CHAPTER 21, THE 4-20mA INSTRUMENT LOOP.

21.A Why the 4-20mA Loop?

There has been a need to transmit analog signals over wire since the first analog sensors and transducers were designed.

In the beginning, engineers had great difficulties in finding an electrical signal that could be transmitted over wires without introducing errors. Using a simple varying voltage was not good enough. Changes in wire length and wire resistance seriously upset the readings.

One solution was to use pulse width modulation, where the length of the pulse was proportional to the analog value. This worked, as long as you also transmitted a pulse length reference, receiving a ratio between the two pulses at the other end. Ingenious! The only problem was that the mechanical rotating cams installed at both ends were expensive and difficult to maintain. These systems were called PDM or Pulse Duration Modulation. A few of these old systems are still around with some gas distribution companies.

Another solution was to use a tone, the frequency of which was proportional to the analog value. This approach involved having expensive and drift-prone tone transmitters at one end and tone receivers at the other. A few of these systems are also still around. Old habits die hard!

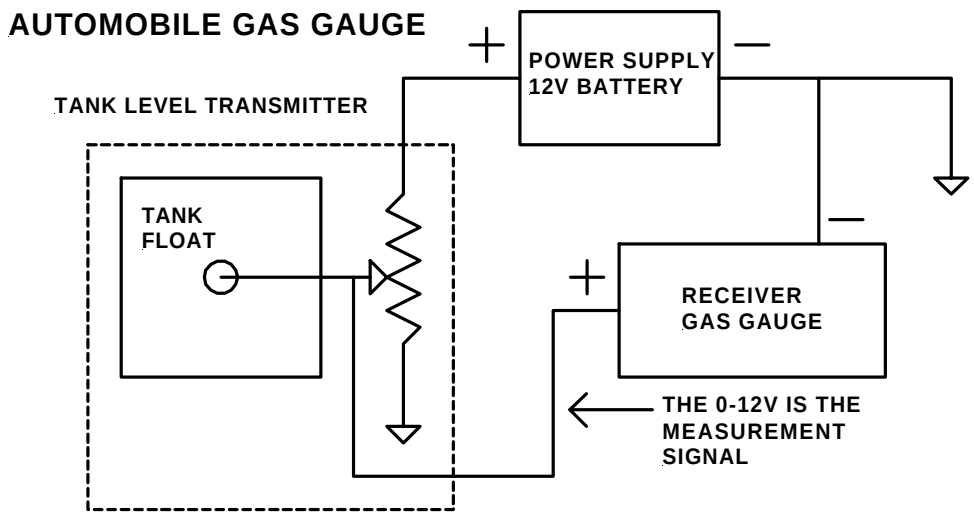
When the 4-20mA loop arrived on the scene it virtually eliminated these old systems and quickly became the world standard. It is supremely accurate, as it is not affected by wire resistance and voltage supply variations.

21.B What is a 4-20mA Instrument Loop?

An example of a simple instrument loop is the gas gauge in your car. You turn on the key and the gas gauge shows you how much gas you have in the tank.

To do this, three components are needed (this is true of any instrument loop).

- You need a transmitter or sensor (a float in the gas tank) to convert the tank level to an electrical signal.
- You need a power supply (the car's battery) to power the system.
- You need a receiver (the gas gauge in your instrument panel) to convert the electric signal to show tank volume.



0 volts to 12 volts from the tank float resistor is the measurement signal. This tank gauge system is, in effect, a 0V to 12V instrument loop system. 0 volts means that the tank is empty, 6 volts means that the tank is half-full and 12V means that the tank is full. This 0-12V automotive instrument loop system is rather primitive and has a number of drawbacks. One is that 0 volts may mean that the tank is empty, or it may mean that the system has a broken wire or has other faults. There is no way of knowing. Another drawback is that the gas gauge voltage (and the indication) varies as the supply voltage varies.

21.C How the 4-20mA Instrument Loop works.

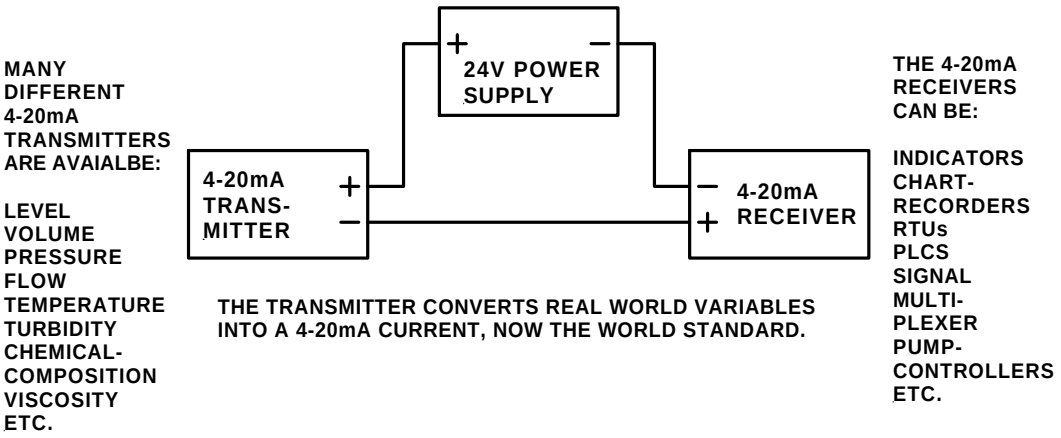
The 0-12V instrument loop system described above may be good enough for automotive use, but far more accurate systems are needed for industrial installations. Here you need systems that:

- Are insensitive to power supply voltage variations.
- Have automatic fault indications.
- Are insensitive to instrument lead length resistance variations.
- Allow connecting multiple receivers into the loop.
- Are capable of great accuracy.

The 4-20mA instrument loop fulfills these and other stringent requirements. It is adopted by ISA (Instrument Society of America) as the standard method for industrial measurements. It is now used in virtually all Water & Wastewater, Petrochemical, Electric Power, Manufacturing and other industries.

The basic 4-20mA instrument loop uses the same three components as the automotive tank gauge system described above:

- A transmitter (or sensor, or transducer, it has different names, all meaning the same thing) that converts levels, pressures, temperatures, flows, etc. to a 4-20mA current.
- A power supply.
- A receiver. It can be a simple tester or an indicator, or a chart recorder, or a pump controller, or a PLC, or an RTU, in short, any device with a 4-20mA input. RTUs, for instance, are used to convert 4-20mA and digital signals to ASCII for transmission to a central SCADA computer or to other RTUs in signal multiplexer systems. Several receivers can be connected to the loop.



21.D The 4-20mA Loop Sensor or Transmitter.

At last count, there were over 2,000 different kinds of 4-20mA transmitters available. They are also often called sensors or transducers. If an industrial variable can be measured, you can be sure that there is a 4-20mA transmitter available for it.

Some common 4-20mA transmitters:

- Tank level
- Pressure
- Delta pressure
- Flow rate
- Temperature
- Turbidity
- Chemical composition
- Actuator position

These 4-20mA transmitters are very capable devices. They will faithfully and accurately convert any variable to a 4-20mA loop current. Regardless of supply voltage variations. Regardless of the loop wire resistance variations. Regardless of how many 4-20 mA receivers are connected into the loop, provided that the loop power supply has enough voltage to overcome the voltage drops in the wiring and in each of the receiver devices.

21.E The 4-20mA Loop Receiver.

The 4-20mA loop receiver receives the 4-20mA current and either displays it, records it and, when connected to a controller, acts on it. The receiver can be a 4-20mA display, such as a simple mA meter or a loop powered display that lets you select between mA and percent readings, like the DIS 4-20.

Some common 4-20mA loop receivers:

- Displays
- Chart recorders
- Pump controllers
- PLC inputs
- RTU inputs
- Signal multiplexer inputs
- Data loggers

Most 4-20mA loop receivers have a 250 ohm input, which means that they act as a resistor when inserted into the loop. The voltage drop across this resistor at 20 mA is 0.02x250 = 5 volts. Several receivers can be inserted into the 4-20mA loop. The voltage drop across each one, provided that they all have a 250 ohm input, is 5V. Add these drops to the drop across the transmitter and you will find what size power supply you need.

Note that many receivers have one end grounded for lightning protection. This means that you can not insert two grounded receivers into the loop and that you will get errors if your sensor or transmitter is also grounded with a different ground point. See section 21.H below on how to deal with grounding errors.

21.F The 4-20mA Loop Power Supply.

The requirements of the 4-20mA loop power supply are:

- That it has enough current for the loop (30mA is generally enough).
- That it has enough voltage to handle the sum of all the drops in all the devices connected into the loop (normally 28V or more).
- That it is completely isolated from the ground with at least 500V isolation.

Small, efficient and cost effective isolated DC power converters are needed to power 4-20mA loops. Many installations use 12V DC to power all RTUs, PLCs and data radios. 12V DC primary standby batteries are also often used.

The IPS series power supplies are used to convert from these 12V DC primary supplies to the 24V DC loop power needed for the 4-20mA instrumentation loops. The IPS power supplies offer snap in installation and quick wiring over two incoming 12V DC terminals at the bottom and two outgoing 24V DC terminals at the top.

These power supplies are fuse protected and DIN rail mountable over LSA Lightning Surge Absorbing DIN rail snap in bases. Standard ISA covers help identify each unit. Special features are:

- Input circuit transient protected.
- Input circuit wrong polarity protected.
- Isolation voltage: 500V minimum.
- DIN rail snap in mounting.
- LSA (Lightning Surge Absorbing) conductive coated bases.
- Wide input voltage tolerance: 9V DC to 18V DC.
- Uses common inexpensive fast acting glass fuses.

For additional information, see descriptions PWM-1366 and IPS-1495.

21.G Testing and Calibrating the 4-20mA Loop.

To test and calibrate all aspects of the 4-20mA loop you need an instrument that:

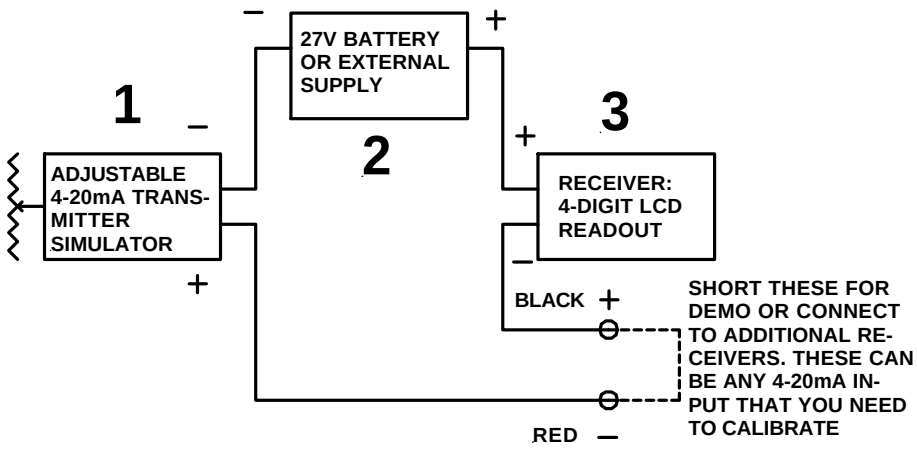
- Can read any 4-20mA loop.
- Can read in mA or in %, switch selectable.

- Has a 4-digit accuracy.
- Can generate 4 to 20 mA with overlap at both ends.
- Can be accurately adjusted with a 10 turn precision potentiometer.
- Has an internal power supply of 28V or more.
- Is approved for use in hazardous installations, such as in nuclear power plants.
- Uses regular 9V alkaline batteries.
- Can use an external 28V power supply.

The CAL 4/20 calibrator surpasses all these requirements.

21.G.1 How a 4-20mA Calibrator works.

The CAL 4/20 calibrator contains the three components needed to form a 4-20mA instrumentation loop:.



1. The transmitter. The round knob is used to set the transmitter's output current.

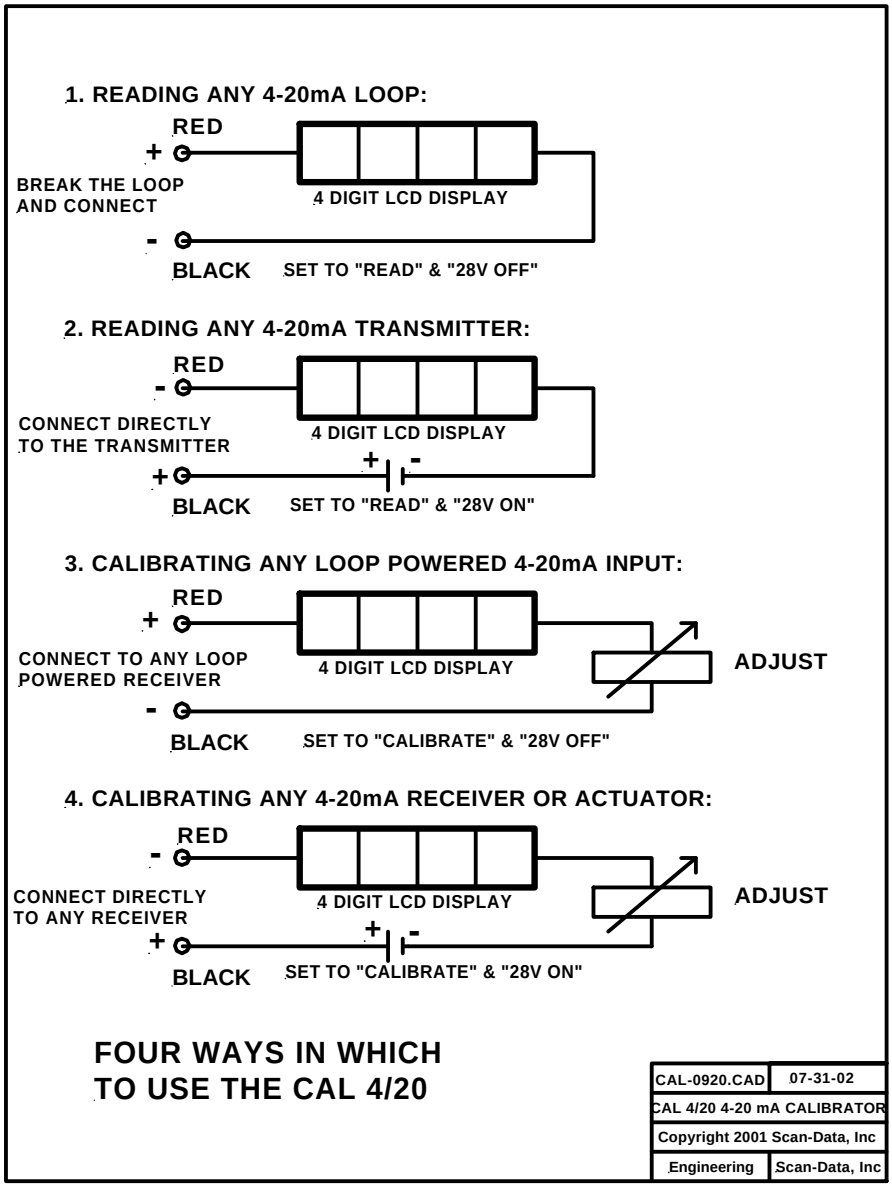
2. The power supply. Three internal 9V batteries or an external power supply.

3. The receiver. The 4-digit LCD readout in the black frame.

These three elements are switch selected to perform different functions:

- Read the current in any 4-20mA instrument loop.

- Power and read any 4-20mA transmitter, transducer or sensor.
- Calibrate any loop powered 4-20mA receiver input.
- Calibrate and power any non-powered 4-20mA input.



The display and the current generator both have resolutions of 0.05% which means that the current can be set and read in increments of 10 microamperes or better, far surpassing the resolution of most 4-20 mA transmitters and receivers.

The CAL-4/20 is designed for the rigors of nuclear power plant operation. It is housed in a cast aluminum housing with an O ring in a grove in the front cover, forming a water tight seal. Three internal common variety 9V batteries furnish the 27V loop voltage. A socket is included for an external 28V power supply.

See descriptions CALC0920, CAL-0945 and APP-1606.

21.G.2 Using a Calibrator to program a Pump Controller.

A common use for the CAL 4/20 is where a Water Company is running a set of pumps to maintain the water level in a storage tank. A level transmitter installed in the tank delivers a 4-20mA current, which is proportional to the water level. A 20mA (100%) current means

that the tank is full, a 12mA (50%) current means that the tank is half full and 4mA (0%) current means that the tank is empty.

This 4-20mA tank level signal is often connected to a pump controller, like the Scan-Data XPC. The controller can be adjusted, for example, to turn the first pump on when the level drops to 80%. It then turns the second pump on when the level drops to 60%. Then turns the third pump on when the level drops to 40% and finally turns the fourth pump on when the level drops to 20%.

These 'ON' levels are all screwdriver adjustable on the XPC and settable to any value of current. The 'OFF' levels are adjustable in the same manner so that you can turn one pump 'OFF' when the next (larger) pump goes 'ON'.

When adjusting the XPC controller, you need different values of 4-20mA level currents. You could manually start and stop the pumps to run the tank up to these different levels. This is tedious and very time consuming. It is surprising to learn that it is still being done in many cases.

Using the CAL 4/20 to set the XPC controller makes the procedure very easy. Momentarily disconnect the input of the XPC from the tank transmitter. Connect the CAL 4/20 in its stead. Set the CAL 4/20 switches to configuration #4 and set the knob to the desired tank 'ON' and 'OFF' level. Adjust the potentiometers on the XPC controller to turn its relays 'ON' and 'OFF' at these levels. Reconnect the tank level transmitter and the job is done!

21.G.3 Using a Calibrator to check a 4-20mA Multiplexer.

Another common use for the CAL 4/20 is where you have installed a 4-20mA Signal multiplexer, sending a number of 4-20mA signals from one site to another.

To check the performance of the multiplexer, connect the CAL 4/20, with the switches set to configuration #4, to each input in turn. Simultaneously, connect another CAL 4/20, with the switches set to configuration #1, to each corresponding far end output in turn. Check that the reading is the same on both instruments for each channel. You can read the current in either 4-20mA or in percent.

21.H Isolating the 4-20mA Loop to eliminate Ground Errors.

The one thing the 4-20mA loop cannot tolerate is grounding errors or multiple grounds. The loop can be grounded in one place only. Multiple grounds or leakage to ground makes the loop inaccurate or inoperative.

The ground point in a 4-20mA loop should be picked with care. For best lightning protection, it usually best to ground the loop at the negative side of the loop transmitter,

as it is often installed out in the field in exposed locations.

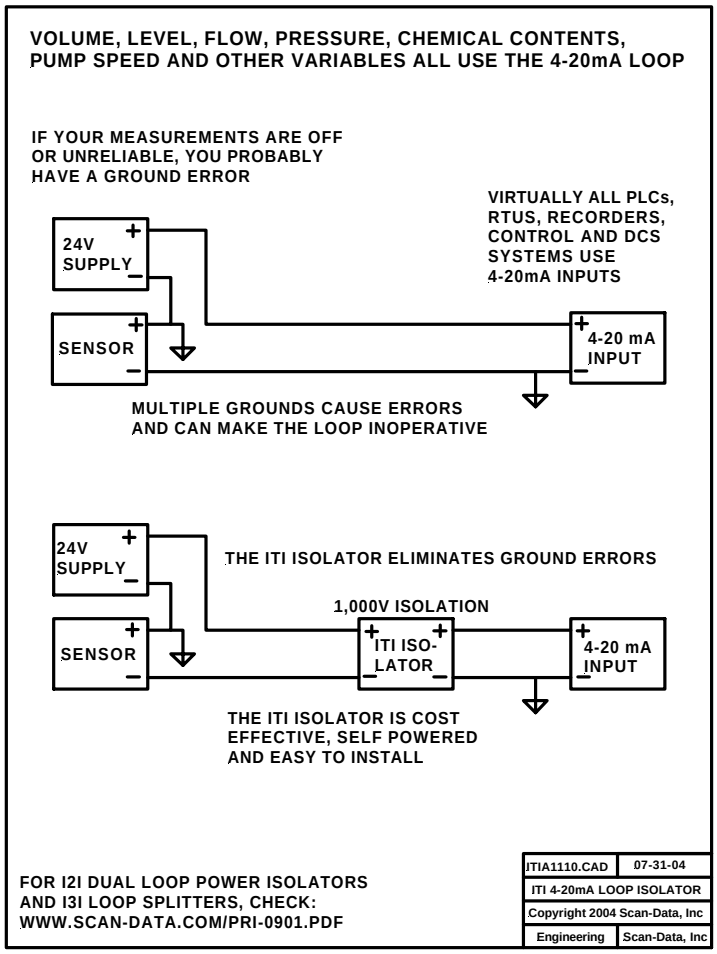
Many water companies, for instance, routinely ground their tank level transmitters at the tank site. The transmitter output negative wire is solidly grounded to help avoid lightning damage.

Should the far end loop receiver input also be grounded (which is often the case), the loop must be isolated to avoid differences in ground voltages introduced by power lines, etc.

Three different kinds of 4-20mA loop isolators are available to meet different requirements. All are loop powered. No external power needed.

21.H.1 Single Loop Powered, Dual Ground 4-20mA Isolator.

The low cost, loop powered model ITI (current to current) isolator eliminates ground errors on 4-20mA instrument loop systems. It isolates two 4-20mA loops from each other. It is powered by the input loop current and in turn powers the output loop current. No external power supply is needed. It easily pays for itself by eliminating lengthy searches for grounding errors and eliminating burned out transducers.

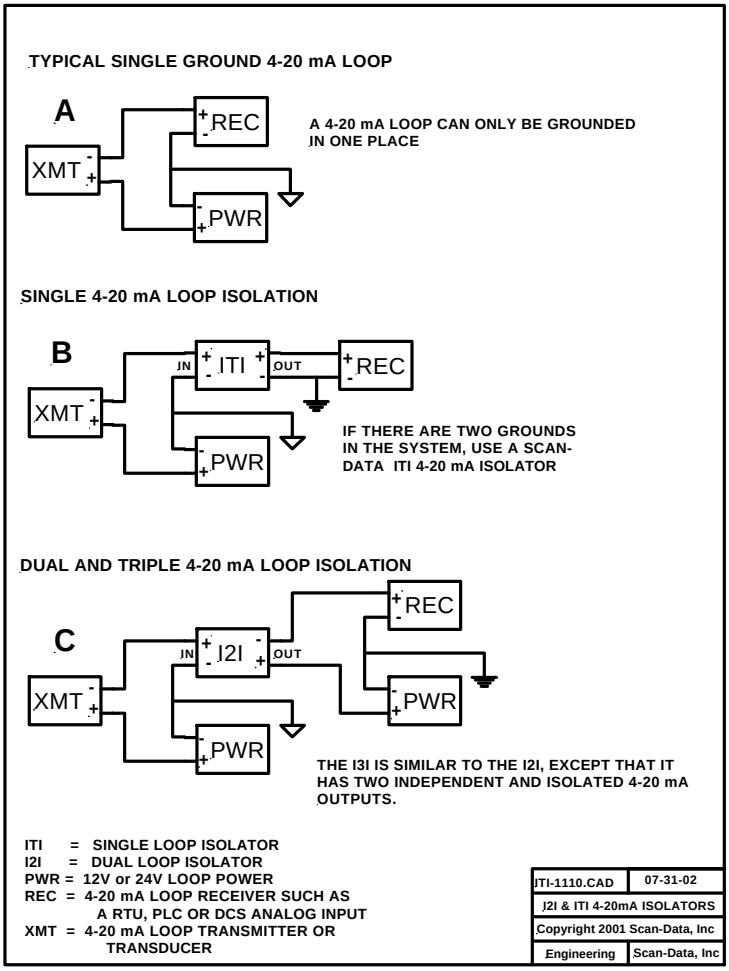


The ITI has excellent accuracy, better than +/- 5 uA, and 500V isolation between the two loops. An ISA cover identifies the ITI and easily lifts off for checking the fuse and for wiring the unit.

The ITI is lightning, surge, reverse current and fuse protected and installs easily by simply snapping it onto any standard DIN rail and connecting the two incoming and outgoing 4-20mA wire pairs.

The LSA (Lightning Surge Absorbing} DIN conductive coated DIN rail base helps prevent damage from voltage surges and lightning induced current discharges.

21.H.2 Dual Loop Powered, Dual Ground 4-20mA Isolator.



All 4-20mA instrument loops always consist of a minimum of three elements, as shown in section A in the drawing at left:

- One transmitter
- One or more receiver(s).
- One power supply.

If there is a ground error, an isolator will have to be inserted, as shown in section B in the drawing at left.

This configuration works well, as the transducer power supply powers the ITI and lets the ITI generate a 'mirror' 4-20mA current output.

Sometimes, things are not that easy. If you were to connect one distributed control (DCS) system to another, you may find that the 4-20mA loop output of one system is internally powered by a 24V supply so that it can directly drive any non-powered receiver.

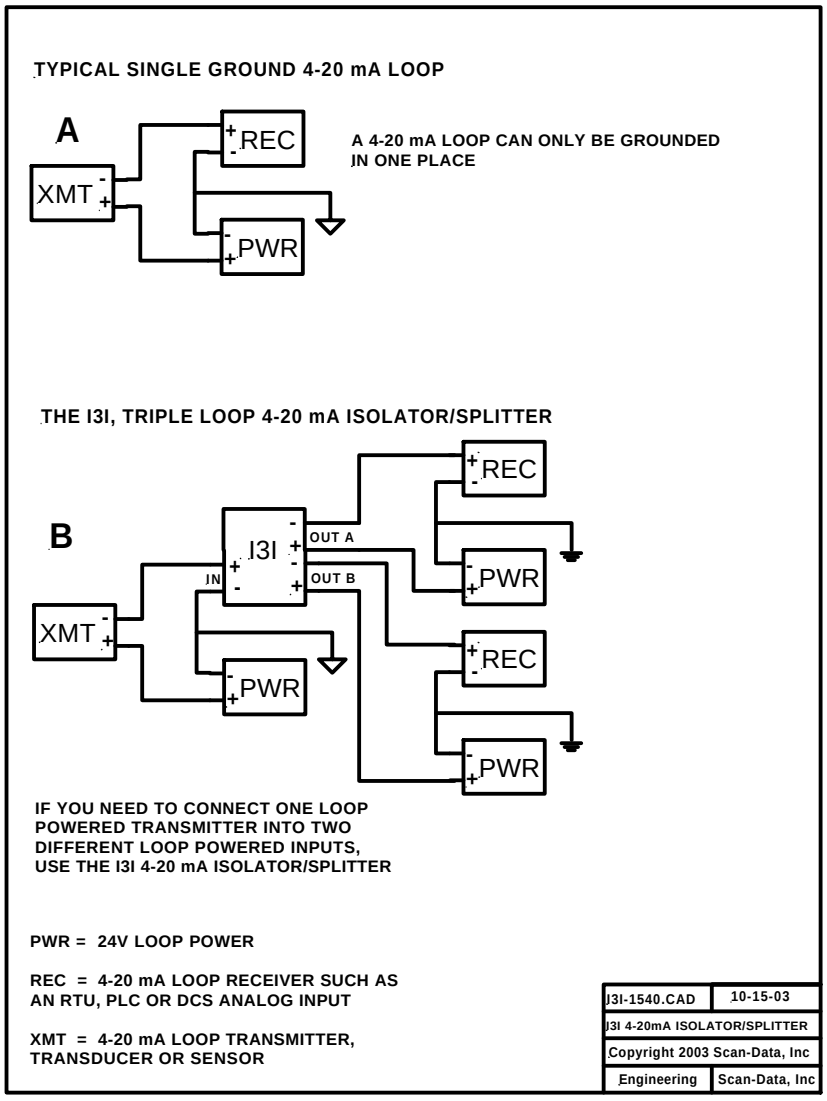
The loop input of a DCS system is also often powered by a 24V supply, so that you can directly connect any non-powered transducer or sensor to this input.

The I2I isolator lets you connect these two powered loops together, as shown in section C of the drawing.

How do you find out whether you have a powered loop or not? Check across the 4-20mA terminals with a tester. If you measure 20 – 30 volts, you have a powered input or output loop. If you measure no voltage but can measure 250 or so ohms across the terminals, you have non-powered loop input.

21.H.3 Triple Loop Powered, Triple Ground 4-20mA Isolator & Splitter:

It is often necessary to connect the output of a 4-20 mA transducer or other 4-20 mA loop current generating device into two different computers, PLCs, controllers or other equipment that need 4-20 mA inputs.



Simply wiring the 4-20 mA output current in series with the two inputs will not work. Each 4-20 mA loop must be independent, each grounded in one place only and each have its own power supply. Drawing I3I-1540, section B shows how one powered 4-20mA loop is split and connected to two 4-20mA loop powered inputs using the I3I isolator and splitter.

Section A of drawing I3I-1540 shows the principal three elements of the 4-20mA instrumentation loop.

Section B shows how this one basic instrumentation three element loop is split into two loops, each with three elements.

The input of the I3I act as a receiver for the first loop and the two outputs of the I3I act as two transmitters for each of the two output loops.

Installation:

The I3I can be mounted on any back plate with four corner studs or mounted with the LSA (Lightning Surge Absorbing) DIN rail base with its ISA identifier cover.

Wire the input 4-20 mA loop wires from a loop powered transducer or other 4-20 mA generating device to the input terminals. Wire the two 4-20 mA current loop outputs to 4-20mA loop powered receivers as shown on drawings I3I-1540 and I3I-1557.

Verify proper operation by opening any one of the three loops and inserting an mA meter or a CAL 4/20 calibrator. The current will be the same in all three loops.

21.H.4 Splitting a Single Loop into four or more Loops.

An I3I isolator and splitter can be connected into two additional I3I splitters. In this manner, one loop current is split into four independent loop currents. You need to add two isolated 24V power supplies. Additional I3I splitters can be added, as needed, for even more independent 4-20 mA loops, all completely isolated from the single input loop.

The available 4-20mA isolators and splitters are summarized as follows:

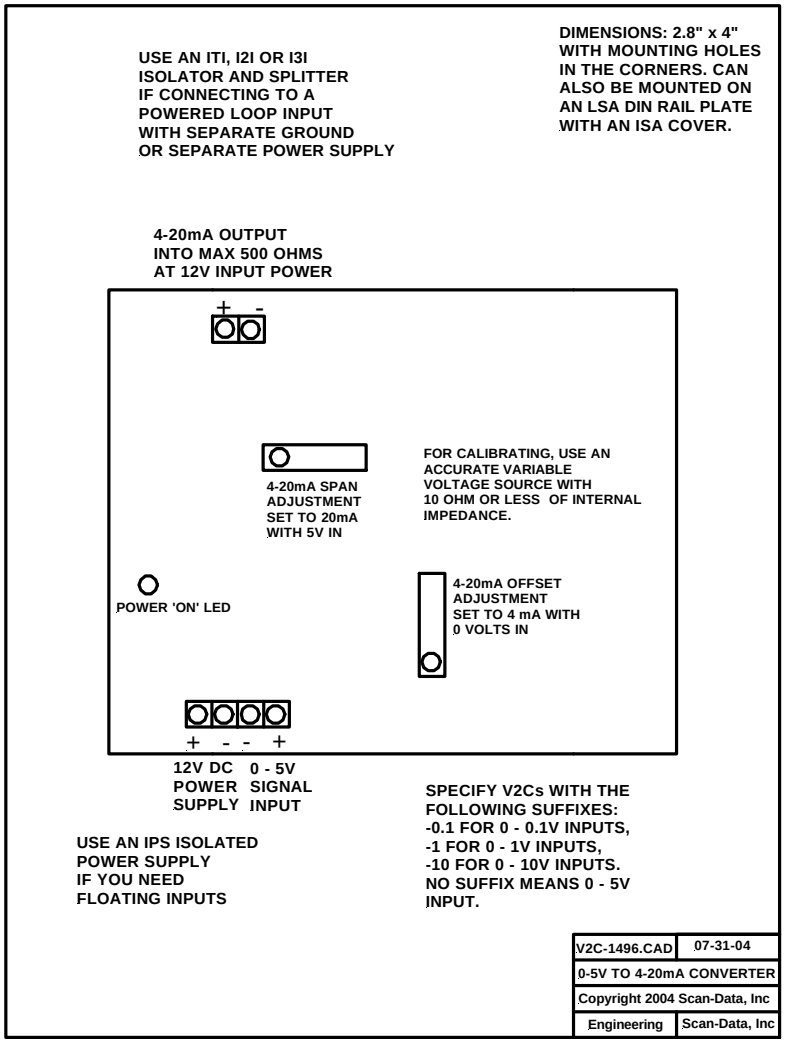
- The ITI 4-20mA isolator accepts a loop powered 4-20mA input and delivers a loop powered output. No power supply is necessary.
- The I2I 4-20mA isolator accepts a loop powered 4-20mA input and delivers a transmitter like output, which is powered by the receiver's loop power supply.
- The I3I accepts a loop powered 4-20mA input, which is split into two independent 4-20mA outputs, both of which are powered by the receivers' loop power supplies.

See descriptions ITI-1504 and ITI-1540.

21.I Converting between Voltage and 4-20mA Signals.

Today, most analog measurement and control signals are in the 4-20mA instrument loop format. Practically all new industrial control and supervisory installations use this format. It has a number of advantages, one of them being the offset. A signal less than 4 mA automatically indicates an error. Another advantage is that the measurements are steady and insensitive to power supply variations and to lead resistance changes.

A lot of older no-offset voltage analog signals are still in use, however. The Scan-Data series C2V (4-20 mA to 0-5V) and V2C (0-5V to 4-20 mA) signal conditioners are designed to interface with these older voltage format measurements. The C2V and V2C convert back and forth between 4-20 mA and 0-5V. Other voltage input and output ranges, such as 0-0.1V, 0-1V and 0-10V are available. These converters are DIN rail mounted on LSA (Lightning Surge Arresting) bases with ISA covers.



Installing and Operating the Converters:

The V2C and C2V converters can be delivered mounted on LSA (Lightning Surge Absorbing) 2.8” x 4” DIN rail bases. The chrome plated DIN rail mounting clips at the rear grounds the LSA base to the DIN rail. An ISA identifier cover snaps in over the base shoulder washers. The converters can also be mounted on any back plate with four 4/40-stand offs.

Connect the 12V power supply and the input and output signal wires as shown in the technical description, V2C-1572.

Use an IPS 12V isolated power supply if you need a floating voltage input or output and use a ITI, I2I or I3I 4-20 mA isolators and splitters if you need floating 4-20 mA inputs or outputs.

Adjust the span and offset potentiometers (if necessary) to obtain the correct 4-20mA readings. See the technical description V2C-1572 for calibrating procedures.

21.I.1 Converting voltage signals to 4-20mA loop currents.

There are still a great many older transmitters, transducers and sensors in use that have the old voltage outputs. The automotive tank gauge transmitter, described above, has a 0-12V output. Other outputs range from 0-1V to +/- 12V. Scan-Data manufactures a voltage to 4-20mA converter, the V2C, which handles conversions from these different voltages into a standard 4-20mA instrument loop current. Specify the input voltage when you place an order for the V2C.

The V2C converter measures 2.8” x 4”. This is a standard DIN rail mount LSA (Lightning Surge Absorbing) size. An ISA identifier cover can be snapped into grooved nylon washers.

The V2C is available in these standard input voltage versions:

- The V2C with no suffix converts 0-5V to 4-20mA.
- The V2C-0.1 converts 0-0.1V to 4-20mA.
- The V2C-1 converts 0-1V to 4-20mA.
- The V2C-10 converts 0-10V to 4-20mA.
- The V2C-10/10 converts -10V +10V to 4-20mA.

Other voltage levels are available on special order

The V2C is powered by an external 12-15V DC power supply. There is a common ground for the power supply, for the voltage input and for the 4-20mA current output, This helps eliminate grounding errors.

V2C Calibration:

The V2C is completely calibrated from the factory and will not need re-calibration in normal service. Should re-calibration become necessary, follow this procedure:

Connect an accurate adjustable voltage source with low internal resistance to the voltage signal input. Connect an accurate mA meter to the 4-20mA output. Power the V2C with 12V. The power indicating LED should light up. If not, check the 0.125mA fuse under the ISA cover.

See drawing V2C-1496. Set the input voltage the low limit value. Adjust the offset adjustment potentiometer so that the output reads 4 mA. Set the input voltage to the high limit value. Set the span adjustment potentiometer so that the output reads 20mA. Go back and forth between these two adjustments until they both read correctly.

See descriptions V2C-1496 and V2C-1572.

21.I.2 Converting 4-20mA Loop Currents to Voltage Signals.

As well as many older transducers with voltage outputs, there are still many older devices around which require voltage inputs. When you need to connect a modern transducer with 4-20mA output to one of these devices, you need a converter that converts from 4-20mA to a voltage output.

Scan-Data manufactures the C2V converter, which does this conversion. Specify the output voltage when you place an order for the C2V.

C2V Description:

The C2V measures 2.8" x 4". This standard DIN rail mount LSA (Lightning Surge Absorbing) size. An ISA identifier cover can be snapped onto the grooved nylon washers.

The C2V is powered by an external 12-15V DC power supply. There is a common ground for the power supply, the voltage input and the 4-20mA current output, which helps eliminate grounding errors.

C2V Output Signal Voltages:

The C2V is available in different input voltage versions:

- The C2V with no suffix converts 4-20mA to 0-5V.
- The C2V-0.1 converts 4-20mA to 0-0.1V.
- The C2V-1 converts 4-20mA to 0-1V.
- The C2V-10 converts 4-20mA to 0-10V.
- The C2V-10/10 converts 4-20mA to –10 +10V.

Other voltage levels are available on special order

C2V Installation:

Snap the C2V onto a grounded standard DIN rail. Wire a 12 – 15V DC power supply to the + and – DC power supply terminals. Wire the 4-20mA current loop to the signal input terminals. Wire the voltage output to your device.

C2V Calibration:

The V2C is completely calibrated from the factory and will not need re-calibration in normal service. Should re-calibration become necessary, follow this procedure:

See drawing C2V-1496. Before you connect power to the unit, set the resistance across the 4-20mA input terminals to 250 ohm with the 'Set to 250 ohms' potentiometer.

Connect a 4-20mA calibrator, such as the Scan-Data CAL 4/20, to the 4-20mA input terminals. Connect 12V power to the DC power supply terminals. The power LED should light. If not, check the .125mA fuse.

Connect a voltmeter to the voltage output terminals. Set the input to 4mA and adjust the offset potentiometer to read the low limit voltage output (normally 0). Set the input to 20mA and adjust the span potentiometer to the high limit voltage output. Go back and forth between these two adjustments until you are satisfied that they are correct.

See descriptions V2C-1496and V2C-1572.

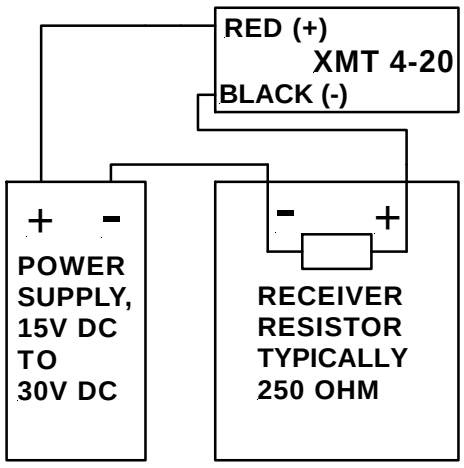
21.J Simulating 4-20mA Loop Transmitters and Sensors.

Summary:

There is often a need to experimentally generate a variable 4-20mA loop current when testing the input of RTUs, PLCs actuators, controllers and other devices. It is impractical and time consuming to pump a water tank level up down, for instance, just to test the device connected to the level transducer. The loop powered Scan-Data XMT 4-20 series loop transmitters makes testing 4-20 mA instrumentation loop easy. They simulate and directly replace any 4-20 mA transducer, transmitter and sensor.

The XMT 4-20 transmitter is also used in installations where some variables remain fairly constant, as for instance the pipe line pressure in a well regulated natural gas pipe line. The controller or DSC system may still need a 4-20mA pipe line pressure input to function correctly, however. Install the XMT in place of the pipe line pressure transducer. It operates just like a transducer. Turning the knob on the XMT-B or the potentiometer on the XMT-D to the desired mA value sets the pressure reading.

Another use for the XMT is where a transducer has to be sent in for repair or replacement. The XMT can then temporarily substitute the transducer, until it is returned and installed again.



CONNECTING THE XMT 4-20

How to use the XMT 4-20:

Disconnect the sensor or transducer (if one is installed) and connect the two wires from the XMT 4-20 in its stead. See the drawing at the left. Connect a tester, capable of reading 0–20mA, or a CAL 4/20 calibrator in series with the XMT-4-20 if you wish to read the current.

Adjust the 10 turn precision potentiometer on the XMT 4-20 to give the current you desire. The XMT 4-20 current remains rock steady, independent of the power supplies voltage and lead resistance variations.

The XMT comes in two versions:

The XMT-B is the tabletop version. It is mounted in an enclosure, has an adjusting knob at the front and test lead sockets at the rear.

The XMT-D version is identical to the XMT, except that it comes in a DIN rail mountable LSA based enclosure. The current is screwdriver adjustable through a hole in the ISA cover.

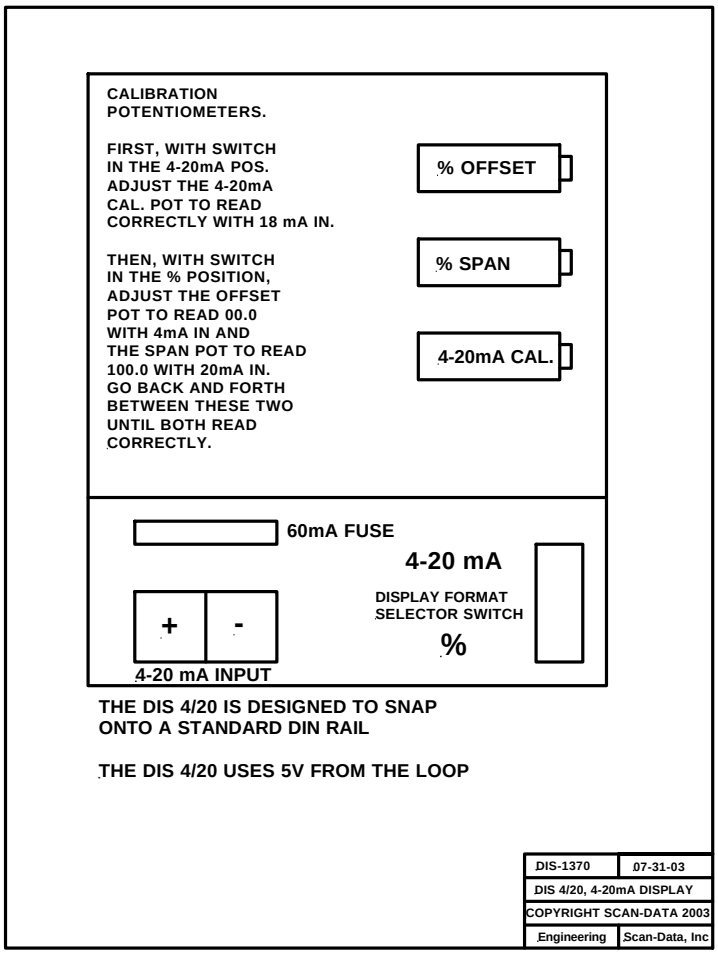
The XMT-D installs easily by snapping it onto any DIN rail. The LSA Lightning Surge Absorbing conductive coated base helps eliminate damages caused by voltage surges and lightning strikes. Simply wire in the two loop wires, as shown in the drawing. Both versions of the XMT are loop powered and need no external power supply..

See description XMT-1462.

21.K Displaying 4-20mA Loop Currents.

Summary:

Most sensors, controllers, analog multiplexers, RTUs and PLCs use the world standard 4-20 mA format. To convert the 4-20 mA loop currents into meaningful readings, the technician has to break the loop, temporarily insert a milliampere meter and measure the 4-20 mA current. He then has to calculate what the 4-20 mA reading means in real world engineering values.



The DIN rail mounted DIS 4-20mA display eliminates much of this work as it reads in both 4-20mA and percent (switch selectable). It relatively easy to translate percent readings into real world engineering values, much easier than to try to calculate it from 4-20mA readings.

The DIS 4-20 4-20mA display has the following features:

- DIN rail mounted.
- Loop powered.
- Four digit accuracy.
- Switch selectable to show current readings in mA or in %.
- Lightning Surge Absorbing (LSA) base.

Installation:

The DIS display snaps onto any DIN rail base. Two clearly marked screw clamp terminals connect to the two wires from the 4-20 mA loop.

Calibration:

Use any variable 4-20mA current source such as the Scan-Data CAL 4/20 calibrator or the XMT-4/20 transmitter, connected in series with a precision digital milliampere meter. Set the current source and adjust the calibrating potentiometers as described on the next page.

For more information, see description EVR-1369.

21.L Sending and Receiving Multiple 4-20mA Signals (Multiplexing).

This section describes how to transmit multiple 4-20mA analog and digital (contact) signals from site to site over cable, fiber, radio and by dialing.

Multiplexing analog and digital signals is very cost effective, compared to the cost of running many individual cable pairs. It is also the only solution for transmitting multiple signals over radio and fiber optic cables.

21.L.1 Why Multiplex Analog and Digital Signals?

Analog and digital signals are used to measure and control many industrial installations. There is often a need to transmit these signals from one point to another in a plant or from a remote site to a central controlling computer or to another remote site.

If the distances are short, cable pairs can be used to transmit the signals without loosing accuracy. Cable pairs can quickly become expensive, however, especially over longer distances or where a large number of signals have to be transmitted. It is also difficult and expensive to add cable pairs in existing installations.

Multiplexing to the rescue! Modern multiplexing equipment such as the Scan-Data RTUs operating in back to back mode transmit multiple digital and 4-20mA analog signals over a single cable pair, over a single fiber optic connection, over a single radio circuit or by dialing from anywhere to anywhere else. And totally immune to electrical interference!

4-20mA analog signals are input at the input end of the multiplexer and re-generated and output as mirrored 4-20mA signals at the other (output) end. Digital signals are input as dry contacts at the input end and output as relay driver signals at the other end. The signal multiplexer works just as if there were a number of cable pairs running from one site to the other. Multiple metering pulse inputs (pulse accumulations) can also be multiplexed, without loosing a single pulse, in addition to multiplexing digital and analog signals.

21.L.2 Cable Costs.

In the early days of plant control, individual cable pairs were often used to transmit analog and digital signals over long distances. Many companies still have miles of signal and communication cables buried in their plants and under the streets in urban areas.

Some gas distribution companies, for example, still use one cable pair from each gas flow meter out in the field, connecting it to the central measuring office. PDM and 4-20mA signals are often transmitted in this manner.

Companies also lease buried cable pairs from the local phone company which generally have many thousands of pairs of phone grade cable running underground or on pole routes all over their service area.

These old cable runs are proving very expensive to maintain. They often consist of lead sheeted cables with a great many paper insulated copper pairs inside. Gas pressurization must be used to keep the moisture out. Once a buried cable start leaking and water enters, problems start. Some phone companies resort, in desperation, to trying to boil the water out by applying raw AC power to some pairs. This has disastrous consequences to the equipment connected to the nearby pairs.

Many buried cable runs are simply abandoned, after years of questionable service, and replaced with modern fiber optic cable runs. This means that the old 'metallic' cable connections, necessary for end to end transmissions of contact, PDM and 4-20mA analog signals are no longer available.

Multiplexing analog and digital signals then becomes not only more cost effective but also the only solution to these problems.

21.L.3 What Multiplexing Equipment to use?

A wide range of Scan-Data 4-20mA and contact multiplexing equipment is available, with a wide selection of I/O (Input and Output) capacities and a variety of transmission modes. These are some of the choices:

- Using two LMR RTUs, with capacity up to 6 I/O circuits, operating back to back over cable, radio or fiber. See descriptions LMRC0890 and LMR-1592.
- Using two LMX RTUs, with capacity up to 32 I/O circuits, operating in the same manner. See descriptions LMXC0794 and LMX-1441.
- Using two M-system RTUs, with capacity up to 4,000 I/O circuits, operating in the same manner. See descriptions MSYC0870 and APP-1336.
- Using the MUX-4 pair for 4 analog and 4 digital I/O circuits or the MUX-8 pair for 8 analog and 8 digital I/O circuits. See description MUXC1073.
- The CDS phone or cellphone dialing multiplexer with 8 4-20mA analog and 8 digital circuits is a lifesaver where cable, radio or fiber connections are not available. See descriptions CDS-1368 and CDS-1310.
- The VBX Alarm Dialer with two 4-20mA inputs, sixteen digital inputs and 8 command outputs gives you a complete report, from any remote station, in your own voice. See descriptions VBXC0929 and CDS-1584.

21.L.4 Installing Signal Multiplexing Equipment.

All Scan-Data RTU, MUX and CDS multiplexers are completely pre-programmed and start operating automatically when power is applied. Proper operation can easily be verified on the test bench by powering up both units and connecting them together over wires that simulate the cable or radio communication links.

21.L.5 What about Transmission Errors?

All multiplexers digitize the information at the transmit end and convert the information back into real world 4-20mA and relay driver values at the receive end.

Seven levels of error checking is done before the signals are output at the receiving end. Should an error be detected, the last good received value remains at the output. In this manner, line noise, questionable radio circuits and other disturbances only result in a slowing of the update time. A faulty signal is never transmitted.

One of the digital output circuits in the RTU can be configured as a communication failure indicator.

Five consecutive polls without a correct answer is considered a communication failure. When this happens, the digital output and the corresponding LED turns on.

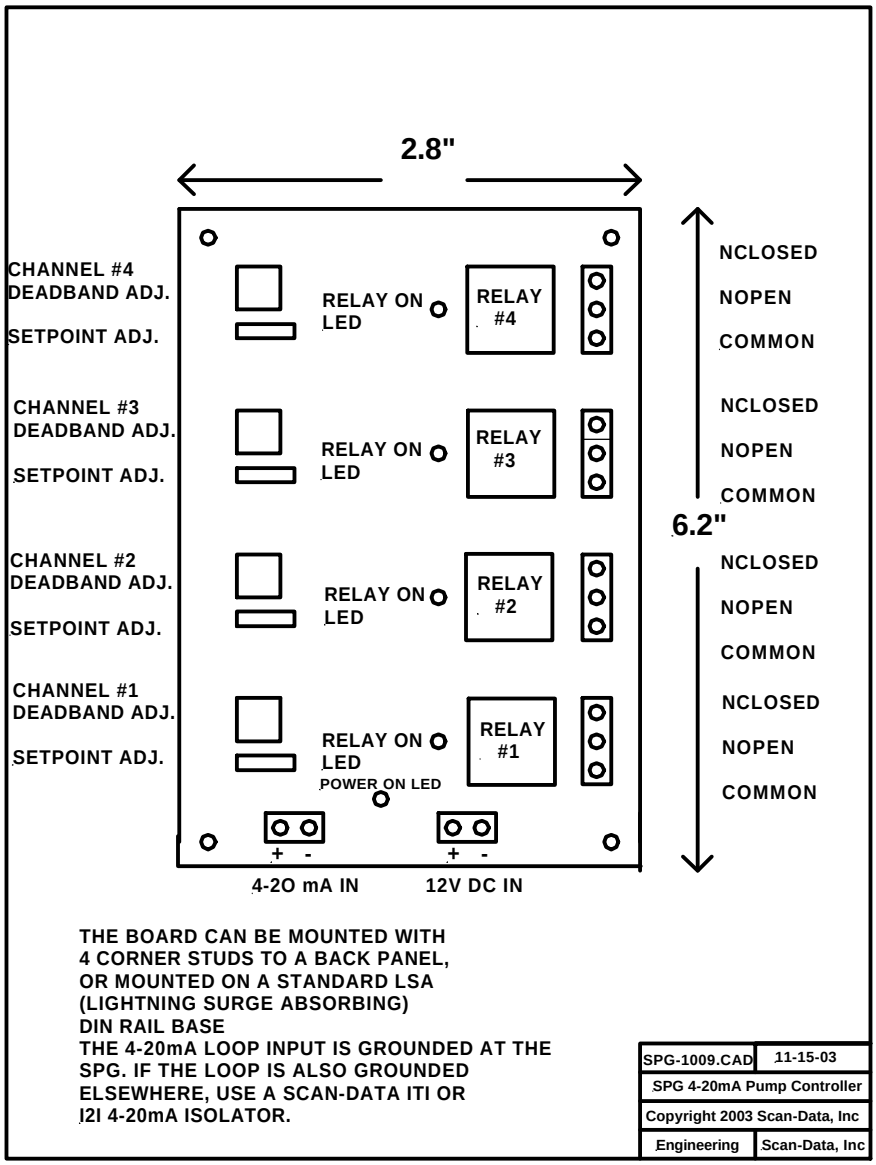
21.M Generating Pump Control Commands from 4-20mA Currents.

There are three principal kinds of 4-20mA to contact converters (pump controllers) in common use. They use different control methods, as follows:

- The **SPG-4** Set Point Generator has four output relays. Each relay can be screwdriver adjusted to turn on and off at any value of the 4-20mA current.
- The **XPC-4** eXpanded Pump Controller has four output relays. Each relay can be screwdriver adjusted to turn on at any value of the 4-20mA current and also to turn off at any other value of the 4-20mA current. In other words, each relay has an adjustable window during which it will remain on.
- The **PPC** Programmable Pump Controller is a fully programmable controller, with two 4-20mA analog inputs, two digital inputs, two 4-20mA analog outputs and two digital relay driver outputs. It includes a complete math package, a timer, a real time clock and a calendar. It is programmed in Basic, the world's most common control language.

21.M.1 The SPG-4 Screwdriver Adjustable Controller.

The SPG-4 Trip Point Generator consists of a 6.5" x 2.8" blue epoxy coated circuit board with clearly marked 4-20mA input, 12V DC input and four relay form C output terminals: center, normally closed and normally open. The dimension of the board fit the Scan-Data standard LSA (Lightning Surge Absorbing) DIN rail mount.



The board has four clearly marked trip point adjusting 15 turn potentiometers, each placed above the corresponding relay output terminal. At the right of each trip point adjusting potentiometer is a 1 turn dead band adjusting potentiometer. Turning these potentiometers clockwise raises the trip point and increases the dead band.

An LED for each trip point turns on when the 4-20mA input current causes the relay to pull in to activate and turns off when the relay opens again. A power on LED indicates that the SPG has power.

A typical application:

Many remote installations require automatic and instantaneous control of certain processes. A typical example is a tank and a pump installation. The pump has to turn on when the tank is low and turn off when the tank is full. The Scan-Data SPG-4 pump controller generates adjustable relay openings and closings directly from the 4-20 mA output from the level sensor installed in the tank. The pump has to turn on when the tank is low and turn off when the tank is full. The Scan-Data SPG-4 pump controller generates four adjustable relay openings and closings directly from the 4-20 mA output from the level sensor installed in the tank. You can connect the SPG-4 relay contacts directly to the pump run relays or add the Scan-Data low cost PPC programmable pump controller if you need additional local programmable controls, such as math, time and date, programmable timers, etc.

Connecting the SPG-4 to the VBX Alarm Dialer:

The SPG-4 trip point generator is designed to interface directly with any device which accepts dry contacts, such as RTUs and PLCs. A typical application is with the VBX-7 Voice Box Supervisor. You can create alarm set points, with dead band adjustments, at any point on the 4-20 mA loop, by simply adjusting the potentiometers on the SPG trip point generator. These can be connected to the VBX, which will dial out with a voice alarm message when the level, pressure and other 4-20mA signals fall below or above safe limits.

You can create alarm set points from levels, pressures, temperatures, etc., in short, from any variable that can be measured with a 4-20 mA loop sensor, transducer or transmitter.

In operation, the SPG-4 generates relay closures at given set points. These relay contacts are connected to some of the VBX-7's 16 digital alarm inputs. When the set point is reached, the relay closes and the VBX-7 proceed to alarm dial one or more of the six telephone numbers in its memory. When the called party is reached, the VBX-7 will read out the alarm in voice, "Low level in the secondary water storage tank" or whatever phrase you programmed in for this alarm.

21.M.2 The XPC-4 Screwdriver Adjustable Controller.

Summary:

The XPC-4 pump controller converts a 4-20mA instrument loop signal into relay contact closings and openings. The XPC contains four relays. Each relay can be independently adjusted to open at any 4-20mA current value and to close at any other 4-20mA current value. Relay contact rating are: 4A at 125VAC.

How the XPC-4 Controller works:

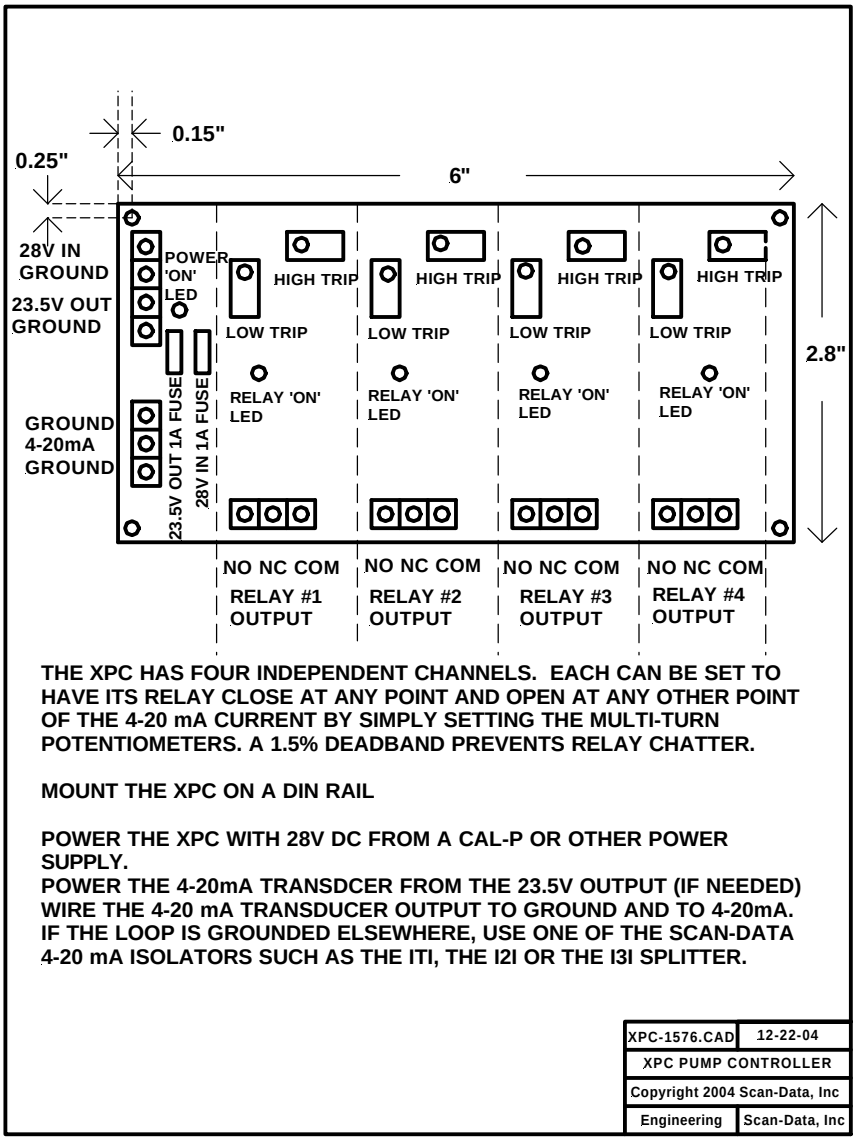
The XPC-4 converts a 4-20mA analog signal from a tank level sensor (or any other 4-20mA transducer) into four relay contacts. If more than four digital signals are needed for a controller application, use two or more XPC-4 controllers. They can all be connected to the same 4-20mA instrument loop signal over ITI 4-20mA isolators.

There are numerous applications for the XPC-4 in the industrial control world. The 4-20mA instrument loop signal converted into relay outputs can turn on different pumps to keep a tank full, for instance. It can turn on a series of ascending lights on a pole, turn on a number of different processes in a plant and turn on a number of warning lights on an operator’s panel. The XPC-4 is widely used to control any number of industrial processes.

It is used wherever a 4-20mA analog instrument loop signal has to be converted to discrete contact outputs.

A typical XPC-4 Application:

For example: many municipal water systems still use float switches in their water tanks to control the pumps that feed the tank. These float switches are submerged inside the tank and fastened to the tank wall. They are therefore difficult to adjust and maintain. The only way to adjust them is to go inside the tank and change their positions. With time, these submerged float switches also become corroded and often cease functioning altogether.



A tank level transducer installed at the bottom of the tank and an XPC-4 pump controller efficiently and cost effectively replaces the old float switch level control system.

Adjusting the levels at which the old float switches opened and closed is now a simple matter of adjusting the XPC-4 controller with a screwdriver. The CAL 4/20 4-20mA calibrator is an ideal instrument to use for simulating different tank levels. See section G above.

The relay for pump #4 (a low capacity pump), for example, can be adjusted to close, and start pump #4, when the tank level drops below 19mA (94% full), and to open at 16mA (75% full) when the higher capacity pump #2 takes over.

The pump #3 (a medium capacity pump) relay can be adjusted to close when the tank level drops below 16mA (75% full) and open at 3.8mA, the safety cut-off point for transducer failure.

The pump #2 (another medium capacity pump) relay can be programmed to close when the tank level drops below 12mA (50% full) and open at 3.8mA, the safety cut-off point for transducer failure.

The pump #1 (a high capacity pump) relay can be programmed to close when the tank level drops below 8mA (25% full) and open at 3.8mA which is the safety cut-off point for transducer failure.

Other uses:

The XPC-4 controller is designed for wide applications in the process control field, wherever digital control signals, derived from 4-20mA loop currents, are needed. In other words, the XPC is used as a programmable control building block, converting 4-20mA currents into digital control signals.

21.M.3 The PPC Programmable Pump Controller.

Summary:

The PPC programmable pump controller is a cost effective, DIN rail mountable, end user programmable logic controller. It is arguably the most cost effective and the easiest to program pump controller and industrial 4-20 ma controller in the market.

The PPC has two 4-20mA analog inputs, two dry contact digital inputs, two 4-20mA analog outputs and 2 digital relay driver outputs. It features a hardware crystal controlled programmable clock & calendar, extra ROM and RAM and two independent timers which can be programmed to trigger on any given day, hour, minute and second.

The PPC controller has the same DIN rail dimensions and form factor as other Scan-Data DIN rail modules, such as RTUs, 4-20 mA trip point generators, 4-20 mA converters, 4-20 mA isolators, 4-20 mA splitters and 4-20 mA trip point generators and controllers. These building block control units make for cost effective and easily programmed control installations.

The PPC uses the same Stamp2 Basic programmable processor as is used in the Scan-Data LMX/PLC and M-system RTUs . The Basic programming language (.bs2 suffix) used in the PPC is probably the most widely used control programming language in the world. A search on the WEB for ‘Stamp2’ or ‘StampII’, ‘BS2’ and ‘Pbasic’ will result in thousands of free control program listings.

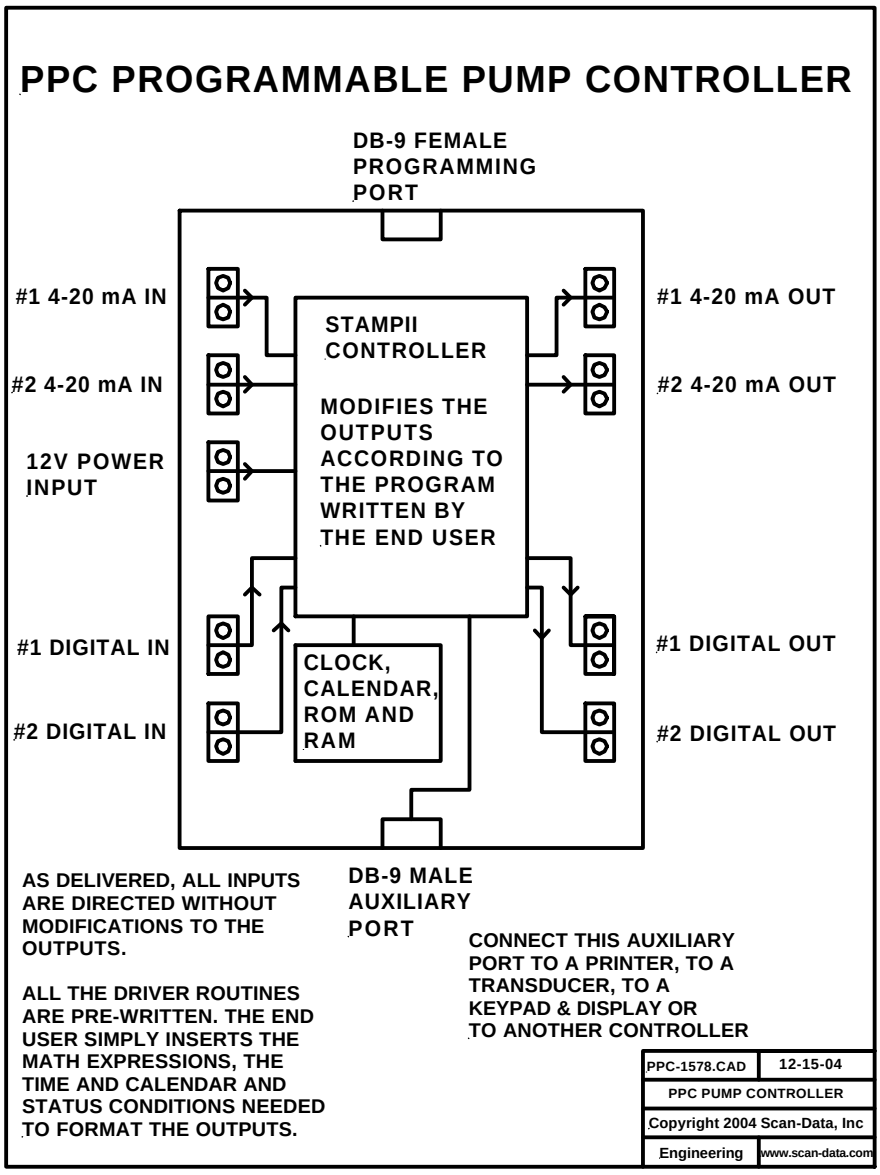
The PPC measures 2.8” x 6” and fits the standard Scan-Data SDB-6 LSA (Lightning Surge Absorbing) DIN rail mounting base.

Technical Description:

The PPC controller has two buffered digital inputs, two buffered digital outputs, two surge protected 4-20mA analog inputs and two surge protected 4-20 mA analog outputs. It is fully 2-part epoxy coated and designed to operate in harsh industrial environments.

The digital inputs and outputs have indicating LEDs that light when the input or output circuits are active (ON). A 12V ’ON’ LED indicates that power is on and a ‘RUNNING’

LED indicates that the PPC controller is running. The digital dry contact inputs connect directly to any dry set of contacts, such as relay contacts, 4-20 mA analog trip point generators and controllers, limit switches and alarm contacts, etc., and to any other dry contact generating device. The relay driver outputs connect directly to all 12V relay coils and to 5V and 10V logic inputs.



Compatibility with other Devices:

The PPC controller uses the Stamp2 processor, programmed in Basic. This processor and these programs are also used in other Scan-Data PLC products, such as the PLCS RTU and PLC combined. Basic program codes can be freely transferred from one device to another. This allows considerable savings in programming costs.

The Programming Port:

The PPC controller has two 9-pin serial ports. The top port is the programming port. Use the supplied Windows programming program in any laptop or other computer to print, edit, change, debug, load and run your program.

The Auxiliary Port:

The bottom port is the auxiliary port. Programs, such as the timer program, can use this port for calibration and for setting and reading the clock, calendar and timer parameters. You can use any laptop or other computer to set and read values over this port, such as the time of day, and date. You can also use this port to set and clear software switches and alarms, to read pump status, to set pump run sequences, etc. The PPC controller can be easily programmed to run these and thousands of other control programs.

PPC programs can use this port to communicate with other serial port devices such PLCs and RTUs and with other PPC controllers to import and export data and to receive and send instructions. You can also use this port to communicate with any RS-232 interface

printer.

Interfacing to any serial device, printer, display, computer, etc., is easy as both the RTS and the CTS pins on the port are independently under program control.

Designing multi-processor systems was never before this simple. Multi-processor control systems are extremely powerful, in spite of their low cost and easy programming. Dividing complex programming problems into small individual tasks, one for each PPC, cuts way down on programming time. Each PPC program is small and easily tested.

Installing the PPC Controller:

Bolt the module to any enclosure back panel with the supplied 4 stand off screws. If the PPC is mounted on an SDB DIN rail base, simply snap it onto any standard DIN rail.

Check the installation drawing and wire the module to 12V DC. It starts operating when power is applied. As delivered from the factory, the PPC program passes all analog and digital inputs directly to its outputs. You can check proper operation by shorting one or the other of the 2 digital inputs. The corresponding digital output LED will light. The bottom (POWER) LED and the top (RUNNING) LED will be lit when the PPC is powered up and running.

Programming the PPC Controller:

Load the supplied StampWin.exe Windows program into your computer. Connect the serial port in your computer to the programming port of the PPC.

Follow the instructions to download, print and save the supplied BS2 source code. All the I/O, clock, calendar, timer, math and other driver routines you need are already written. As delivered, the PPC controller passes all analog and digital inputs directly to its analog and digital outputs. This makes it easy to test the unit and to insert your own control code segments where needed.

To insert your own program segments, all you have to do is to rewrite a small section of this pass through code and insert your own routines, such as pump control, time and date dependent functions, variable speed drive compensation or any other control code that you need. The PPC controller keeps running while you are re-writing the source code. It will start running with the new code as soon as you give it the load command.

The clock and calendar are set with the values in your program as you load the program. The current time and date should therefore be written into your code. These values will be entered into the PPC controller’s clock and calendar the moment you load the program.

Using the PPC Controller for Pump Control:

A very common application for the PPC controller is for pump control in municipal water systems. Accurate tank level information is needed in these applications.

For instance, using a Scan-Data SPG-4 or XPC-4 trip point generators and controllers makes it easy to create exact level trip point contact closures from 4-20 mA water tank

level sensor outputs. No programming is needed with these devices. The individual trip points are easily set with a screwdriver on the SPG-4 and XPC-4 units. Using a Scan-Data CAL 4/20 calibrator makes this a simple task and saves you from having to run the tank levels up and down, just to set the trip points.

Once the PPC controller has the different tank level contact inputs defined over the SPG-4 or XPC-4 and wired into the PPC controller digital inputs, writing the pump control program is easy. You can construct virtually any pump control program, with time and date, alternating pump usage, etc., with a few simple lines of Basic code.

If you need 4-20 mA analog outputs for variable speed pump control or for other devices that need a 20mA signal, use the 4-20mA analog outputs in the PPC. The Basic code needs only a small modification to accomplish this.

You can also wire your tank level transducer analog signals directly into the PPC 4-20mA inputs and create your setpoints in Pbasic code. With this approach, there is no need to use the SPG-4 trip point generator as you write the setpoint routines yourself in Pbasic. Use the CAL 4/20 calibrator to simulate different tank levels. Run the CAL 4/20 up and down and check that the outputs act in the way you intended.

21.N Lightning and Surge Protecting the 4-20mA Loop.

Summary:

SCADA and PLC equipment for the Water & Waste, Petrochemical and other industries is often installed in remote sites, prone to lightning hits. Long transducer leads and other field wiring needs surge protection before connecting them to the inputs of RTUs, PLCs and other electronic equipment.

The LSA Lightning Surge Absorbing I/O boards are designed to efficiently divert the incoming lightning energy to the grounded DIN rail trough the LSA conductive coated DIN rail base. Narrow arcing paths, soft corona discharge paths and easily replaceable, inexpensive glass fuses protect the boards against lightning hits. All boards are 2-part epoxy conformal coated for service in harsh environments.

The LSA modules are available in four versions: The SIL and SLL 4-conductor modules and the SDL and the SEL 8- conductor modules. The Design Guide and Price List, PRI-0901, available on our WEB site, is a good guide when designing these systems.

Installing and operating the Lightning Surge Protectors:

The Surge Protecting modules come complete, ready to install. They are mounted on LSA (Lightning Surge Arresting) 2.8” x 2” or 2.8” x 4” DIN rail bases. The chrome plated DIN rail mounting clip at the rear automatically grounds the module to the DIN rail. The DIN rail should be securely grounded to the mounting plate (normally the back plate in the enclosure). Using #10 sheet metal screws to fasten the DIN rail accomplishes this. The back plate itself should also be securely grounded, preferably over a heavy gauge stranded copper cable to a

ground rod. See the chapter 18 of this handbook for details on how to properly install lightning protection.

Replacing Lightning Surge Protection Fuses:

The modules normally come with 1A fuses installed. This is an average value for the Scan-Data type of robust analog, digital and modem signal inputs and outputs. A blown fuse is easily replaced by popping it out and popping in the new one. Equipment lightning susceptibly and lightning severity differ from installation to installation. It is therefore difficult to give firm recommendations as to the fuse size that should be used. If the fuses tend to blow often, it is possible to double the fuse size. Sensitive unprotected equipment may need lower fuse values, ¼A or less. These fuses are easily available in ranges from 1/8 A to 15A and are low in cost.

21.O How to get more Information:

The descriptions listed above, together with hundreds of other helpful descriptions and application notes, are available on our literature page on the WEB. For general information on the 4-20mA loop, check application note APP-1115, 'How the 4-20mA loop works', and APP-1104, 'Sending multiple analog and digital signals over radio and cable'. Also check Chapters 1, 10 and 12 in this handbook for references to the 4-20mA loop.

Our sites have click on blue buttons to get you to our literature page.

Or go directly to our literature page:

www.scan-data.com/morinfpg.htm

For a good look at 4-20mA accessories:

www.4-20maloop.com

Or you can call us, **818 785 6200**, or FAX us, **818 785 4415** or E-mail us for more information:

Info@scan-data.com

Other informative and helpful WEB pages are:

www.4-20mamux.com

www.bell-202modem.com

www.pumps-control.com

www.alarm-dialer.com

www.scadahandbook.com

www.scan-data.com

www.telemetryandscada.com