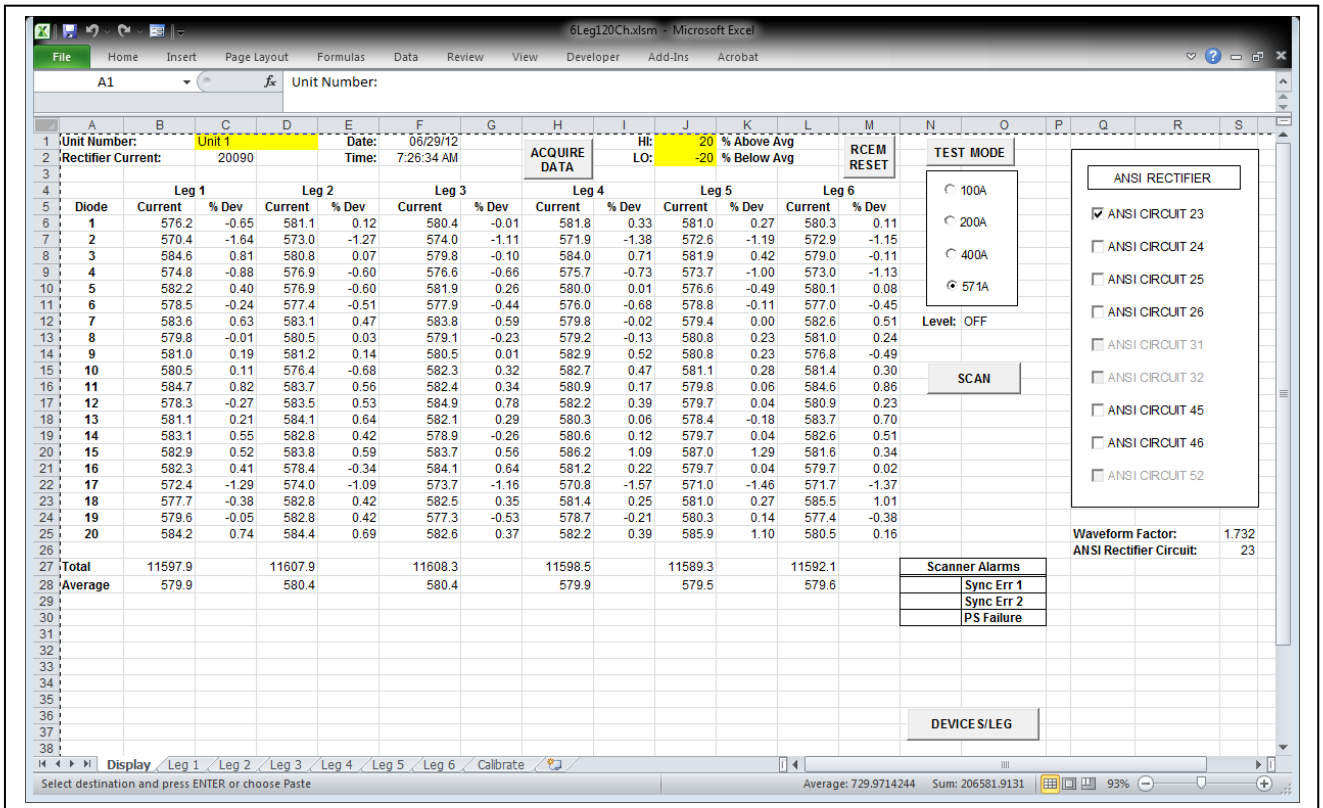
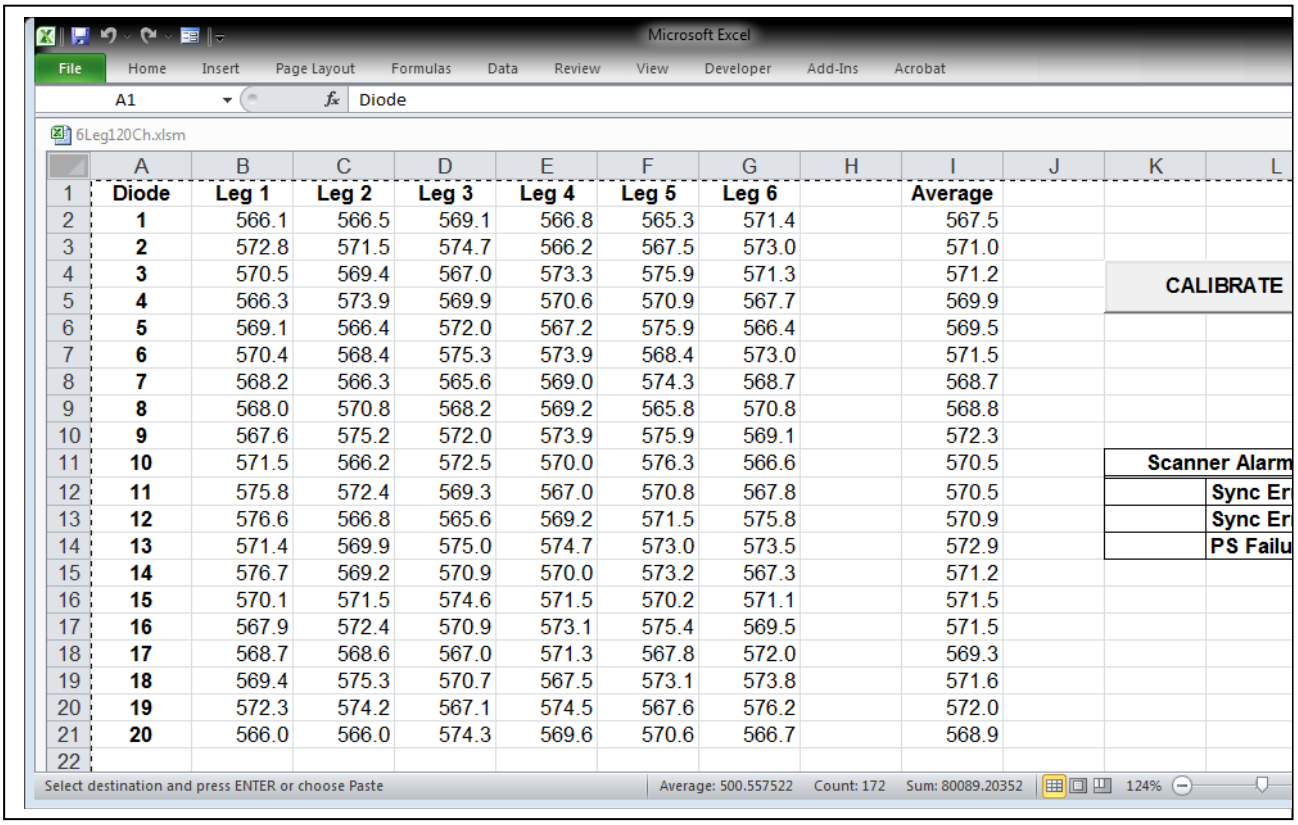


Figure B.1
6Leg120Ch Display Spreadsheet



Diode	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5	Leg 6	Average
1	566.1	566.5	569.1	566.8	565.3	571.4	567.5
2	572.8	571.5	574.7	566.2	567.5	573.0	571.0
3	570.5	569.4	567.0	573.3	575.9	571.3	571.2
4	566.3	573.9	569.9	570.6	570.9	567.7	569.9
5	569.1	566.4	572.0	567.2	575.9	566.4	569.5
6	570.4	568.4	575.3	573.9	568.4	573.0	571.5
7	568.2	566.3	565.6	569.0	574.3	568.7	568.7
8	568.0	570.8	568.2	569.2	565.8	570.8	568.8
9	567.6	575.2	572.0	573.9	575.9	569.1	572.3
10	571.5	566.2	572.5	570.0	576.3	566.6	570.5
11	575.8	572.4	569.3	567.0	570.8	567.8	570.5
12	576.6	566.8	565.6	569.2	571.5	575.8	570.9
13	571.4	569.9	575.0	574.7	573.0	573.5	572.9
14	576.7	569.2	570.9	570.0	573.2	567.3	571.2
15	570.1	571.5	574.6	571.5	570.2	571.1	571.5
16	567.9	572.4	570.9	573.1	575.4	569.5	571.5
17	568.7	568.6	567.0	571.3	567.8	572.0	569.3
18	569.4	575.3	570.7	567.5	573.1	573.8	571.6
19	572.3	574.2	567.1	574.5	567.6	576.2	572.0
20	566.0	566.0	574.3	569.6	570.6	566.7	568.9

Figure B.2
6Leg120Ch Calibrate Spreadsheet

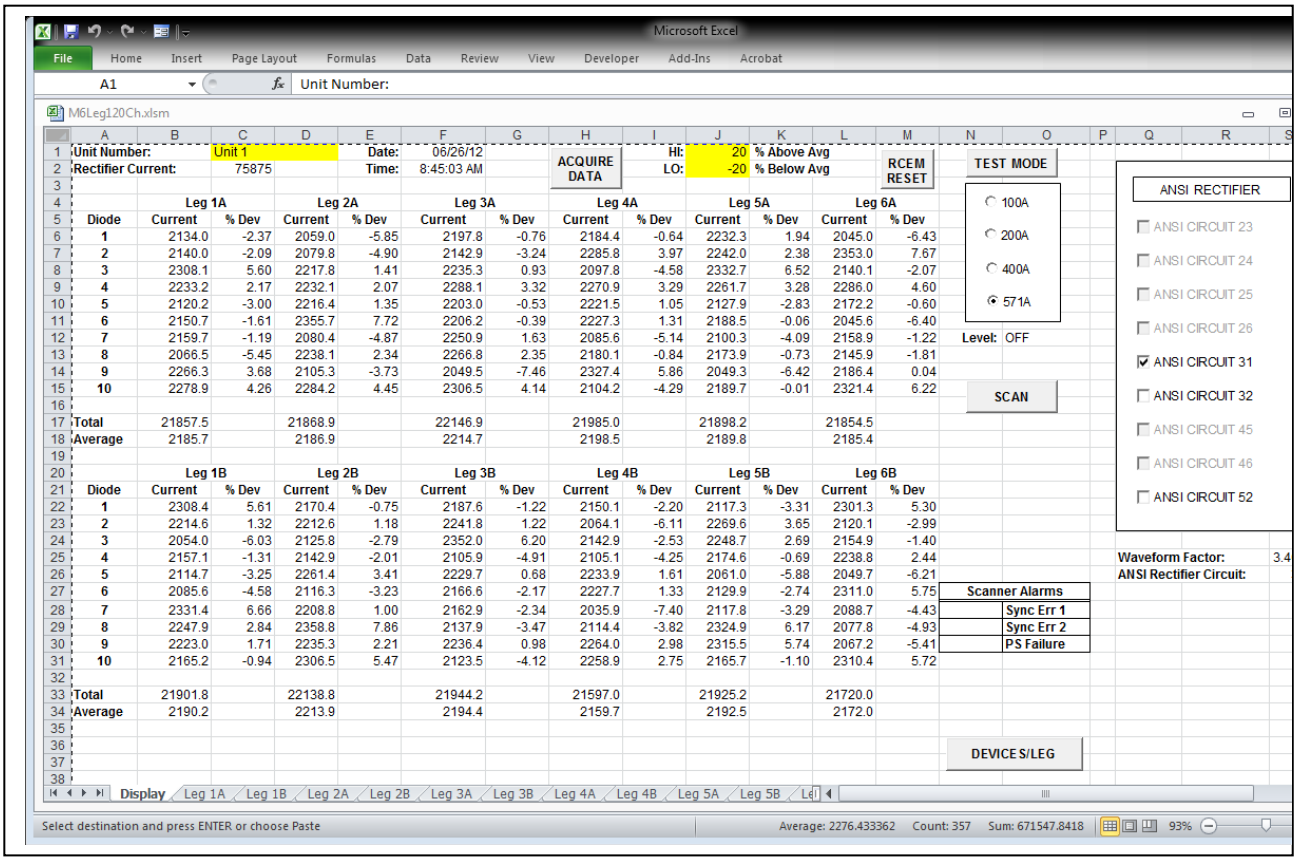
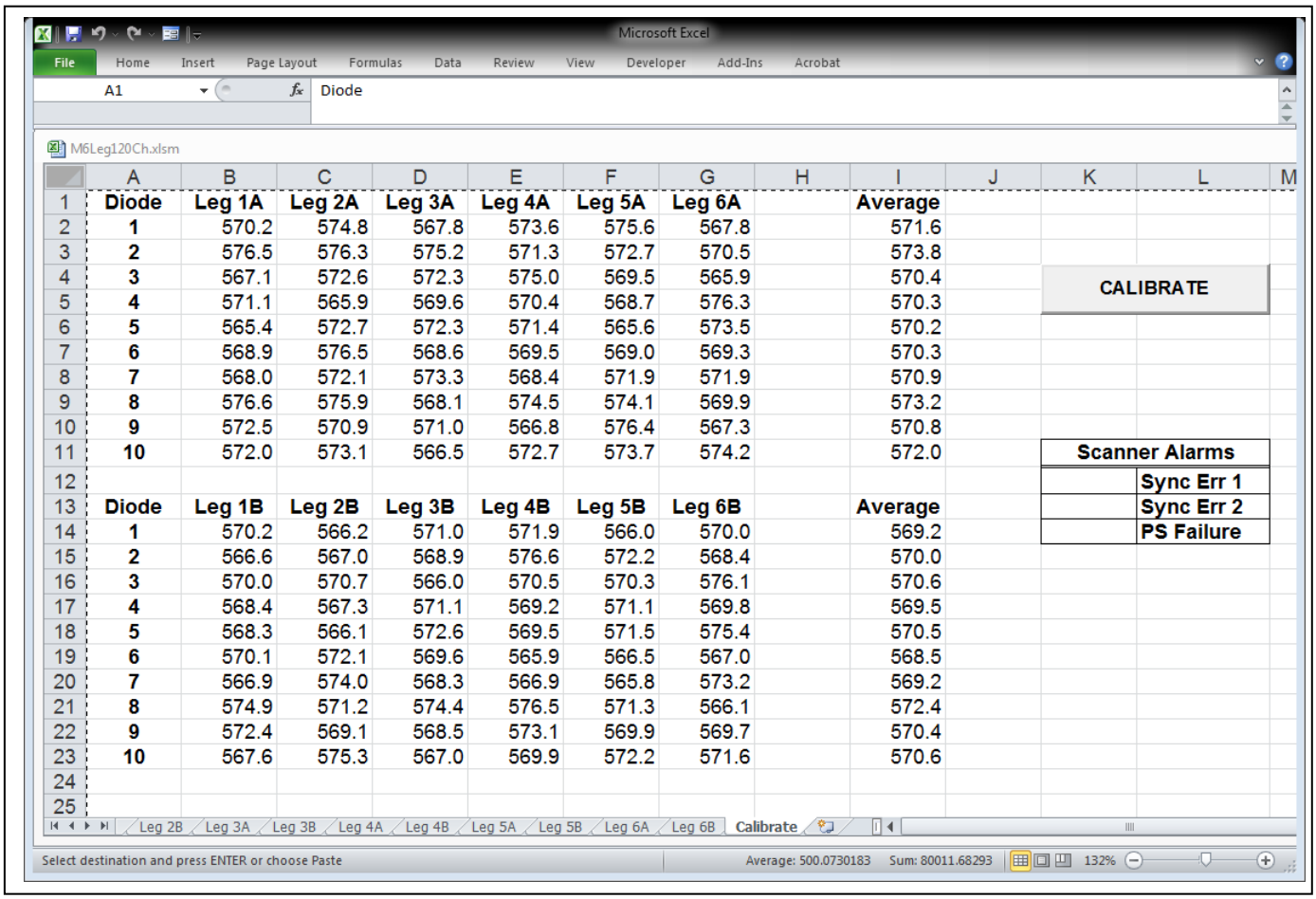


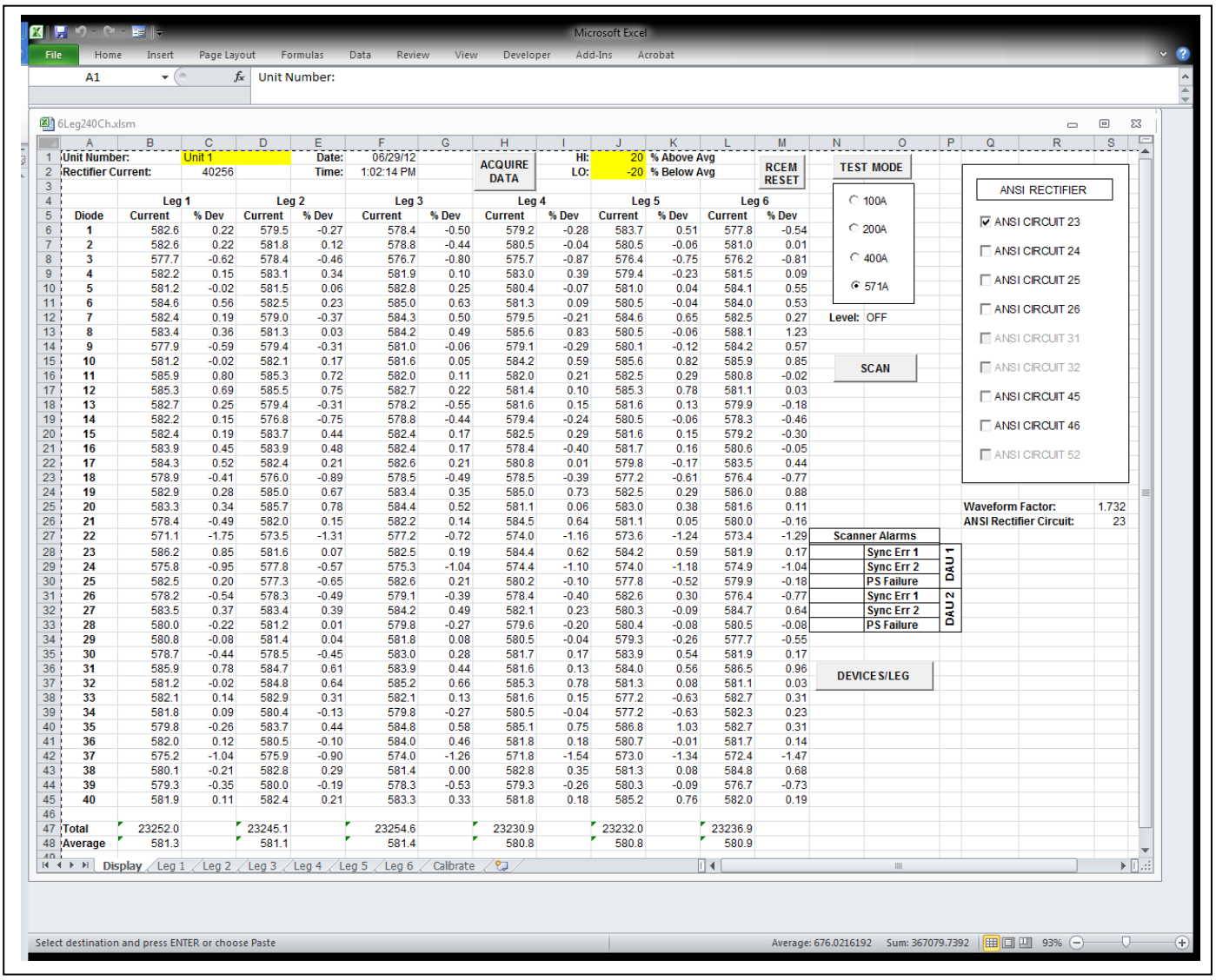
Figure B.3
M6Leg120Ch Display Spreadsheet



Diode	Leg 1A	Leg 2A	Leg 3A	Leg 4A	Leg 5A	Leg 6A	Average
1	570.2	574.8	567.8	573.6	575.6	567.8	571.6
2	576.5	576.3	575.2	571.3	572.7	570.5	573.8
3	567.1	572.6	572.3	575.0	569.5	565.9	570.4
4	571.1	565.9	569.6	570.4	568.7	576.3	570.3
5	565.4	572.7	572.3	571.4	565.6	573.5	570.2
6	568.9	576.5	568.6	569.5	569.0	569.3	570.3
7	568.0	572.1	573.3	568.4	571.9	571.9	570.9
8	576.6	575.9	568.1	574.5	574.1	569.9	573.2
9	572.5	570.9	571.0	566.8	576.4	567.3	570.8
10	572.0	573.1	566.5	572.7	573.7	574.2	572.0

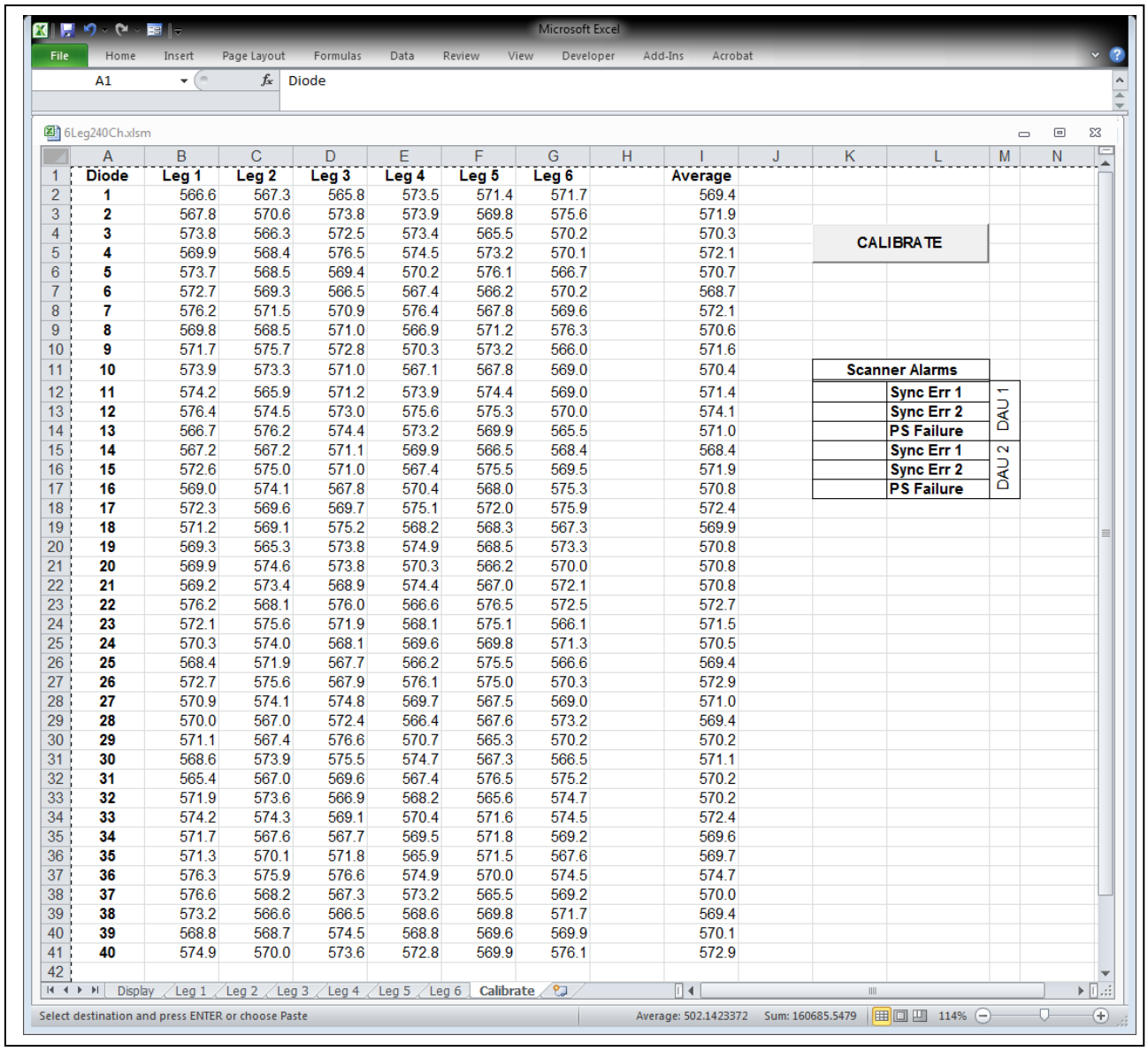
Diode	Leg 1B	Leg 2B	Leg 3B	Leg 4B	Leg 5B	Leg 6B	Average
1	570.2	566.2	571.0	571.9	566.0	570.0	569.2
2	566.6	567.0	568.9	576.6	572.2	568.4	570.0
3	570.0	570.7	566.0	570.5	570.3	576.1	570.6
4	568.4	567.3	571.1	569.2	571.1	569.8	569.5
5	568.3	566.1	572.6	569.5	571.5	575.4	570.5
6	570.1	572.1	569.6	565.9	566.5	567.0	568.5
7	566.9	574.0	568.3	566.9	565.8	573.2	569.2
8	574.9	571.2	574.4	576.5	571.3	566.1	572.4
9	572.4	569.1	568.5	573.1	569.9	569.7	570.4
10	567.6	575.3	567.0	569.9	572.2	571.6	570.6

Figure B.4
M6Leg120Ch Calibrate Spreadsheet



Diode	Leg 1 Current	Leg 1 % Dev	Leg 2 Current	Leg 2 % Dev	Leg 3 Current	Leg 3 % Dev	Leg 4 Current	Leg 4 % Dev	Leg 5 Current	Leg 5 % Dev	Leg 6 Current	Leg 6 % Dev
1	582.6	0.22	579.5	-0.27	578.4	-0.50	579.2	-0.28	583.7	0.51	577.8	-0.54
2	582.6	0.22	581.8	0.12	578.8	-0.44	580.5	-0.04	580.5	-0.06	581.0	0.01
3	577.7	-0.62	578.4	-0.46	576.7	-0.80	575.7	-0.87	576.4	-0.75	576.2	-0.81
4	582.2	0.15	583.1	0.34	581.9	0.10	583.0	0.39	579.4	-0.23	581.5	0.09
5	581.2	-0.02	581.5	0.06	582.8	0.25	580.4	-0.07	581.0	0.04	584.1	0.55
6	584.6	0.56	582.5	0.23	585.0	0.63	581.3	0.09	580.5	-0.04	584.0	0.53
7	582.4	0.19	579.0	-0.37	584.3	0.50	579.5	-0.21	584.6	0.65	582.5	0.27
8	583.4	0.36	581.3	0.03	584.2	0.49	585.6	0.83	580.5	-0.06	588.1	1.23
9	577.9	-0.59	579.4	-0.31	581.0	-0.06	579.1	-0.29	580.1	-0.12	584.2	0.57
10	581.2	-0.02	582.1	0.17	581.6	0.05	584.2	0.59	585.6	0.82	585.9	0.85
11	585.9	0.80	585.3	0.72	582.0	0.11	582.0	0.21	582.5	0.29	580.8	-0.02
12	585.3	0.69	585.5	0.75	582.7	0.22	581.4	0.10	585.3	0.78	581.1	0.03
13	582.7	0.25	579.4	-0.31	578.2	-0.55	581.6	0.15	581.6	0.13	579.9	-0.18
14	582.2	0.15	576.8	-0.75	578.8	-0.44	579.4	-0.24	580.5	-0.06	578.3	-0.46
15	582.4	0.19	583.7	0.44	582.4	0.17	582.5	0.29	581.6	0.15	579.2	-0.30
16	583.9	0.45	583.9	0.48	582.4	0.17	578.4	-0.40	581.7	0.16	580.6	-0.05
17	584.3	0.52	582.4	0.21	582.6	0.21	580.8	0.01	579.8	-0.17	583.5	0.44
18	578.9	-0.41	576.0	-0.89	578.5	-0.49	578.5	-0.39	577.2	-0.61	576.4	-0.77
19	582.9	0.28	585.0	0.67	583.4	0.35	585.0	0.73	582.5	0.29	586.0	0.88
20	583.3	0.34	585.7	0.78	584.4	0.52	581.1	0.06	583.0	0.38	581.6	0.11
21	578.4	-0.49	582.0	0.15	582.2	0.14	584.5	0.64	581.1	0.05	580.0	-0.16
22	571.1	-1.75	573.5	-1.31	577.2	-0.72	574.0	-1.16	573.6	-1.24	573.4	-1.29
23	586.2	0.85	581.6	0.07	582.5	0.19	584.4	0.62	584.2	0.59	581.9	0.17
24	575.8	-0.95	577.8	-0.57	575.3	-1.04	574.4	-1.10	574.0	-1.18	574.9	-1.04
25	582.5	0.20	577.3	-0.65	582.6	0.21	580.2	-0.10	577.8	-0.52	579.9	-0.18
26	578.2	-0.54	578.3	-0.49	579.1	-0.39	578.4	-0.40	582.6	0.30	576.4	-0.77
27	583.5	0.37	583.4	0.39	584.2	0.49	582.1	0.23	580.3	-0.09	584.7	0.64
28	580.0	-0.22	581.2	0.01	579.8	-0.27	579.6	-0.20	580.4	-0.08	580.5	-0.08
29	580.8	-0.08	581.4	0.04	581.8	0.08	580.5	-0.04	579.3	-0.26	577.7	-0.55
30	578.7	-0.44	578.5	-0.45	583.0	0.28	581.7	0.17	583.9	0.54	581.9	0.17
31	585.9	0.78	584.7	0.61	583.9	0.44	581.6	0.13	584.0	0.56	586.5	0.96
32	581.2	-0.02	584.8	0.64	585.2	0.66	585.3	0.78	581.3	0.08	581.1	0.03
33	582.1	0.14	582.9	0.31	582.1	0.13	581.6	0.15	577.2	-0.63	582.7	0.31
34	581.8	0.09	580.4	-0.13	579.8	-0.27	580.5	-0.04	577.2	-0.63	582.3	0.23
35	579.8	-0.26	583.7	0.44	584.8	0.58	585.1	0.75	586.8	1.03	582.7	0.31
36	582.0	0.12	580.5	-0.10	584.0	0.46	581.8	0.18	580.7	-0.01	581.7	0.14
37	575.2	-1.04	575.9	-0.90	574.0	-1.26	571.8	-1.54	573.0	-1.34	572.4	-1.47
38	580.1	-0.21	582.8	0.29	581.4	0.00	582.8	0.35	581.3	0.08	584.8	0.68
39	579.3	-0.35	580.0	-0.19	578.3	-0.53	579.3	-0.26	580.3	-0.09	576.7	-0.73
40	581.9	0.11	582.4	0.21	583.3	0.33	581.8	0.18	585.2	0.76	582.0	0.19
Total	23252.0		23245.1		23254.6		23230.9		23232.0		23236.9	
Average	581.3		581.1		581.4		580.8		580.8		580.9	

Figure B.5
6Leg240Ch Display Spreadsheet



Diode	Leg 1	Leg 2	Leg 3	Leg 4	Leg 5	Leg 6	Average
1	566.6	567.3	565.8	573.5	571.4	571.7	569.4
2	567.8	570.6	573.8	573.9	569.8	575.6	571.9
3	573.8	566.3	572.5	573.4	565.5	570.2	570.3
4	569.9	568.4	576.5	574.5	573.2	570.1	572.1
5	573.7	568.5	569.4	570.2	576.1	566.7	570.7
6	572.7	569.3	566.5	567.4	566.2	570.2	568.7
7	576.2	571.5	570.9	576.4	567.8	569.6	572.1
8	569.8	568.5	571.0	566.9	571.2	576.3	570.6
9	571.7	575.7	572.8	570.3	573.2	566.0	571.6
10	573.9	573.3	571.0	567.1	567.8	569.0	570.4
11	574.2	565.9	571.2	573.9	574.4	569.0	571.4
12	576.4	574.5	573.0	575.6	575.3	570.0	574.1
13	566.7	576.2	574.4	573.2	569.9	565.5	571.0
14	567.2	567.2	571.1	569.9	566.5	568.4	568.4
15	572.6	575.0	571.0	567.4	575.5	569.5	571.9
16	569.0	574.1	567.8	570.4	568.0	575.3	570.8
17	572.3	569.6	569.7	575.1	572.0	575.9	572.4
18	571.2	569.1	575.2	568.2	568.3	567.3	569.9
19	569.3	565.3	573.8	574.9	568.5	573.3	570.8
20	569.9	574.6	573.8	570.3	566.2	570.0	570.8
21	569.2	573.4	568.9	574.4	567.0	572.1	570.8
22	576.2	568.1	576.0	566.6	576.5	572.5	572.7
23	572.1	575.6	571.9	568.1	575.1	566.1	571.5
24	570.3	574.0	568.1	569.6	569.8	571.3	570.5
25	568.4	571.9	567.7	566.2	575.5	566.6	569.4
26	572.7	575.6	567.9	576.1	575.0	570.3	572.9
27	570.9	574.1	574.8	569.7	567.5	569.0	571.0
28	570.0	567.0	572.4	566.4	567.6	573.2	569.4
29	571.1	567.4	576.6	570.7	565.3	570.2	570.2
30	568.6	573.9	575.5	574.7	567.3	566.5	571.1
31	565.4	567.0	569.6	567.4	576.5	575.2	570.2
32	571.9	573.6	566.9	568.2	565.6	574.7	570.2
33	574.2	574.3	569.1	570.4	571.6	574.5	572.4
34	571.7	567.6	567.7	569.5	571.8	569.2	569.6
35	571.3	570.1	571.8	565.9	571.5	567.6	569.7
36	576.3	575.9	576.6	574.9	570.0	574.5	574.7
37	576.6	568.2	567.3	573.2	565.5	569.2	570.0
38	573.2	566.6	566.5	568.6	569.8	571.7	569.4
39	568.8	568.7	574.5	568.8	569.6	569.9	570.1
40	574.9	570.0	573.6	572.8	569.9	576.1	572.9

Figure B.6
6Leg240Ch Calibrate Spreadsheet

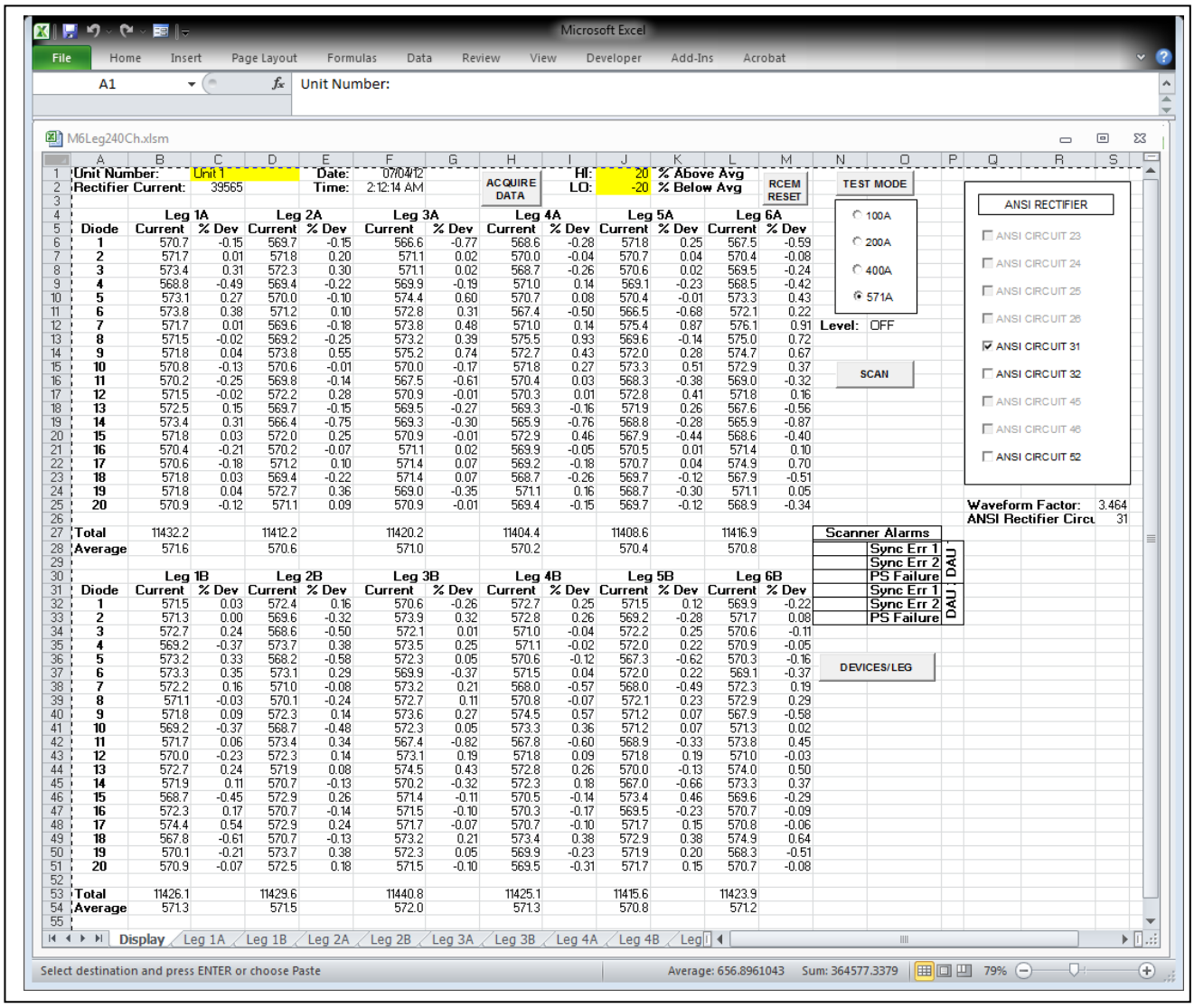
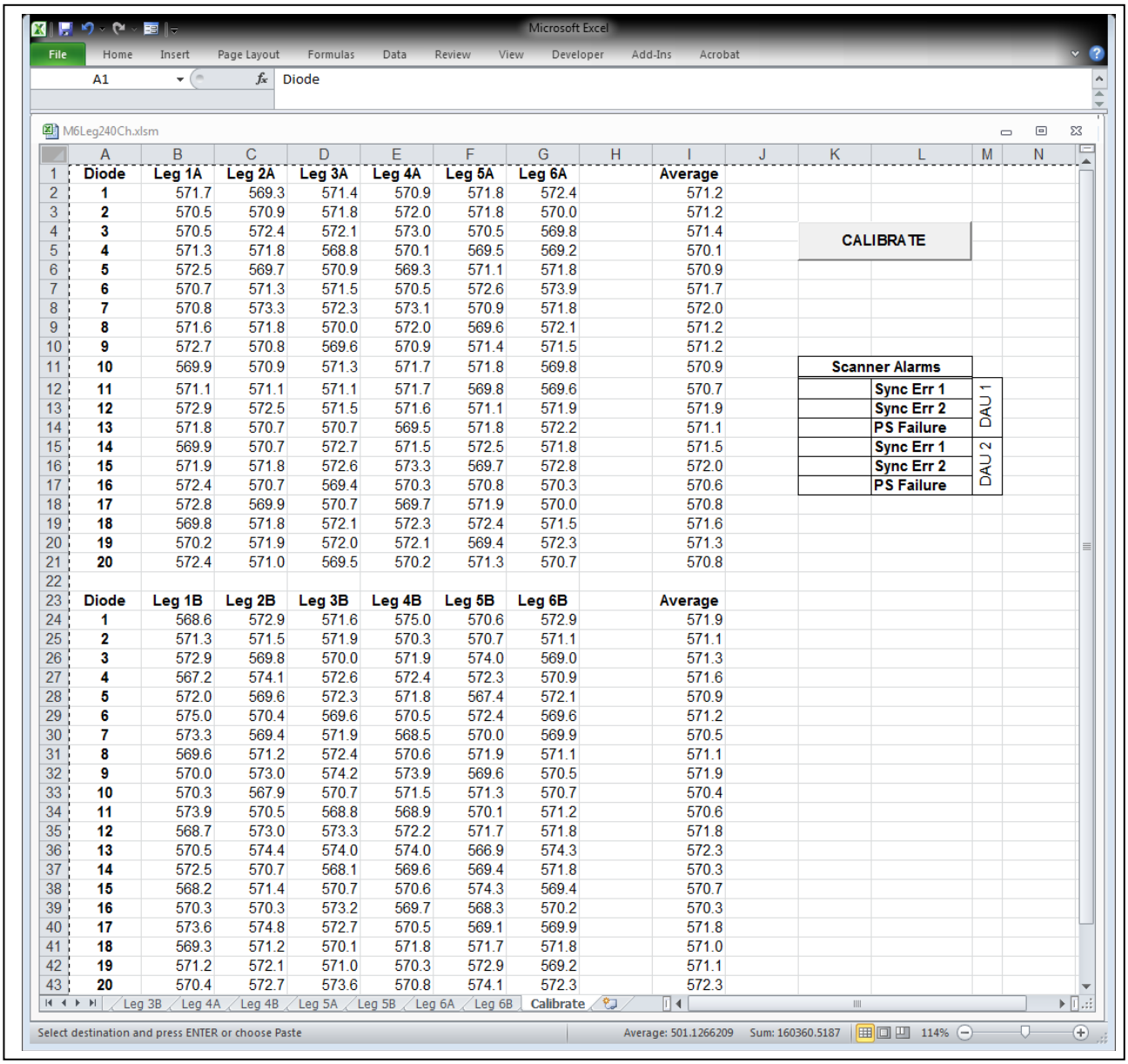


Figure B.7
M6Leg240Ch Display Spreadsheet



Diode	Leg 1A	Leg 2A	Leg 3A	Leg 4A	Leg 5A	Leg 6A	Average
1	571.7	569.3	571.4	570.9	571.8	572.4	571.2
2	570.5	570.9	571.8	572.0	571.8	570.0	571.2
3	570.5	572.4	572.1	573.0	570.5	569.8	571.4
4	571.3	571.8	568.8	570.1	569.5	569.2	570.1
5	572.5	569.7	570.9	569.3	571.1	571.8	570.9
6	570.7	571.3	571.5	570.5	572.6	573.9	571.7
7	570.8	573.3	572.3	573.1	570.9	571.8	572.0
8	571.6	571.8	570.0	572.0	569.6	572.1	571.2
9	572.7	570.8	569.6	570.9	571.4	571.5	571.2
10	569.9	570.9	571.3	571.7	571.8	569.8	570.9
11	571.1	571.1	571.1	571.7	569.8	569.6	570.7
12	572.9	572.5	571.5	571.6	571.1	571.9	571.9
13	571.8	570.7	570.7	569.5	571.8	572.2	571.1
14	569.9	570.7	572.7	571.5	572.5	571.8	571.5
15	571.9	571.8	572.6	573.3	569.7	572.8	572.0
16	572.4	570.7	569.4	570.3	570.8	570.3	570.6
17	572.8	569.9	570.7	569.7	571.9	570.0	570.8
18	569.8	571.8	572.1	572.3	572.4	571.5	571.6
19	570.2	571.9	572.0	572.1	569.4	572.3	571.3
20	572.4	571.0	569.5	570.2	571.3	570.7	570.8

Diode	Leg 1B	Leg 2B	Leg 3B	Leg 4B	Leg 5B	Leg 6B	Average
1	568.6	572.9	571.6	575.0	570.6	572.9	571.9
2	571.3	571.5	571.9	570.3	570.7	571.1	571.1
3	572.9	569.8	570.0	571.9	574.0	569.0	571.3
4	567.2	574.1	572.6	572.4	572.3	570.9	571.6
5	572.0	569.6	572.3	571.8	567.4	572.1	570.9
6	575.0	570.4	569.6	570.5	572.4	569.6	571.2
7	573.3	569.4	571.9	568.5	570.0	569.9	570.5
8	569.6	571.2	572.4	570.6	571.9	571.1	571.1
9	570.0	573.0	574.2	573.9	569.6	570.5	571.9
10	570.3	567.9	570.7	571.5	571.3	570.7	570.4
11	573.9	570.5	568.8	568.9	570.1	571.2	570.6
12	568.7	573.0	573.3	572.2	571.7	571.8	571.8
13	570.5	574.4	574.0	574.0	566.9	574.3	572.3
14	572.5	570.7	568.1	569.6	569.4	571.8	570.3
15	568.2	571.4	570.7	570.6	574.3	569.4	570.7
16	570.3	570.3	573.2	569.7	568.3	570.2	570.3
17	573.6	574.8	572.7	570.5	569.1	569.9	571.8
18	569.3	571.2	570.1	571.8	571.7	571.8	571.0
19	571.2	572.1	571.0	570.3	572.9	569.2	571.1
20	570.4	572.7	573.6	570.8	574.1	572.3	572.3

Figure B.8
M6Leg240Ch Calibrate Spreadsheet

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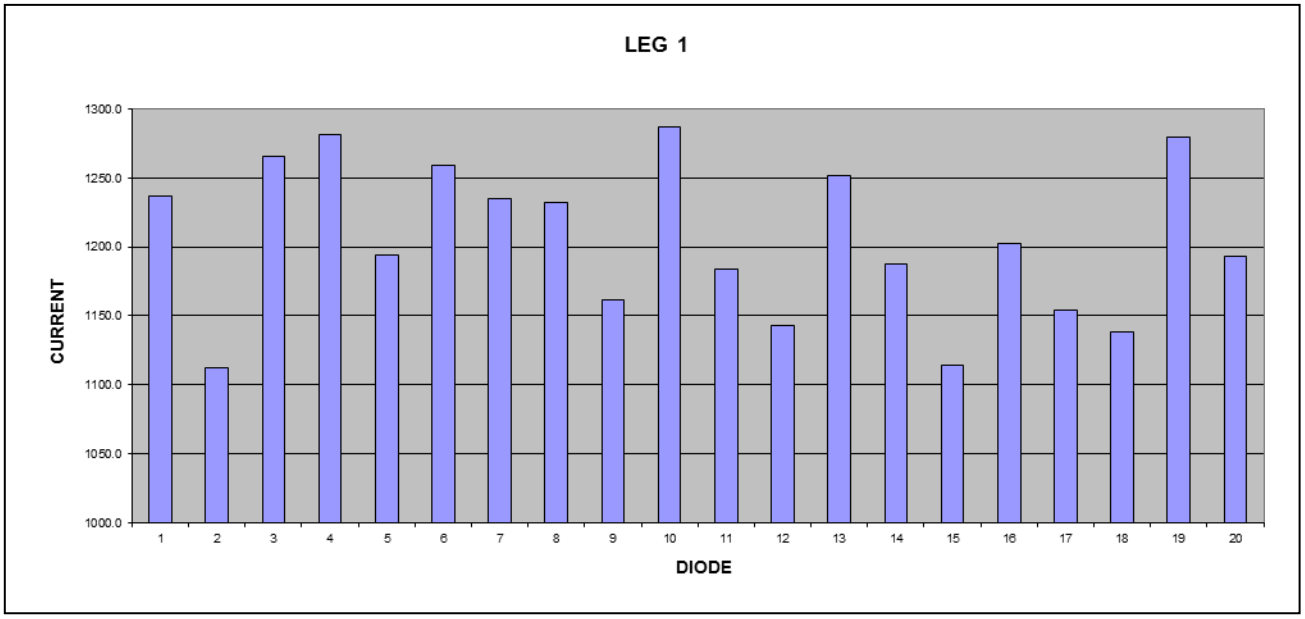


Figure B.9
Leg 1 Bar Chart