General

The 10X/98 MIU and TSMIU analog circuitry consists of six, or optionally 12 discrete channels of precision instrumentation amplifiers. These amplifiers have an input impedance of 10 megohms, making them ideal for use as general purpose analog channels for a wide variety of transducers that have an analog output of 0 VDC to 10 VDC. Those transducers, using the proper gain resistor, include J and K thermocouples, hydraulic pressure transducers, liquid flow transducers, linear potentiometers, dew point sensors, air pressure transducers, etc. (Note: due the input impedance required by load sensors, it is not recommended to directly connect these devices to the MIU. An external device is recommended that provides a re-transmitted 0 VDC to 10 VDC output).

Additional information concerning correct transducer wiring may be found in the "MIU Wiring & Installation Instructions, #710-0043", located in "On-Line Documentation" on the Mattec Corporation web site, www.mattec.com

NOTE: Mattec does not recommend parallel wiring of ANY transducer. Separate linear transducers are recommended and dual element thermocouples are recommended. Failure to follow this advice may affect machine performance, causing erratic behavior.

Hardware Gain

In order to attain the greatest resolution from the input device, hardware gain is applied to each channel. This hardware gain is necessary to allow the output of the amplifier to provide as near as possible a 0 VDC to 10VDC output to the A/D (analog to digital) converter, which then presents the analog data in digital format to the MIU processor. The formula for gain with the 1NA114 instrumentation amplifier is:

$$\mathbf{G = 1 + 50{,}000/Rg}$$

Where G = Gain and Rg = Gain Resistor.

Consequently, if the transducer (such as a thermocouple) provides a very small input voltage to the MIU, a fairly small gain resistor must be used. If the transducer (such as a linear pot) provides a large input voltage (e.g. 0 VDC to 10 VDC), a gain of 1 is all that is required. Two typical gain calculations are shown below.

Example 1

Assume the input device is a linear pot with an output swing of 0VDC to 10 VDC. Simple math shows that the gain for this device must be "1". Therefore:

$$\mathbf{G = 1 + 50000/Rg}$$
$$\mathbf{1 = 1 + 50{,}000/Rg}$$
$$\mathbf{0 = 50{,}000/Rg \text{ or } Rg = infinity.}$$

One can see that the gain resistor for a linear pot with a 0 VDC to 10 VDC output must be as large as possible. That is achieved by removing the gain resistor entirely.

Example 2

Assume the input device has a sensitivity of 2 mv / volt, as is typical with many transducers. Simple division can determine the required gain for any transducer. In this case, divide 1VDC by .002 VDC, resulting in a required gain of 500. Therefore:

$$\mathbf{G = 1 + 50000/Rg}$$
$$\mathbf{500 = 1 + 50{,}000/Rg}$$
$$\mathbf{500Rg = Rg + 50{,}000, \text{ or } 499Rg = 50{,}000}$$
$$\mathbf{Or}$$
$$\mathbf{Rg \approx 100\ \Omega.}$$

Consequently the gain resistor for a 2 mv/V transducer is 100 Ω

Note: When the specific precision resistor is not available, use the next larger size.

In order to provide the most accuracy with the circuitry, precision gain resistors are used. The standard resistors provided by the analog Simms in the TSMIU and the 10X/98 MIU are shown in the following table:

MIU Channel	Resistor	Gain Resistor	Transducer Type
Channel 1 and 7	R18	182 Ω	J / K Thermocouple
Channel 2 and 8	R15	182 Ω	J / K Thermocouple
Channel 3 and 9	R14	182 Ω	J / K Thermocouple
Channel 4 and 10	R13	182 Ω	J / K Thermocouple
Channel 5 and 11	R22	150 Ω	3mv/V Transducer
Channel 6 and 12	R23	150 Ω	3mv/V Transducer

Additional information about the analog Simms and gain resistors may be found in the “MIU Wiring & Installation Instructions, #710-0043”, located in “On-Line Documentation” on the Mattec Corporation web site, www.mattec.com

Software Gain and Offset

In order to properly calibrate the transducers, software gain and offset is provided at the MIU. Hardware gain allows the instrumentation amplifiers to provided the greatest output range for a given transducer in order to provide the greatest output swing in voltage. This in turn provides the greatest swing in digital values. For an amplifier output voltage of 10 VDC, the digital output will be 2048, and for an amplifier output voltage of 0 VDC, the digital output value will be 0. Software gain and offset provides the fine adjustment necessary to accurately calibrate the signal by taking the native digital value and converting it to the appropriate engineering units. In addition, for J and K type thermocouples, the software controls the linearization of these transducers, but the gain and offset must be set properly for accurate calibration. On the TSMIU, the Analog Calibration screen is located in the Service menu. On the 10X/98 MIU, Analog Calibration is the fist menu selection under “22 MIU Information” from the Main Menu.

Once in the Analog Calibration screen, saving the data is slightly different in ProHelp® EPM vs. ProHelp® Millennium. In ProHelp® EPM, simply press the “store” or “Save to the Host” button. In ProHelp® Millennium, the information cannot be save to the host unless the “Remote Analog Calibration” flag is turned on in System Manager. Otherwise, the information must be written down and manually entered at the host. For more information on this, see the ProHelp® Millennium Operators Guide, 710-0088, or the Touchscreen MIU Operator’s Manual, 710-0091 on the Mattec Corporation web site, www.mattec.com .

Software Gain calculations are shown in the procedures listed below. The calculation for Offset is:

Offset = (Software Gain)*(MIU Low) + / - (Machine Low)

There are a number of ways to determine offset; this is one. Other methods are also viable.

Calibration Procedures

Listed below are recommended calibration procedures for the standard transducers used by ProHelp® Millennium and ProHelp® EPM. For assistance in calibrating other types of transducers, contact the Mattec Customer Service Department. To calibrate any transducer, make sure that the channel selected for calibration has the software gain set to “1.000” and the Offset set to “0” initially. In addition, the signal definition and decimal value must be set up properly at the host computer. For thermocouples, select the appropriate type at the host. For linear pots and linear pressure transducers, select “Linear Analog” at the host. One must also know the output resolution of the transducer, which can be found in the transducer specifications. Typical pressure transducers have a 3mv/V output, typical Linear Pots have a typical 1V/V output, and thermocouples have millivolt outputs. While any appropriate transducer may be connected to any channel, typically the hardware gain of the MIU is set to assume channels 1 through 4 are thermocouples and channel 5 and 6 are 3mv/V transducers. If different transducers are connected to these channels, the gain resistors must be adjusted accordingly.

Linear Potentiometers

Long method

Linear Potentiometers are typically connected to channel 5 of the MIU. If the 10 Volt excitation voltage provided by the MIU is used as the excitation for the linear pot, a gain of 1 is required. In addition, it is recommended for loading purposes that the linear pot be at least 5KΩ. Normally, customers monitor "Shot Size" and "Cushion" on the machine with a linear pot. Shot size is the largest value of the pot, and cushion is the smallest value. In order to properly calibrate this, one must be able to move the linear pot to the full forward mechanical stop on the machine and the full reverse mechanical stop. If the linear pot reads minimum at the full reverse position, the excitation voltage is wire backwards.

To calibrate, and assuming a linear pot is installed on a molding machine:

1. Remove the gain resistor from the appropriate channel (assuming the gain is 1. If the gain is something other than 1, install the appropriate gain resistor by using the formula provided in "Hardware Gain".
2. Move the screw to the full reverse position. Accurately note the position on the machine-mounted scale or on the machine operator station. Note the "value" reading on the MIU.
3. Move the screw to the full forward position. Accurately note the position on the machine-mounted scale or on the machine operator station. Note the "value" reading on the MIU.
4. Use these values to calculate the software gain using the following simple ratio formula:

   [(Machine High) – (Machine Low)] / [(MIU High) – (MIU Low)] = Software Gain

   For Example:

   MIU High = 18.00 MIU Low = .18
   Machine High = 17.75 Machine Low = .15

   [(17.75) – (.15)] / [(18.00) – (.18)] = (17.6) / (17.82) = .987

5. Enter the calculated gain in the Gain field on the MIU, in this case .987
6. Run the screw to the full reverse position. Verify that the machine reads the same position. Then verify that the MIU reads the same as the machine. Note any differences plus or minus.
7. Run the screw to the full forward position. Verify that the machine is at the same position as in step 3. Verify the MIU reading and note any difference.
8. Assuming the difference, if any, is the same for both full forward and full reverse, enter that difference in the offset field.

The linear pot is now calibrated. This can be verified by monitoring the actual value when the machine runs. Make sure these values are stored at the host.

Short Method (Used when it is impractical to position the screw to it's max and min)

To use this method, one must be able to get an accurate reading of the screw position with the machine stopped. In addition, this assumes that the linear pot is linear over its full range. Normally this is true, but occasionally near the ends of the pot, some linearity is skewed. If one can assume that the pot is of sufficient length that the actual mechanical movement of the machine falls within 80% of the full range of the pot, this short method works quite well.

1. Remove the gain resistor from the appropriate channel (assuming the gain is 1. If the gain is something other than 1, install the appropriate gain resistor by using the formula provided in "Hardware Gain"
2. With the machine stopped, note the machine position on the operator panel. Note the reading in the "value" field on the MIU
3. Divide the MIU reading by the Machine reading and apply the appropriate offset

In the example above, assume the machine value is 17.75 and the MIU value is 15.30. Doing the appropriate math yields a gain of .86, the same as in the long method. The short method is valid due to the assumption that the linear pot is truly linear over at least 80% of its range, and that the machine truly moves in a linear plane. Again, make sure these values are stored at the host.

Pressure Transducers

Assuming that pressure transducers are linear over a certain percent of their range, one can use similar methods to calibrate the transducers. First, assure that the analog channel is set up as “linear analog” at the host, and that the appropriate gain resistor is installed. In addition, verify that the gain and offset for the appropriate channel are set to 1.000 and 0 respectively.

Shunt Resistor Method

Current state of the art pressure transducers are supplied with shunt calibration wires. When these wires are shorted together, the pressure transducer guarantees an output voltage (see the transducer’s specifications) that is typically 80% of the transducer’s output. For a 3000 PSI transducer, that output would be 2400 PSI. For a 5000 PSI transducer, that value would be 4000 PSI. Note that one can assume that the output of the transducer will be 0 Volts at 0 pressure, and 2400 PSI for 80% full scale, simulated when the shunt resistors are shorted.

1. Short the shunt resistor wires together. Note the “value” field on the MIU screen. This value will be the “MIU High Value”. The “Machine High” value is 2400 (with a 3000 PSI transducer)
2. Open the shunt resistor wires and relieve all hydraulic pressure from the line, noting the MIU value reading. That value will be the “MIU Low” reading. The “Machine Low” reading is assumed to be 0 PSI with all pressure bled off
3. Use these values to calculate the software gain using the following simple ratio formula:

   [(Machine High) – (Machine Low)] / [(MIU High) – (MIU Low)] = Software Gain

   For Example:

   MIU High = 1680 MIU Low = 11
   Machine High = 2400 Machine Low = 0

   [(2400) – 0)] / 1680) – (11)] = (2400) / (1669) = 1.438

4. Apply the gain and calculate the appropriate offset. In the example, after applying the gain, the offset formula yields an offset of –16

Machine Gauge Method

A slightly more accurate method of calibrating pressure transducers is available when actual machine pressure is used to calibrate the transducer. Many machines have the ability to pressurize the hydraulic system in order to calibrate the machine, or a pressure pump may be used. With either method, and again knowing the specification of the transducer, calibration is quite simple using the method described in the Shunt Resistor method.

1. Pump up the hydraulics to a known value that does not exceed 80% of the transducers full range. Note the Machine Value and the MIU Value
2. Release the pressure and pump up the pressure to a value approximately 20% of the transducer range. For a 3000 PSI transducer, the value would be approximately 600 PSI Note the Machine Value and the MIU Value
3. Use these values to calculate the software gain using the following simple ratio formula:

   [(Machine High) – (Machine Low)] / [(MIU High) – (MIU Low)] = Software Gain

   For Example:

   MIU High = 1560 MIU Low = 455
   Machine High = 2300 Machine Low = 650

[(2300) – (650)] / (1560) – (455)] = (1650) / (1105) = 1.493

4. Apply the gain and calculate the appropriate offset. In the example, after applying the gain, the offset formula yields an offset –29

When using the Machine Gauge Method, it is wise to repeat the procedure more than once in order to average the inaccuracies in the hydraulic system

With either method, the final step is to transmit or manually enter the values in the host computer.

Thermocouples

Calibration of thermocouples requires that the temperature in the MIU be stable. Therefore it is recommended that the MIU front door remain closed for at least 15 minutes before calibration is attempted. In addition, it is necessary to know the type of thermocouple (J-type or K-type, Grounded or Ungrounded) and whether the reading is to be in Fahrenheit or Celsius. The type and reading must be properly set up in the host computer and the gain resistor must be correct. A thermocouple calibrator such as an Altek Model 322 is highly recommended. In addition, in order to maintain the stability of the MIU, it is recommended that all calibration be done with the door closed. This will require an access point external to the MIU, but typically that is available at the Thermocouple junction box mounted on the machine. Again verify that the gain and offset of the channel to be calibrated is set to 1.000 and 0 respectively.

Normal installation of thermocouples requires that jumpers **JA1** thru **JA14** in the MIU be set properly. For all thermocouples, JX2 must be "on". For ungrounded thermocouples, the appropriate ground jumper in the MIU must be "on". For grounded thermocouples, the appropriate ground jumper in the MIU must be "off". Location of the appropriate jumpers may be found in the MIU Wiring and Installation Guide, 710-0043, located on the Mattec Corporation web site, www.mattec.com.. Using the Altek simulator requires disconnecting the thermocouple at the junction, which essentially un-grounds the thermocouple channel. Therefore, in order to efficiently calibrate the thermocouples using the simulator, it is recommended that all the ground jumpers be "on", which has the effect of grounding the simulator as each channel is calibrated.

Once the proper thermocouple type is set up at the host, each thermocouple channel at the MIU may be calibrated. It is important to know the range of calibration required for a given channel. Thermocouples are very non-linear devices, and software in the MIU is used to linearize the thermocouple temperature curve. However, that linearization is somewhat different for different parts of the temperature curve. Therefore it is recommended that one calibrate somewhat near the range of interest. For example, if the thermocouple is used to monitor oil temperature, the range of interest may be 50 to 150 deg F, rather than 50 to 700 deg F, since the area of interest is typically around 110 degrees F. On the other hand, nozzle temperatures are typically in the 400 to 700 deg F range, so it doesn't make sense to calibrate to 50 degrees.

Normal Procedure

1. Verify that the ground jumper is "on" and that the host is set up properly, and that the MIU has been stable for at least 15 minutes. This can be checked on the TSMIU by monitoring the MIU temperature on the Service display.
2. Hook up the simulator to the proper channel, making sure that proper polarity is followed (on a J-type thermocouple for instance, the red lead is the minus lead and the white lead is the positive lead)
3. Set the simulator to the proper thermocouple type and "source".
4. Set the simulator to the desired high temperature, note the reading and note the value displayed on the MIU "value" field. These will be the "Machine High" value and the "MIU High" value.
5. Set the simulator to the desired low temperature and note the simulator reading and the MIU reading. These will be the "Machine Low" value and the "Miu Low" value

Note that since the host setup defines the type of analog channel, readings in the MIU "value" field will be fairly close to the appropriate temperature, rather than in bit weight when the channel is defined as linear analog.

6. Apply the formula as previously described:

[(Machine High) – (Machine Low)] / [(MIU High) – (MIU Low)] = Software Gain

For Example:

MIU High = 785 MIU Low = 470
Machine High = 750 Machine Low = 450

[(750) – (450)] / (785) – (470)] = (300) / (315) = .952

7. Apply the gain to the MIU low value to determine the offset. In the example above, applying the gain formula yields an offset of +3

These values must then be sent to the host computer as previously described. Once the calibration procedure is complete, the discrete thermocouples may be plugged in and the appropriate ground jumper positions set.

Alternate Procedure

This alternate procedure is described due to the fact that the above procedure assumes ideal conditions, and does not take into account physical wire length, physical differences in the thermocouples, whether the machine has been properly calibrated, electrical noise in the system, and a number of other real world problems. Thermocouple outputs are in the small mv range, and 1 mv can make a huge difference in the actual reading of the thermocouple. If one were to be as accurate as possible, one would calibrate the machine thermocouples at the same time the MIU thermocouples are being calibrated; however, this is normally not practical. Customers generally want the MIU thermocouple to "read the same as" the machine thermocouple, and typically the actual thermocouple readings for nozzle, zone 1, etc. are available on the machine control pane. Therefore it is quite acceptable in many instances to calibrate the MIU thermocouple to "read the same as" the machine.

1. Verify that the thermocouple channel is set up properly at the host, and that the ground jumpers are set properly for the type of thermocouple
2. Set the software gain and offset for the channel to be calibrated to 1.000 and 0
3. Note the reading of the machine for the desired zone
4. Calculate the gain (if required) and offset required to make the MIU "read the same as" the machine
5. Save these to the host

   For example, assume the machine actual nozzle thermocouple reads 545 degrees F. Assume that with a gain of 1.000 and an offset of 0, the MIU reads 564 degrees. Find the gain by dividing the Machine Value by the MIU Value. In this case it would be .966. Multiply the MIU value by the gain to determine the offset, if required. In this case, an offset of +1 might be desired.

Again, this procedure may be considered appropriate in many instances since this actually can take into account the physical properties of the Machine / MIU combination. However, this procedure will only work if the machine control provides the appropriate actual temperature, not just a set-point. For water and oil it is not likely that this procedure will work. However, reading the thermocouple at the MIU with the thermocouple calibrator and then applying the above procedure can apply a modified version of this procedure.