TCM-1A
THREE-CHANNEL SIGNAL CONDITIONER
INSTRUCTION MANUAL
REV. D

November, 2008

PREPARED BY:

Macintyre Electronic Design Associates, Inc.
(MEDA, Inc.)
43676 Trade Center Place, Suite 145
Dulles, Virginia 20166
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FUNCTIONS AND CONTROLS</td>
<td>1</td>
</tr>
<tr>
<td>1.1 FRONT PANEL FUNCTIONS AND CONTROLS</td>
<td>1</td>
</tr>
<tr>
<td>1.2 REAR PANEL FUNCTIONS AND CONTROLS</td>
<td>1</td>
</tr>
<tr>
<td>2. INTRODUCTION</td>
<td>3</td>
</tr>
<tr>
<td>3. DESCRIPTION</td>
<td>4</td>
</tr>
<tr>
<td>4. OPERATING INSTRUCTIONS</td>
<td>5</td>
</tr>
<tr>
<td>4.1 ELECTRONIC OPERATING INSTRUCTIONS</td>
<td>5</td>
</tr>
<tr>
<td>4.2 BATTERY MAINTENANCE INSTRUCTIONS</td>
<td>6</td>
</tr>
<tr>
<td>4.3 BATTERY REPLACEMENT</td>
<td>6</td>
</tr>
<tr>
<td>5. CIRCUIT DESCRIPTION</td>
<td>7</td>
</tr>
<tr>
<td>5.1 SIGNAL CONDITIONER</td>
<td>7</td>
</tr>
<tr>
<td>5.1.1 Signal Processing Amplifiers</td>
<td>7</td>
</tr>
<tr>
<td>5.2 NOTCH FILTERS</td>
<td>8</td>
</tr>
<tr>
<td>5.3 BATTERY CHARGER CIRCUIT</td>
<td>8</td>
</tr>
<tr>
<td>5.4 VOLTAGE SPLITTER</td>
<td>9</td>
</tr>
<tr>
<td>6. SUGGESTIONS FOR ELECTRONIC CHECKOUT</td>
<td>10</td>
</tr>
<tr>
<td>6.1 SIGNAL CONDITIONER</td>
<td>10</td>
</tr>
<tr>
<td>6.2 FREQUENCY RESPONSE TEST OF COMPLETE INSTRUMENT</td>
<td>10</td>
</tr>
<tr>
<td>6.3 CALIBRATION CHECK</td>
<td>10</td>
</tr>
<tr>
<td>7. SPECIFICATIONS</td>
<td>12</td>
</tr>
<tr>
<td>APPENDICES:</td>
<td></td>
</tr>
<tr>
<td>APPENDIX A - DRAWINGS</td>
<td>13</td>
</tr>
<tr>
<td>APPENDIX B - PARTS LIST</td>
<td>19</td>
</tr>
</tbody>
</table>
1. FUNCTIONS AND CONTROLS

1.1 FRONT PANEL FUNCTIONS AND CONTROLS

- **SENSOR** receptacle accepts the cable connector from the coil and preamplifier.

- **FILTERS** switch inserts line-frequency-rejection filters in the circuit immediately following the preamplifier. A choice of 50 or 60 Hz filter sets is switch selectable (see rear panel controls). About 40 dB of rejection is provided at the power line frequency and at each of its first four harmonics (i.e., 50, 100, 150, 200, 250 Hz or 60, 120, 180, 240, 300 Hz).

- **GAIN** multiplies instrument gain in steps: x1, x3, x10, x30, x100. Instrument scale factors are multiplied by the same number.

- **LEVEL** variable attenuator allows continuous adjustment of signal gain from unity at “CAL” down to zero when the pointer is in full clockwise position. To ensure unity gain, be sure to rotate control fully counterclockwise until it “clicks”.

- **OVERLOAD** indicator lights when the instrument output exceeds ±10 volts.

- **OUTPUT** is a BNC connector carrying an analog output signal +10 volts full scale with gain independent of signal frequency. Scale factor is 25 mV/gamma at x1 and **GAIN** at “CAL”.

- **LO BATT** indicator glows when battery needs recharging. Full charge takes about 16 hours.

- **POWER** push-on push-off switch with lampless indicator. Indicator shows Black when out (OFF) and Orange when in (ON).

1.2 REAR PANEL FUNCTIONS AND CONTROLS

- **MONITOR OUTPUT** BNC connector provides the signal conditioner output signal on the front panel.
• **CALIBRATION** is a BNC connector to a calibration winding on the sensor that produces a magnetic field with a scale factor of 20 nanotesla/volt.

• **NOTCH FILTERS** switch selects power line frequency to which line reject filters are tuned.

• **POWER SELECT** is a three position rotary switch permitting choice of power supply mode:

  1) **AC**  Powered by 115 VAC line.
  2) **AC/CHG**  Unit powered by a.c. line and batteries being charged.  Associated front panel LED glows during charging.
  3) **BAT**  Unit powered by internal NICAD batteries.
2. **INTRODUCTION**

The TCM-1A is a portable, wide bandwidth, low noise three-channel signal conditioner for use with MEDA magnetometer sensors, such as the MGC-1 and MGC-1A. The unit consists of a three-channel signal conditioner unit. The sensors and signal conditioner store inside a rugged aluminum carrying case, which is suitable for typical field operating environments. The signal conditioner can be easily removed and installed in a standard NEMA rack with mounting ears provided.

The preamplifier of each sensor is connected through a 20 foot cable to the signal conditioner unit which provides power to and conditions the output from the preamplifier. The signal conditioner controls allow the operator to select five different amplification levels (x1, x3, x10, x30, x100). A separate potentiometer can be used by the operator to adjust the gain between zero and the maximum value.

The output is independent of the frequency of the measured field from 5 Hz to 10,000 Hz (3dB points). An LED indicator light which is associated with each channel indicates overloads in the output.

Calibration inputs are provided on the signal conditioner rear panel which enable a current to be passed through an independent calibration winding on each sensor.

Two sets of power line rejection filters can be switched into the circuit to overcome saturation induced by power line interference. Either 50 or 60 Hz filters can be selected. The power line frequency and each of its first four harmonics are rejected by notch filters approximately 40 dB deep.
3. DESCRIPTION

The signal conditioner package provides d.c. power to as many as three preamplifiers through 20-foot cables. The same 6 conductor shielded cables carry the preamplifier signals back to the conditioner package. See Figure 3.1.

All calibration inputs and signal outputs are brought out to BNC connectors on the rear panel.
4. OPERATING INSTRUCTIONS

4.1 ELECTRONIC OPERATING INSTRUCTIONS

It is of utmost importance that saturation of the sensor preamplifiers be prevented during data collection. The following procedure is recommended to avoid preamplifier overload:

1) **FILTER** switch to out.

2) **GAIN** at “x1”; attenuator at “CAL”.

3) Move sensor until **OVERLOAD** indicator is extinguished.

An explanation of how this procedure works is given below with reference to the Single Axis Block Diagram in Figure 4.1.

The approach to avoiding preamplifier saturation is to use the signal conditioner overload detector circuit to monitor the output voltage of the preamplifier itself. This is possible when the gain of the intervening circuits is exactly one. In order to ensure unity gain from the preamp output to the overload detector, it is necessary to place the variable attenuator at CAL and the Gain Range Switch at X1. Overload is caused by power line pickup at 60 Hz and its harmonics. For this reason, it is important that the power line rejection filters be switched out of the signal path when the overload detector is being used to monitor saturation of the preamplifier. Otherwise, the preamplifier output could be saturating at power line frequency or one of its harmonics, yet the rejection filters would prevent the overload indicator from revealing this condition to the operator.

When preamplifier overload is detected, there is no remedy other than relocating or reorienting the coil or coils in question. Note carefully that the line notch filters are of absolutely no avail because they are downstream of the preamplifier output where the saturation is occurring. Also, the line filters can be harmful, because they can mask the effects of preamplifier saturation if switched in, as explained above.

Given that the preamplifier is operating linearly, the gain and variable attenuator controls are set to provide a conveniently large output signal. It is here that the line notch filters have their proper use. Switching them in can eliminate an output saturation condition caused by power line pickup.
4.2 BATTERY MAINTENANCE INSTRUCTIONS

The NICAD batteries should be used until the LO-BAT indicator comes on before being recharged. They should then be recharged overnight by placing the POWER SELECT switch on the rear panel in the AC/CHG position and connecting the a.c. line power cord to a source of 115 VAC. A full charge takes about 16 hours and, while charging may be continued longer without immediate damage, the switch should not be left in the charge position for extended periods.

The charge indicator LED on the front panel will dim when the batteries approach full charge but will not extinguish.

Note that for optimum noise performance of the signal conditioner, the a.c. line cord should be disconnected. Operation on a.c. is provided only as an expedient.

4.3 BATTERY REPLACEMENT

Remove the case of the signal conditioner by first removing twelve (12) Phillips head screws and then sliding the cover to the rear. It is recommended that the Battery Fuse be removed during this operation.

Invert the signal conditioner chassis and remove two 6-32 screws securing the battery bracket.

Replace the batteries with two of the following:

Alexander H4463B, 15V, 500 mAH.

These batteries are widely used in portable communications gear and are thought to be available worldwide.

Reverse the above procedures, being sure to reinsert the battery fuse.
5. CIRCUIT DESCRIPTION

5.1 SIGNAL CONDITIONER

5.1.1 Signal Processing Amplifiers

Refer to the schematic drawing of the Signal Conditioner in Appendix A, Figure 5.1. The description below is in terms of the X channel which is shown explicitly in the diagram; it applies also to the identical y and z channels of which the component designations begin with 1 and 2, respectively.

In the signal conditioner, switch S11 places the line notch filters in or out of the signal path. C103 and R120 form a high pass filter that prevents d.c. offset voltage of the preamplifier from being amplified by U14A. Control R120 is the variable attenuator that allows continuous gain adjustment from 0 to unity. Another high pass filter is formed by C105, R136 and R137. Trimming potentiometer R136 allows calibration of the channel gain. The parallel combination of R136 and R137 forms a low pass filter with C106 that rolls the instrument gain off above 18 kHz.

Amplifier U14 is a unity gain buffer required to drive input resistor R156 without attenuation.

The saturation detector consists of zener diode CR15 in series with light emitting diode CR16. Diodes CR11 - CR14 form a full wave rectifier that makes the L.E.D. glow on both polarities of signal excursion. Resistor R155 controls the L.E.D. current and sets its brightness. Approximately 9 volts of amplifier output are required to cause the zener to conduct. Full brightness is achieved at 10 volts output, and output amplifier clipping occurs at about +12 volts output.

Note that the connection between power supply common and high quality ground occurs at, and only at, the positive input of the preamplifier. Thus, all voltage amplification in the signal processor is referred to the same reference point as the sensor coil, namely the positive input of the preamplifier.

In order for the signal conditioner to operate properly when being tested, this connection between HQ ground and Power ground must be made externally. That is the function served by the connection between pins B and E on the input connector shown in Figure 6.1.
5.2 NOTCH FILTERS

The top tier of circuitry on the schematic diagram is the notch filter electronics; it consists of 5 sets of cascaded circuits which are identical except for element values. The first set comprises amplifiers U11A and U11B and performs the band-reject or notch filter function for the fundamental frequency of power line interference. Amplifier U11A is a tuned amplifier which is resonant at the notch frequency; its gain is minus unity at resonance and small elsewhere as dictated by a Q of approximately 10. The inverted output of the resonator is added to the signal itself in amplifier U11B to implement the band reject function. Analog switch U16 connects resistors R102 and R103 into the circuit to raise the resonant frequency from 50 to 60 Hz.

The other sets of cascaded circuits perform analogously to provide notches at the first four harmonics of the selected power line frequency.

Switch S11 selects whether or not the filters are in the signal path. It also removes power from the integrated circuits when the filters are not in use.

Switch S2 on the rear panel selects 50 Hz or 60 Hz operation of the notch filters.

5.3 BATTERY CHARGER CIRCUIT

The three-mode circuit which provides line power and charges the NICAD batteries is shown in Figure 5.2 in Appendix A.

When rotary switch S3 is in position 1, AC, the circuit is purely a.c. powered, and the NICAD batteries are disconnected. When the switch is in position 2, AC/CHG, the unit continues to be powered by a.c., but the NICAD batteries are connected so as to charge in parallel across the 30V d.c. supply provided by power supply PS1. That is battery BAT 2 is connected in series with R13 and CR4 across the supply voltage. Resistor R13 sets the charging current at the 16-hour rate (about 36 mA). Diode CR4 prevents self discharge of the batteries in the event of a.c. interruption. Battery BAT 1, Resistor R10 and diode CR3 function in the same way.

When the rotary switch is in position 3, BAT, the batteries are connected in series to form a 30 VDC supply and power supply PS1 is open circuited.
5.4 VOLTAGE SPLITTER

In both a.c. and battery modes, a voltage splitting circuit provides a power common or ground terminal for the signal conditioner. Please refer to Figure 5.2 in Appendix A. Resistors R4 and R5 and voltage follower amplifier U2 provide a low impedance ground rail by splitting the incoming 30 volt supply.

A voltage monitor circuit is formed by resistive divider R2, R3 and integrated circuit U1. A fraction of the battery voltage is compared with an internal reference voltage. When the battery voltage falls below 24.6 volts nominal, the LO BAT LED, CR1, is illuminated.
6. SUGGESTIONS FOR ELECTRONIC CHECKOUT

6.1 SIGNAL CONDITIONER

Overall performance of the signal processor can be verified using an audio signal generator and a LEMO FGG.1B307 clad connector, as shown in Figure 6.1. Be sure to jump pin B to pin E or the circuit will not function.

The operation of the overload detector circuit can be verified by observing the output on an oscilloscope while varying the input signal amplitude.

The relative gains provided by the Gain Range Switch can also be checked using this setup.

6.2 FREQUENCY RESPONSE TEST OF COMPLETE INSTRUMENT

A check of the instrument can be performed using a coil of wire and the Hewlett-Packard 3582A Spectrum Analyzer. The general arrangement of the test is given in Figure 6.2.

The performance of the notch filters can be conveniently demonstrated and measured with the setup of Figure 6.2 by running transfer functions with filters switched in.

6.3 CALIBRATION CHECK

A CALIBRATION INPUT BNC connector for each channel is found on the rear panel of the TCM-1A. A signal source connected to this input produces a magnetic field of 20 nanotesla/volt in any standard MEDA sensor. Because the basic scale factor of the instrument is 25 mV/nanotesla, this calibration input produces 1 volt out for two volts in.

A function check of the instrument can be made by connecting an audio signal generator to the CAL. INPUT and testing with an oscilloscope to verify that there is a gain of 0.5 at the MONITOR OUTPUT BNC on the rear panel or OUTPUT BNC on the front panel. Perform this check for each channel and vary the frequency over the bandwidth specified for the sensor in use.
Be sure that:

1) The variable **GAIN** control on the front panel is turned fully counterclockwise to the click position.

2) The **GAIN** switch on the front panel is set to 1. (In fact, the operation of this control can be verified during this test, because the gain of the instrument from **CAL** input to **OUTPUT** should be exactly the same as the setting of this **GAIN** switch.

The overall transfer function of the instrument can be measured conveniently as follows:

Connect a spectrum analyzer such as the HP 3582A to measure the transfer function between the **CAL** input and the **OUTPUT** or MONITOR OUTPUT. The effect of the notch filters will be observed in the transfer function when the **FILTERS** switch is **IN**.
### 7. SPECIFICATIONS

<table>
<thead>
<tr>
<th>FREQUENCY RESPONSE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Output:</td>
<td>5 Hz to 10 kHz (3dB points)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACCURACY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>@ 160 Hz:</td>
<td>±1%</td>
</tr>
<tr>
<td>20 &lt;frequency &lt;2000 Hz:</td>
<td>Maximum 1dB peak-to-peak deviation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>POWER LINE REJECTION FILTERS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch Selectable:</td>
<td>40 dB notches at 50, 100, 150, 200, 250 Hz</td>
</tr>
<tr>
<td></td>
<td>40 dB notches at 60, 120, 180, 240, 300 Hz</td>
</tr>
</tbody>
</table>

| A.C. POWER: | 105 V to 125 V ac, 50 to 400 Hz - 7.2 WATTS |

<table>
<thead>
<tr>
<th>BATTERY POWER SUPPLY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery:</td>
<td>2 Alexander H4463B, in Series</td>
</tr>
<tr>
<td>Voltage:</td>
<td>30 V</td>
</tr>
<tr>
<td>Capacity:</td>
<td>500 mAH</td>
</tr>
<tr>
<td>Charging Time from Full Discharge:</td>
<td>16 H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CURRENT DRAIN (NOMINAL)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>All Filters In:</td>
<td>161 mA</td>
</tr>
<tr>
<td>Filters Out:</td>
<td>122 mA</td>
</tr>
</tbody>
</table>
APPENDIX A

DRAWINGS
## TCM-1A SIGNAL CONDITIONER ASSEMBLY

<table>
<thead>
<tr>
<th>REF. DES.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCHEMATIC DIAGRAM, SIG COND</td>
<td>402197-1</td>
<td>MACHINING DRAWING PCB, SIG COND</td>
<td>MEDA</td>
</tr>
<tr>
<td>FRONT PANEL, SIG COND</td>
<td>400042-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>REAR PANEL, SIG COND</td>
<td>401069-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>HOUSING, SIG COND</td>
<td>400044-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>MOUNTING EAR, RACK</td>
<td>200045-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>BUTTON, LAMPLESS INDICATOR</td>
<td>FA-201</td>
<td>ITT SCHADOW</td>
<td></td>
</tr>
<tr>
<td>SWITCH DETENT BRACKET</td>
<td>200038-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>KNOB - GAIN SELECT</td>
<td>KPN-500B 1/8</td>
<td>ALCO</td>
<td></td>
</tr>
<tr>
<td>KNOB - POWER SELECT</td>
<td>KPN-500B ¼</td>
<td>ALCO</td>
<td></td>
</tr>
<tr>
<td>KNOB - VARIABLE GAIN</td>
<td>KLN-500B 1/8</td>
<td>ALCO</td>
<td></td>
</tr>
<tr>
<td>TILT STAND</td>
<td>MP40008-10</td>
<td>BUCKEYE</td>
<td></td>
</tr>
<tr>
<td>BATTERY BRACKET</td>
<td>301064-1</td>
<td>MEDA</td>
<td></td>
</tr>
<tr>
<td>NICAD BATTERY, 5V, 500 mAH</td>
<td>B1 + B2</td>
<td>ALEXANDER</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>199D336X9025EE2</td>
<td>33 µF, 25V, ELECTROLYTIC</td>
<td>SPRAGUE</td>
</tr>
<tr>
<td>C2</td>
<td>199D336X9025EE2</td>
<td>33 µF, 25V, ELECTROLYTIC</td>
<td>SPRAGUE</td>
</tr>
<tr>
<td>C3</td>
<td>199D336X9025EE2</td>
<td>33 µF, 25V, ELECTROLYTIC</td>
<td>SPRAGUE</td>
</tr>
<tr>
<td>C4</td>
<td>CK05BX104K</td>
<td>.1 µF, CERAMIC, 10%</td>
<td>AVX</td>
</tr>
<tr>
<td>C101</td>
<td>PPA11.1-1-100</td>
<td>.1 µF, 1%, POLYPROPYLENE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C102</td>
<td>PPA11.1-1-100</td>
<td>.1 µF, 1%, POLYPROPYLENE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C103</td>
<td>CK06BX105K</td>
<td>1 µF, CERAMIC</td>
<td>AVX</td>
</tr>
<tr>
<td>C104</td>
<td>CC05CG101G</td>
<td>100 pF, 2%, NPO CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C105</td>
<td>CK05BX104K</td>
<td>.1 µF, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C106</td>
<td>CCO5CG220F</td>
<td>22 µF, 1%, NPO CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C111</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C112</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C113</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C114</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C115</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C116</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C117</td>
<td>CC05CG101G</td>
<td>100 pF, 2%, NPO CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C121</td>
<td>PPA11.1-1-100</td>
<td>.1 µF, 1%, POLYPROPYLENE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C122</td>
<td>PPA11.1-1-100</td>
<td>.1 µF, 1%, POLYPROPYLENE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C141</td>
<td>PPA11.025-1-100</td>
<td>.025 µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C142</td>
<td>PPA11.025-1-100</td>
<td>.025 µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C151</td>
<td>CK05BX104K</td>
<td>.1 µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C161</td>
<td>PPA11.025-1-100</td>
<td>.025 µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C162</td>
<td>PPA11.025-1-100</td>
<td>.025 µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C181</td>
<td>PPA11.025-1-100</td>
<td>.025 µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
</tbody>
</table>

*NOTE: X CHANNEL PARTS: TENS & ONE HUNDRED SERIES (LISTED)  
Y CHANNEL PARTS: TWENTY & TWO HUNDRED SERIES (NOT LISTED)  
Z CHANNEL PARTS: THIRTY & THREE HUNDRED SERIES (NOT LISTED)
### TCM-1A SIGNAL CONDITIONER ASSEMBLY

<table>
<thead>
<tr>
<th>REF. DES.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>C182</td>
<td>PPA11.025-1-100</td>
<td>.025µF, 1%, POLYCARBONATE</td>
<td>F-DYNE</td>
</tr>
<tr>
<td>C191</td>
<td>CK05BX104K</td>
<td>.1µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>C192</td>
<td>CK05BX104K</td>
<td>.1µF, 10%, CERAMIC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>CR1</td>
<td>SLD821-2</td>
<td>L.E.D., RED</td>
<td>ALCO</td>
</tr>
<tr>
<td>CR2</td>
<td>SLD821-2</td>
<td>L.E.D., RED</td>
<td>ALCO</td>
</tr>
<tr>
<td>CR3</td>
<td>1N4001</td>
<td>DIODE</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>CR4</td>
<td>1N4001</td>
<td>DIODE</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>CR11</td>
<td>1N914</td>
<td>DIODE, SILICON</td>
<td>MOTOROLA</td>
</tr>
<tr>
<td>CR12</td>
<td>1N914</td>
<td>DIODE, SILICON</td>
<td>MOTOROLA</td>
</tr>
<tr>
<td>CR13</td>
<td>1N914</td>
<td>DIODE, SILICON</td>
<td>MOTOROLA</td>
</tr>
<tr>
<td>CR14</td>
<td>1N914</td>
<td>DIODE, SILICON</td>
<td>MOTOROLA</td>
</tr>
<tr>
<td>CR15</td>
<td>1N753A</td>
<td>DIODE, ZENER, 6.2V</td>
<td>MOTOROLA</td>
</tr>
<tr>
<td>CR16</td>
<td>SLD821-2</td>
<td>L.E.D., RED</td>
<td>ALCO</td>
</tr>
<tr>
<td>F1</td>
<td>270-1171</td>
<td>FUSE, 1 AMP SLOW-BLOW, 5X20 mm</td>
<td>RADIO SHACK</td>
</tr>
<tr>
<td>F2</td>
<td>270-1169</td>
<td>FUSE, ½ AMP SLOW-BLOW, 5X20 mm</td>
<td>RADIO SHACK</td>
</tr>
<tr>
<td>FH1</td>
<td>270-362</td>
<td>FUSE HOLDER</td>
<td>RADIO SHACK</td>
</tr>
<tr>
<td>FH2</td>
<td>270-362</td>
<td>FUSE HOLDER</td>
<td>RADIO SHACK</td>
</tr>
<tr>
<td>J1</td>
<td>17252</td>
<td>RECEPTACLE, AC</td>
<td>BELDEN</td>
</tr>
<tr>
<td>J13</td>
<td>17758</td>
<td>POWER CORD SET</td>
<td>BELDEN</td>
</tr>
<tr>
<td>J14</td>
<td>211</td>
<td>BATTERY CONTACT</td>
<td>KEYSTONE</td>
</tr>
<tr>
<td>J15</td>
<td>3384</td>
<td>RIVET, SEMI-TUBULAR</td>
<td>KEYSTONE</td>
</tr>
<tr>
<td>L11</td>
<td>EGG1B 307 CLL</td>
<td>CONNECTOR, SENSOR INPUT</td>
<td>LEMO</td>
</tr>
<tr>
<td>L12</td>
<td>800-2540-03-25</td>
<td>CONNECTOR, BNC ISOLATED</td>
<td>CONCORD</td>
</tr>
<tr>
<td>L13</td>
<td>800-2540-03-25</td>
<td>CONNECTOR, BNC ISOLATED</td>
<td>CONCORD</td>
</tr>
<tr>
<td>L14</td>
<td>800-2540-03-25</td>
<td>CONNECTOR, BNC ISOLATED</td>
<td>CONCORD</td>
</tr>
<tr>
<td>L15</td>
<td>800-2540-03-25</td>
<td>CONNECTOR, BNC ISOLATED</td>
<td>CONCORD</td>
</tr>
<tr>
<td>L16</td>
<td>56-590 65/4A6</td>
<td>INDUCTOR, FERRITE BEAD</td>
<td>FERROX-CUBE/PHILLIPS</td>
</tr>
<tr>
<td>P1</td>
<td>2.15.200</td>
<td>POWER SUPPLY</td>
<td>CALEX</td>
</tr>
<tr>
<td>R1</td>
<td>RC07C1242J</td>
<td>2.4K, 1/8W, 5% CC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R2</td>
<td>RN55D5623F</td>
<td>562K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R3</td>
<td>RN55D3921F</td>
<td>3.92K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R4</td>
<td>RN55D3921F</td>
<td>3.92K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R5</td>
<td>RN55D3921F</td>
<td>3.92K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R6</td>
<td>RN55D1004F</td>
<td>RESISTOR, 1M, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R7</td>
<td>RN55D4993F</td>
<td>RESISTOR, 499K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R9</td>
<td>RC07GF395J</td>
<td>RESISTOR, 3.9M, 1/4W, 5% CC</td>
<td>ANY MFR.</td>
</tr>
</tbody>
</table>
## TCM-1A SIGNAL CONDITIONER ASSEMBLY

<table>
<thead>
<tr>
<th>REF. DES.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>R10</td>
<td>RNC65J9530FS</td>
<td>953 OHMS, 5%, 1/2W</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R11</td>
<td>RN55D5621F</td>
<td>5.62K OHMS, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R12</td>
<td>RN55D5621F</td>
<td>5.62K OHMS, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R13</td>
<td>RNC65J9530FS</td>
<td>953 OHMS, 5%, 1/2W</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R101</td>
<td>RNC55H2673B</td>
<td>RESISTOR, 267K, 1/8W, 0.1%, 50 ppm</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R102</td>
<td>RN55D4121F</td>
<td>RESISTOR, 4.12K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R103</td>
<td>3292W-1-501</td>
<td>POT, 20T, 500 OHMS, CERMET</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R104</td>
<td>RN55D1821F</td>
<td>RESISTOR, 1.82K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R105</td>
<td>3292W-1-201</td>
<td>POT, 20T, 200 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R108</td>
<td>RN55D5636F</td>
<td>RESISTOR, 536K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R109</td>
<td>RC07GF395J</td>
<td>RESISTOR, 3.9M, 1/4W, 5%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R110</td>
<td>RN55D2002F</td>
<td>RESISTOR, 20K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R111</td>
<td>RN55D2002F</td>
<td>RESISTOR, 20K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R112</td>
<td>RN55D2002F</td>
<td>RESISTOR, 20K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R113</td>
<td>RC07GF305J</td>
<td>RESISTOR, 3M, 1/4W, 5%, CC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R115</td>
<td>RC07GF126J</td>
<td>RESISTOR, 12M, 1/4W, 5%, CC</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R116</td>
<td>RNC55H1302BS</td>
<td>RESISTOR, 13K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R117</td>
<td>RN55C2941B</td>
<td>RESISTOR, 2.94K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R118</td>
<td>RN55C9090B</td>
<td>RESISTOR, 909 OHMS, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R119</td>
<td>RNC55H2670B</td>
<td>RESISTOR, 267 OHMS, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R120</td>
<td>70L4G032R104W</td>
<td>POT, SINGLE TURN, 100K, CERMET</td>
<td>CLAROSTAT</td>
</tr>
<tr>
<td>R121</td>
<td>RN55D1333F</td>
<td>RESISTOR, 133K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R122</td>
<td>RN55D1821F</td>
<td>RESISTOR, 1.82K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R123</td>
<td>3292W-1-501</td>
<td>POT, 20T, 500 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R124</td>
<td>RN55D9090F</td>
<td>RESISTOR, 909 OHMS, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R125</td>
<td>3292W-1-201</td>
<td>POT, 20T, 200 OHMS, CERMET</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R128</td>
<td>RNC55H2673B</td>
<td>RESISTOR, 267K, 1/8W, 0.1%, 50 ppm</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R130</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R131</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R132</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R135</td>
<td>RN55C2612B</td>
<td>RESISTOR, 26.1K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R136</td>
<td>3292W-1-503</td>
<td>POT, 20T, 50K, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R137</td>
<td>RN55D8253F</td>
<td>RESISTOR, 825K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R141</td>
<td>RN55D3573F</td>
<td>RESISTOR, 357K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R142</td>
<td>RN55D5621F</td>
<td>RESISTOR, 5.62K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R143</td>
<td>3292W-1-501</td>
<td>POT, 20T, 500 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R144</td>
<td>RN55D241F</td>
<td>RESISTOR, 2.49K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R145</td>
<td>3292W-1-201</td>
<td>POT, 20T, 200 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R148</td>
<td>RN55D7153F</td>
<td>RESISTOR, 715K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R150</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R151</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R152</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R153</td>
<td>RC07GF305J</td>
<td>RESISTOR, 3M, 1/4W, 5%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R155</td>
<td>RC07GF301J</td>
<td>RESISTOR, 300 OHMS, 1/4W, 5%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R156</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
</tbody>
</table>
TCM-1A SIGNAL CONDITIONER ASSEMBLY

<table>
<thead>
<tr>
<th>REF. DES.</th>
<th>PART NUMBER</th>
<th>DESCRIPTION</th>
<th>MANUFACTURER</th>
</tr>
</thead>
<tbody>
<tr>
<td>R157</td>
<td>RN55D902F</td>
<td>RESISTOR, 90.9K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R158</td>
<td>RN55D2612F</td>
<td>RESISTOR, 26.1K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R161</td>
<td>RNC55H2673B</td>
<td>RESISTOR, 267K, 1/8W, 0.1%, 50 ppm</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R162</td>
<td>RN55D4121F</td>
<td>RESISTOR, 4.12K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R163</td>
<td>3292W-1-501</td>
<td>POT, 20T, 500 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R164</td>
<td>RN55D1821F</td>
<td>RESISTOR, 1.82K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R165</td>
<td>3292W-1-201</td>
<td>POT, 20T, 200 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R168</td>
<td>RN55D5363F</td>
<td>RESISTOR, 536K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R170</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R171</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R172</td>
<td>RN55C2002B</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R173</td>
<td>RN55D49R9F</td>
<td>RESISTOR, 49.9 OHMS, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R174</td>
<td>RN55D49R9F</td>
<td>RESISTOR, 49.9 OHMS, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R175</td>
<td>RN55D49R9F</td>
<td>RESISTOR, 49.9 OHMS, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R181</td>
<td>RN55D2103F</td>
<td>RESISTOR, 210K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R182</td>
<td>RN55D3321F</td>
<td>RESISTOR, 3.32K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R183</td>
<td>3292W-1-501</td>
<td>POT, 20T, 500 OHMS, CERMET</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R184</td>
<td>RN55D1431F</td>
<td>RESISTOR, 1.43K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R185</td>
<td>3292W-1-201</td>
<td>POT, 20T, 200 OHMS, CERMET</td>
<td>BOURNS</td>
</tr>
<tr>
<td>R188</td>
<td>RN55D4223F</td>
<td>RESISTOR, 422K, 1/8W, 1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R190</td>
<td>RN55C2002F</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R191</td>
<td>RN55C2002F</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R192</td>
<td>RN55C2002F</td>
<td>RESISTOR, 20K, 1/8W, 0.1%</td>
<td>ANY MFR.</td>
</tr>
<tr>
<td>R193</td>
<td>RC07GF395J</td>
<td>RESISTOR, 3.9M, 1/4W, 5%, CC</td>
<td>ANY MFR.</td>
</tr>
</tbody>
</table>

| S1        | NE1800E5F08010 1124201NN | SWITCH, POWER | ITT SCHADOW |
| S2        | A123S1YZQ          | SWITCH, SPDT | ALCO        |
| S3        | 71BD36-03-2-AJN    | SWITCH, POWER SELECT | GRAYHILL  |
| S11       | A323S1YZQ          | SWITCH, 3PDT TOGGLE | ALCO       |
| S13       | 50CD36-01-1-AJN    | SWITCH, 36 DEG. ROTARY | GRAYHILL |
| U1        | LM10CN             | OP AMP       | NSC         |
| U2        | LM346N             | OP AMP       | NSC         |
| U11       | LM346N             | OP AMP       | NSC         |
| U12       | LM346N             | OP AMP       | NSC         |
| U13       | LM346N             | OP AMP       | NSC         |
| U14       | AD712AH            | OP AMP DUAL BI-FET | ANALOG DEVICES |
| U15       | AD712AH            | OP AMP DUAL BI-FET | ANALOG DEVICES |
| U16       | CD4066BE           | ANALOG SWITCH | RCA        |
| U17       | CD4066BE           | ANALOG SWITCH | RCA        |