
SmartSensor™

Operation / Installation Manual

Manual Part Number: A8M5027
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SAFETY PRECAUTIONS – READ BEFORE USING

Welding is not particularly hazardous when certain safety practices are followed. Everyone using this equipment should be thoroughly trained in safe welding practices. Failure to observe safe practices may cause serious injury.

Handling welding torches presents no danger if the appropriate safety regulations are strictly adhered to. For example:

- Starting procedures must be reserved for those fully conversant with processes relating to arc welding equipment.
- Arc welding can prove damaging to eyes, skin, and hearing! It is therefore imperative that both management and operators understand and follow the ANSI Standard Z49.1, SAFETY IN WELDING AND CUTTING. All Personal Protective Equipment (PPE) shall be in place in accordance with this referenced specification and all other applicable and governing regulations.
- The operating data provided in the Specifications are maximum values. Overloading the welding torch will inevitably damage the product and void any and all warranties.
- Before changing any parts on the torch or control box, disconnect the torch from the welding power source and disconnect the control box input power source. Unplug the control box from the electrical outlet.
- The operating instructions for all other welding components - e.g. power source, wire feed and cooling unit must be followed per the manufacturer's recommendations.
- Never pull the cable assembly across sharp edges or set down on a hot surface.
- Never move the torch by pulling or dragging by the welding torch or cable.
- Curtains or partitions shall be installed to protect other workers or observers from arc radiation.
- When handling gas cylinders, consult the instructions issued by the manufacturers and the suppliers of the pressurized gas.
- Work pieces that have been degreased using chlorinated solvents must be sprayed down with clean water before welding starts to avoid the risk of phosgene forming. For the same reason, no degreasing baths containing chlorine must be placed close to the welding point.
- All vapors given off by metals can cause harm and a special warning is attached to lead, cadmium, copper, zinc, and beryllium. Take appropriate precautions to ensure that the legal maximum levels of toxic concentrations are not exceeded.
- Do not touch the welding torch with bare skin until it has had adequate time to cool down.
- Wait to adjust the rotation diameter until the torch has cooled to room temperature.

Fume and Gases



FUMES AND GASES can be hazardous. Welding and cutting produces fumes and gases. Breathing these fumes and gases can be hazardous to your health.

- Keep your head out of the fumes. Do not breathe the fumes.
- If inside, ventilate the area and/or use local forced ventilation at the arc to remove welding and cutting fumes and gases. The recommended way to determine adequate ventilation is to sample for the composition and quantity of fumes and gases to which personnel are exposed.
- If ventilation is poor, wear an approved air-supplied respirator.
- Read and understand the Safety Data Sheets (SDSs) and the manufacturer's instructions for adhesives, coatings, cleaners, consumables, coolants, degreasers, fluxes and metals.
- Work in a confined space only if it is well ventilated, or while wearing an air-supplied respirator. Always have a trained watch-person nearby. Welding fumes and gases can displace air and lower the oxygen level causing injury or death. Be sure the breathing air is safe.

- Do not weld or cut in locations near degreasing, cleaning, or spraying operations. The heat and rays of the arc can react with vapors to form highly toxic and irritating gases.
- Do not weld or cut on coated metals, such as galvanized, lead, or cadmium plated steel, unless the coating is removed from the weld area, the area is well ventilated, and while wearing an air supplied respirator. The coatings and any metals containing these elements can give off toxic fumes if welded.

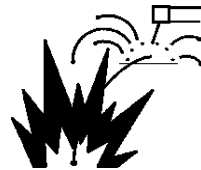
Arc Rays



ARC RAYS can burn eyes and skin. Arc rays from welding and cutting processes produce intense visible and invisible (ultraviolet and infrared) rays that can burn eyes and skin. Sparks fly off from the weld.

- Wear an approved welding helmet fitted with a proper shade of filter lenses to protect your face and eyes from arc rays and sparks when welding, cutting, or watching (see ANSI Z49.1 and Z87.1 listed in Safety Standards).
- Wear approved safety glasses with side shields under your helmet.
- Use protective screens or barriers to protect others from flash, glare and sparks; warn others not to watch the arc.
- Wear body protection made from durable, flame resistant material (leather, heavy cotton, wool).
- Body protection includes oil-free clothing such as leather gloves, heavy shirt, cuff less trousers, high shoes and a cap.

Welding and Cutting



Welding or cutting on closed containers such as tanks, drums or pipes, can cause them to blow up. Sparks can fly off from the welding or cutting arc. The flying sparks, hot work piece and hot equipment can cause fires and burns. Accidental contact of electrode to metal objects can cause sparks, explosion, overheating or fire. Check and be sure the area is safe before doing any welding or cutting.

- Remove all flammables within 35 ft. (10.7 m) of the welding or cutting arc. If this is not possible, tightly cover them with approved covers.
- Do not weld or cut where flying sparks can strike flammable material.
- Protect yourself and others from flying sparks and hot metal.
- Be aware that welding sparks and hot materials from welding and cutting can easily go through small cracks and openings to adjacent areas.
- Watch for fire, and keep a fire extinguisher nearby.
- Be aware that welding or cutting on a ceiling, floor, bulkhead or partition can cause fire on the hidden side.
- Do not weld or cut on containers that have held combustibles, or on closed containers such as tanks, drums, or pipes unless they are properly prepared according to AWS F4.1 and AWS A6.0 (see Safety Standards).
- Do not weld or cut where the atmosphere may contain flammable dust, gas, or liquid vapors (such as gasoline).
- Connect work cable to the work as close to the welding or cutting area as practical to prevent welding or cutting current from traveling long, possibly unknown paths and causing electric shock, sparks and fire hazards.
- Do not use welder to thaw frozen pipes.
- Remove stick electrode from holder or cut off welding wire at contact tip when not in use.

- Remove any combustibles, such as a butane lighter or match, from your person before doing any welding or cutting.
- After completion of work, inspect area to ensure it is free of sparks, glowing embers, and flames.
- Use only correct fuses or circuit breakers. Do not oversize or by-pass them.
- Follow requirements in OSHA 1910.252 (a) (2) (iv) and NFPA 51B for hot work and have a fire watcher and extinguisher nearby.
- Read and understand the Safety Data Sheets (SDSs) and the manufacturer's instructions for adhesives, coatings, cleaners, consumables, coolants, degreasers, fluxes and metals.

Electric Shock



Touching live electrical parts can cause fatal shocks or severe burns. The electrode and work circuit is electrically live whenever the output is on. The input power circuit and machine internal circuits are also live when power is on. In gas metal arc welding (GMAW), the wire, wire reel, drive roll housing and all metal parts touching the welding wire are electrically live. Incorrectly installed or improperly grounded equipment is a hazard.

- Do not use AC output in damp areas, if movement is confined, or if there is danger of falling.
- Use AC output ONLY if required for the welding or cutting process.
- If AC output is required; use remote output control if present on unit. Additional safety precautions are required when any of the following electrically hazardous conditions are present: in damp locations or while wearing wet clothing; on metal structures such as floors, gratings or scaffolds; when in cramped positions such as sitting, kneeling or lying; or when there is a high risk of unavoidable or accidental contact with the workpiece or ground. For these conditions, use the following equipment in order presented: 1) a GMAW DC constant voltage (wire) welder, 2) a DC manual (stick) welder or 3) an AC welder with reduced open circuit voltage. In most situations, use of a DC, constant voltage wire welder is recommended. And, do not work alone!
- Disconnect input power or stop engine before installing or servicing equipment. Lockout/tagout input power according to OSHA 29 CFR 1910.147 (see Safety Standards).
- Properly install, ground, and operate this equipment according to its Owner's Manual and national, state/provincial and local codes.
- Always verify the supply ground – check and be sure that input power cord ground wire is properly connected to ground terminal in disconnect box or that cord plug is connected to a properly grounded receptacle outlet.
- When making input connections attach proper grounding conductor first and double-check connections.
- Keep cords dry, free of oil and greases and protected from hot metal and sparks.
- Frequently inspect power cord for damage or bare wiring. Replace cord immediately if damaged. Bare wiring can kill.
- Turn off all equipment when not in use.
- Do not use worn, damaged, undersized or poorly spliced cables.
- Do not drape cables over your body.
- If earth grounding of the workpiece is required; ground it directly with a separate cable.
- Do not touch electrode if you are in contact with the work, ground or another electrode from a different machine.
- Do not touch electrode holders connected to two welding machines at the same time since double open circuit voltage will be present.
- Use only well-maintained equipment. Repair or replace damaged parts at once. Maintain unit according to manual.
- Wear a safety harness if working above floor level.
- Keep all panels and covers securely in place.

- Clamp work cable with good metal-to-metal contact to workpiece or worktable as near the weld as practical.
- Insulate work clamp when not connected to workpiece to prevent contact with any metal object.
- Do not connect more than one electrode or work cable to any single weld output terminal. Disconnect cable for process when not in use.

Cylinders

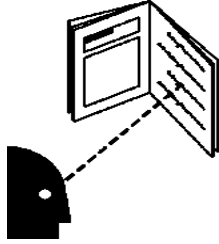


Compressed gas cylinders contain gas under high pressure. If damaged, a cylinder can explode. Since gas cylinders are normally part of the welding process, be sure to treat them carefully.

- Protect compressed gas cylinders from excessive heat, mechanical shocks, physical damage, slag, open flames, sparks and arcs.
- Install cylinders in an upright position by securing to a stationary support or cylinder rack to prevent falling or tipping.
- Keep cylinders away from any welding, cutting or other electrical circuits.
- Never drape a welding electrode or cutting torch over a gas cylinder.
- Never allow a welding electrode or cutting torch to touch any cylinder.
- Never weld on a pressurized cylinder – explosion will result.
- Use only the correct compressed gas cylinders, regulators, hoses and fittings designed for the specific application; maintain them and associated parts in good condition.
- Turn face away from valve outlet when opening cylinder valve. Do not stand in front of or behind the regulator when opening the valve.
- Keep protective cap in place over valve except when cylinder is in use or connected for use.
- Use the right equipment, correct procedures and sufficient number of persons to lift and move cylinders.
- Read and follow instructions on compressed gas cylinders, associated equipment, and Compressed Gas Association (CGA) publication P-1 listed in Safety Standards.

Additional Safety Warnings for Installation, Operation and Maintenance

READ INSTRUCTIONS



- Read and follow all labels and the Owner's Manual carefully before installing, operating, or servicing the unit.
- Read the safety information at the beginning of the manual and each section.
- Use only genuine replacement parts from the manufacturer.
- Perform maintenance and service according to the Owner's Manual, industry standards and national, state/provincial and local codes.

ELECTRIC AND MAGNETIC FIELDS (EMF) can affect implanted Medical Devices



- Wearers of Pacemakers and other Implanted Medical Devices should keep away.
- Implanted Medical Device wearers should consult their doctor and the device manufacturer before going near arc welding, spot welding, gouging, plasma arc cutting or induction.

H.F. RADIATION can cause interference



- High-frequency (H.F.) can interfere with radio navigation, safety services, computers and communications equipment.
- Have only qualified persons familiar with electronic equipment perform this installation. The user is responsible for having a qualified electrician promptly correct any interference problem resulting from the installation.
- Have the installation regularly checked and maintained.
- If notified by the FCC about interference, stop using the equipment at once.
- Keep high-frequency source doors and panels tightly shut, keep spark gaps at correct setting and use grounding and shielding to minimize the possibility of interference.

California Proposition 65 Warnings

Welding or cutting equipment produces fumes or gases that contain chemicals known to the State of California to cause birth defects and in some cases, cancer. (California Health & Safety Code Section 25249.5 et seq.) This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm. Wash your hands after using.

EMF Information

Electric current flowing through any conductor causes localized electric and magnetic fields (EMF). The current from arc welding (and allied processes including spot welding, gouging, plasma arc cutting, and induction heating operations) creates an EMF field around the welding circuit. EMF fields may interfere with some medical implants, e.g. Pacemakers. Protective measures for persons wearing medical implants have to be taken. For example, restrict access for passersby or conduct individual risk assessment for welders. All welders should use the following procedures in order to minimize exposure to EMF fields from the welding circuit:

1. Keep cables close together by twisting or taping them, or using a cable cover.
2. Do not place your body between welding cables. Arrange cables to one side and away from the operator.
3. Do not coil or drape cables around your body.
4. Keep head and trunk as far away from the equipment in the welding circuit as possible.

5. Connect work clamp to workpiece as close to the weld as possible.
6. Do not work next to, sit or lean on the welding power source.
7. Do not weld while carrying the welding power source wire feeder.

About Implanted Medical Devices:

Implanted Medical Device wearers should consult their doctor and the device manufacturer before performing or going near arc welding, spot welding, gouging, plasma arc cutting, or induction heating operations. If cleared by your doctor, then following the above procedures is recommended.

Safety Standards

- ANSI Standard Z49.1, SAFETY IN WELDING AND CUTTING, American Welding Society, 2501 N.W. 7th St., Miami, FL 33125. Free download at http://www.aws.org/technical/AWS_Z49.pdf
- ANSI Standard Z41.1, STANDARD FOR MEN'S SAFETY - TOE FOOTWEAR obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.
- ANSI Standard Z49.2, FIRE PREVENTION IN THE USE OF CUTTING AND WELDING PROCESSES obtainable from the American National Standards Institute, 1430 Broadway, New York, NY 10018.
- OSHA, SAFETY AND HEALTH STANDARDS, 29CFR 1910, obtainable from the U.S. Government Printing Office, Washington, D.C. 20402.
- OSHA, PERSONAL PROTECTIVE EQUIPMENT, OSH 3151-12R 2003. Free download at <https://www.osha.gov/Publications/osha3151.pdf>

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1.0 GENERAL DESCRIPTION

The SmartSensor™ is an Embedded Microcontroller device designed to collect and monitor welding parameters. In its basic form the SmartSensor is configured to monitor welding current and provides two user 24 VDC inputs and 24 VDC outputs. It also provides a RS-485 serial port with the Modbus™ protocol to allow the user to access the run time data and enable control functions. Additional sensors can be added to monitor other welding parameters. The SmartSensor can monitor Voltage, Wire Speed, Travel Speed, Gas Flow or Temperature. The SmartSensor can be used for the following monitoring functions:

- Arc On Time
- Weld Counter
- Duty Cycle
- Average Current and Arc On Time
- Record Average Volt, Amp, Wire Speed, Travel Speed and Gas Flow or Temperature (Wire, Travel, Gas, Temperature require additional sensors)
- With user supplied inputs and optional sensors, the control can provide PASS/FAIL testing for each completed weld based on a four-part memory mapped learn cycle and user defined deviation values
- Sensor can provide two levels of PASS/FAIL testing:
 - Weld Pass/Fail
 - Part Pass/Fail

1.1 The Sensor for ARC ON/ACTIVE Detection

The unit provides weld current detection and can be used as an arc active sensor. It also provides an accumulative arc on timer and will accumulate the weld current during a weld cycle. At the end of the weld cycle the average weld current and arc on time is stored in Non-Volatile memory. The SmartSensor has onboard memory to store up to 1040 weld summary data records.

The SmartSensor provides a RS-485 serial com port using the Modbus Protocol to allow external communications with the SmartSensor. Using this com port the user can upload runtime weld current from the SmartSensor. This com port is also used to upload the stored weld data records and accumulative arc time. The weld data records can then be used to perform SPC trending.

The SmartSensor has two 24 VDC inputs and two 24 VDC solid state relay (SSR) outputs. Input 1 is used as a “PART” input and Input 2 is used as a “LEARN” input. CR1 is a “READY/ARCON” output and CR2 is used as a “PASS/FAIL” output. No inputs are required when using the SmartSensor as an arc active sensor or as a Current/Arc time sensor. CR1 is asserted when the welding current is less then 10 amps.

When the current exceeds the 10 amp value for 0.1 seconds then CR1 is cleared indicating a valid arc on condition.

Using the two inputs will allow the SmartSensor to perform some basic weld validation functions. The “PART” input is used to signify the start of a new part. The “LEARN” input is used to teach the SmartSensor the statistical base line data for a part. To learn a part, set the “LEARN” input high then set the “PART” input high and weld 5 consecutive parts. The Part input must be Cleared and reset for each of the 5 parts. After completing the 5 parts reset the “LEARN” input and the SmartSensor will determine the process limits based on the 5 part sample. Each part can have from one to 250 welds per part. The SmartSensor will

establish a process control schedule for each weld on a part. After learning the part the SmartSensor can be used to validate the arc on time and average current for each weld on the part. To enable PART TESTING after a part has been learned, set the "PART" input high at the start of each part. At the end of each weld CR2 will be set if the weld average current and arc time were within the user defined process limits. CR2 will be cleared if the weld failed the process test limits. When the "PART" input is cleared the SmartSensor will perform a part verification test to validate the total average current, the total arc on time and that the minimum weld count has been performed. CR2 will be set if the Part passed the validation test and will be cleared if the part failed the test. Using the Serial port the user can verify the type of fault that occurred.

1.2 The Sensor

The sensor can also provide Arc Voltage data acquisition and monitoring, and with individually purchased sensors provide Wire Speed, Travel Speed, and Gas Flow or Temperature data acquisition and monitoring.

The additional sensors will allow the SmartSensor to validate the volume and work applied for each weld and for the complete part. The user can use the Modbus serial port to upload run time and stored weld data records. When the additional sensors are used the unit will perform an additional Accumulative Arc Density (AAD) test for each completed weld and then perform an AAD test for the complete part. If the optional external wire speed sensor is used an additional Volume test will be performed for each weld and the complete part.

2.0 GENERAL SPECIFICATIONS

The SmartSensor embedded microcontroller provides two TTL level encoder inputs that are used for measuring wire speed and travel speed. There are three analog inputs that are used to monitor welding current, Arc Voltage and a third input that can be used to monitor gas flow using the GFM sensor or some other 0 – 5 Vdc sensor. There are two 24 Vdc inputs and two 24 Vdc SSR outputs. The SmartSensor has a RS-485 serial port that provides a Modbus™ protocol and can be used to program and download weld data from the SmartSensor. The SmartSensor can also be used with an Ethernet port and provide Modbus over Ethernet connectivity. This will allow multiple users to connect to multiple sensors via an Ethernet connection. The SmartSensor can be configured to store up to 1040 weld summaries in internal NVRAM. The Date/Time stamped summaries can then be downloaded via the Modbus Port.

2.1 Sensor Tentative Specifications

Dimensions: 2.1"H x 2.5"W x 5.6"L (53mm x 64mm x 143mm)

*Note: Allow an additional clearance of 1.5" (38mm) below sensor for connector clearance.
Max welding cable size 1" (25 mm).*

Weight: 7oz (0.198kg)

Power Input: 12 – 26 Vdc @ 100ma

Arc Current: 0-500 ADC; Accuracy: $\pm 2.0\%$ Full Scale ± 2 digits

0-950 ADC; Accuracy: $\pm 2.5\%$ Full Scale ± 3 digits

Arc Voltage: 0-80 VDC; Accuracy: $\pm 1.5\%$ Full Scale ± 2 digits

0-100 VDC; Accuracy $\pm 2.0\%$ Full Scale ± 2 digits

Wire Speed: 10 – 1000 IPM; Accuracy $\pm 3.0\%$ Full Scale ± 2 digits

Travel Speed: 1.0 – 100.0 IPM; Accuracy $\pm 3.0\%$ Full Scale ± 2 digits

Analog Input: 0-5.0 Vdc; Accuracy $\pm 1.5\%$ Full scale ± 2 digits

Digital Inputs: 10 – 28 Vdc @ 5 ma

Digital Outputs: 12 – 26 Vdc (Depends on Voltage Input) @ 100ma.

Welds/Part: 1 - 200 Welds/Part

Weld Memory: 1040 Welds summaries stored in NVRAM

Weld Testing*1: Pass/Fail per Weld based on Volume, AAD and Work applied

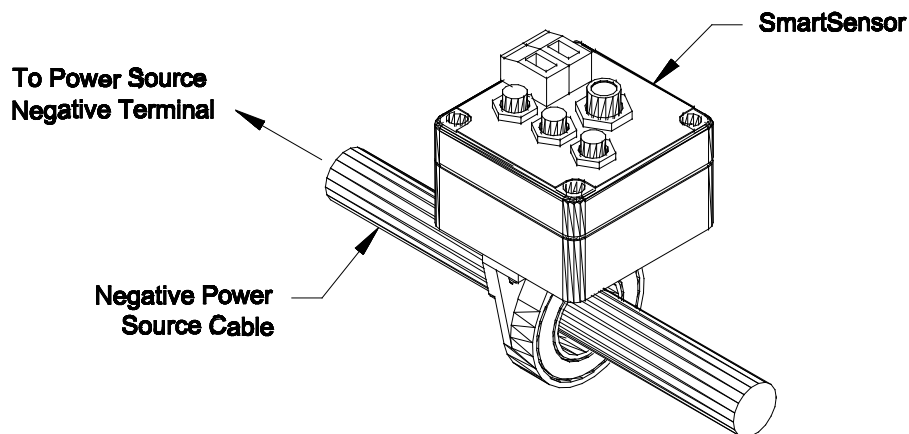
Part Testing*1: Pass/Fail per Part based on Weld Count, Total Volume, Total AAD and Total Work Applied.

* Notes:

1. Testing requires Volt, Amp and Wire speed sensor for calculations of Volume and work applied.

3.0 INSTALLATION

The SmartSensor must be installed into the welding system. The sensor should be installed as close as possible to the wire feed drive motor assembly. The preferred location is at the attachment point of the weld cable to the wire drive assembly. The SmartSensor uses a Thru-Hole linear current sensor. The sensor has a 1.0" (25mm) opening. The sensor must be installed around the welding cable. To install the sensor, disconnect the welding cable from the wire feed drive. Insert the cable thru the sensor. Observe the Current Direction markings on the sensor for proper operation. Note: You may need to fabricate a pig-tail adapter to connect double welding cables through the current sensor to the wire feeder.



3.1 Volt Sensor

If the Volt sensor option is installed then perform the following. For volt sensor cable installation on a MIG/MAG application, connect a 18 AWG RED wire to the "VOLT+" terminal on the SmartSensor and the other end to the wire feed drive motor welding power cable connection. Connect a 18 AWG black wire to the "VOLT-" terminal on the SmartSensor to a suitable location on the welding fixture. Note: If you are not able to mount the volt sensor cable at the wire drive assembly it is recommended that a 1.0 amp in-line fuse be connected to the positive sense lead at the motor drive. This will prevent excessive current be drawn thru the wire if the sense lead becomes damaged.

3.2 Optional Wire Speed

If the Wire Speed option is installed connect the Wire speed sensor cable to the Wire Speed sensor and the other end to the SmartSensor "WIRE" connector. Install the wire speed sensor as close as possible to the wire drive motor.

The Wire Feed Speed transducer consists of an optical tachometer, a precision drive wheel, a mounting housing, and a control cable. This device is designed to clamp directly on the welding wire. A fixed or stationary mounting of the wire feed speed transducer to the wire feeder is the preferred method of installation. The transducer is electrically isolated from the welding electrode so the transducer can be mounted to any part of the wire feeder.

NOTE: Make sure when permanently mounting the transducer on the wire feeder that the inlet and outlet of the transducer are in line with the wire guides of the wire feeder.

An optional clip-on wire speed transducer can be purchased and installed by simply clamping it over the welding wire at some point prior to where the wire enters the wire feeder. This device is designed to clamp directly on the welding wire and can be installed without the removal of the welding wire from the wire feeder during installation. To install the wire speed transducer using this method, simply depresses the handle on the top of the transducer, slip the assembly over the wire, and release the handle.

3.3 Optional Gas Flow Meter

The Gas Flow option consists of a transducer assembly and a sensor cable. The unit is designed to measure gas flows with a maximum inlet pressure of 50 psi. The transducer should be installed with supplied fittings, in the welding shielding gas lines, on the outlet side of the gas control solenoid valve. The unit should be located as close to the welding torch as practical.

NOTE: To avoid damage to the transducer assembly, do not use any type of pipe dope when making the connection.

The gas flow transducer is supplied with a cable. To connect the sensor cable to the unit, locate the connector labeled "ANL" on the SmartSensor. Plug the GFM cable into the "ANL" connector.

3.4 Optional Travel Speed Sensor

The Travel Speed Transducer assembly consists of a tachometer that measures the travel speed of the welding torch and a control cable. The transducer is a surface contact device supplied with a spring-loaded hinge to ensure proper surface tension. The hinge provides for a +20 to -10 degree movement of the transducer with respect to the drive carriage of the torch. In order to ensure accurate measurement, the transducer must be rigidly mounted on the drive carriage with the drive wheel perpendicular to the drive surface.

The spring-loaded hinge has two tapped 10-32 holes on the upper bracket for mounting purposes and may be located on either side or on top of the transducer housing. To move the hinge to the other side of the transducer housing, follow these steps:

Remove the hinge bolt and slowly release the spring's tension.

Loosen the mounting screws and move the lower hinge bracket to the desired location on the transducer housing.

Secure the bracket to the housing. Using a small piece of 1/4-inch tubing to compress the spring, position the spring in the lower bracket and reassemble the hinge.

Remove the tubing from the end of the spring once the hinge bolt and locknut is installed.

CAUTION: BEFORE REMOVING THE HINGE BOLT, MAKE SURE THE TOP BRACKET OF THE HINGE IS SECURED IN ORDER TO PREVENT THE UNCONTROLLED RELEASE OF THE SPRING TENSION.

The Travel Speed Transducer is supplied with a cable. To connect the sensor cable to the unit, locate the connector labeled "TRAVEL" on the SmartSensor. Plug Travel speed cable into the "TRAVEL" connector.

4.0 OPERATION

4.1 Arc Detection

A Modbus Coil (CR1) input (“ARC ON”) has been provided to allow an external control source ,such as a PLC via Modbus communication, to provide a remote Arc On condition. When this input is asserted, the SmartSensor will begin data logging and will continue until the input is reset. The user must activate this input by setting the corresponding mode via the Modbus RS-485 communication port. If the “Auto Arc Detect” mode (CR6) is reset the SmartSensor will use the remote arc on coil. When the “Auto Arc Detect” mode (CR6) is asserted the SmartSensor will use the arc current to determine when to log welding data. The arc current must exceed the user defined threshold values to set an “Arc On” condition. When the Current falls below the user specified value the SmartSensor would set an “Arc Off” condition and stop data logger. The Arc On current threshold is modified by changing the Modbus Register 20 (See Section 5.0 for Modbus Registers)

4.2 Embedded Firmware

The embedded firmware has basic scaling and averaging capabilities as well as Slave Mode ModBus RTU Communications protocol support. The SmartSensor will provide user defined average and data collection mode to allow Run time and/or average data storage. The Run time data will be generated based on the averaging sample time specified by the user. The Raw analog data will be sampled at a 25 kHz rate. The SmartSensor will average 25 samples to produce a 1 khz data rate for all analog sensors. The Wire feed conversion time will be based on the actual wire feed rate (16.6 Hz – 16.6 KHz).

Configuration of scaling and averaging parameters will be possible through the ModBus network port. The user may specify the number of samples (X) to be averaged before saving the data point in memory for later play back. The SmartSensor will also generate a weld summary for each weld, which will be the average of all sampled data during the last weld cycle. The Data will be Date/Time stamped and stored in NV-RAM. Up to 1040 weld summaries may be stored before downloading. The SmartSensor provides continuous averaging of the X most recent data values, and queries by the host system at lower frequencies of either last data value or last average value.

4.3 Host System Interface

The SmartSensor will provide a RS-485 compatible serial port and will support the ModBus RTU protocol. The default baud rate is 19.2K.The following is the general specification for the RS-485 port:

| | |
|------------------------|-------------------------------------|
| Serial | |
| Physical support | Twisted Pair |
| Connector | 8 pin male M12 circular connector |
| Network | RS 485 – Half Duplex |
| Data exchange protocol | Modbus RTU 19,200 8 data 1 stop bit |

The RS-485 is a M12 connector and will provide the RS-485 connections and the power to operate the SmartSensor. The SmartSensor provides a user configurable 120-ohm termination resistor for the RS-485 serial cable. The Host controller will provide the necessary power to operate the SmartSensor. The power will be connected to the SmartSensor through the RS-485 cable. The SmartSensor requires an input voltage of 12 – 26 vdc @ 3.6 watts. The SmartSensor

will provide polarity and over current protection. The SmartSensor terminal connector will pin out as follows:

| Pin | Wire | Function |
|-----|--------|--|
| 1 | WHITE | Sensor (12 – 26 Vdc) Positive Power Input |
| 2 | BROWN | “B/RxTd+” RS-485 Signal High |
| 3 | GREEN | “A/RxTd-“ RS-485 Signal Low |
| 4 | YELLOW | “PART” Input (12 – 24 Vdc) from User |
| 5 | GRAY | “LEARN” Input (12 -24) Vdc from User |
| 6 | PINK | “READY/ARCON” Output (12 – 24 Vdc) to User |
| 7 | BLUE | “PASS/FAULT” Output (12 – 24 Vdc) to User |
| 8 | RED | RS-485/Sensor Power Common |

4.4 SmartSensor Remote I/O User Interface

The SmartSensor interface is comprised of two 24 VDC inputs and two 24 VDC sourcing outputs. INP2 “*Learn*” input is used to invoke a learn mode for the SmartSensor. When the optional sensors are installed this input will allow the SmartSensor to monitor multiple parts and to establish the necessary control limits that will be used to verify production parts.

The INP1 “*Part*” input is configured to allow the user to indicate when a part is being welded. This input must be asserted during the complete part cycle. The SmartSensor uses this input to establish when a new part is being welded. When the input is cleared the SmartSensor will perform a final analysis of all the welds made and set the pass/fail Part output signals. When the optional sensors are installed the pass-fail outputs will be set based on weld volume, weld counts and work-applied calculations.

The two output signals are used to indicate the operational and pass-fail status for each weld and part. CR1 is the “*READY*” output and is asserted when the user INP1 has been cleared and the SmartSensor has completed its Part evaluation routines. When INP1 is asserted the “*Ready*” (CR1) output will act as a “*Weld Active*” output. The “*READY*” output will be cleared while the weld is active and will be asserted when the weld is completed and the Pass/Fail testing is complete. This output can be used to validate operation of the SmartSensor and to determine when the Weld “*PASS/FAULT*” CR2 (PASS=On, FAULT=off) output status is valid.

When the “*Part Input*” (INP1) input is asserted then any faults indicated will be based on individual welds. When the “*Part Input*” (INP1) is cleared then the Fault indication will be the result of a Part totalize error. The second output CR2 provides a “*Pass/Fault*” (PASS=On, FAULT=off) output. This output will be asserted when the each weld has terminated and no faults were detected during the weld cycle. When the “*Part Input*” (INP1) is cleared the “*Pass/Fault*” (CR2) output will be asserted if the AAD testing passed the established limits. The “*PASS/Fault*” (CR2) output will always be cleared when a fault is detected. The “*Pass/Fault*” (CR2) output will always be asserted when a new weld is detected. At the end of every weld and/or Part the “*PASS/Fault*” CR2 or will indicate the Pass or Fault status of the previous Weld or Part.

4.5 BASIC MODE OPERATIONAL DESCRIPTION

The basic mode operation of the Smart Sensor is as a DATA LOGGER / ARC ON detector and only requires one user provided input for ARC ON notification and a user provided computer communications connection with the Arc Track II Software to log welding data. In the basic mode the SMART Sensor will not test welding data for an out-of-limit welding condition.

4.6 ADVANCE MODE OPERATIONAL DESCRIPTION

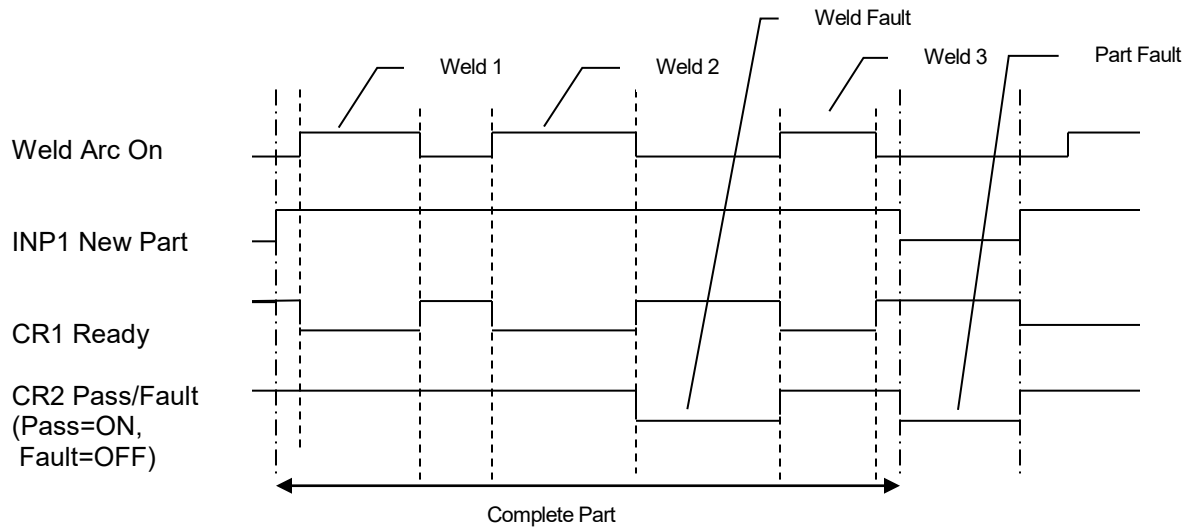
The normal operation of the SmartSensor requires a user provide “*INP1-New Part*” signal that must be asserted at the beginning of the part weld sequence. This input must be held during the complete part weld cycle. The SmartSensor will count and test each weld as the part is welded. Each weld will then be verified based on AAD process algorithms.

At the end of each weld the previous test status will be asserted by the “*CR2-Pass/Fault*” output. The status of the last weld output will be set at the end of the weld. If a fault occurs during the weld cycle then the “*CR2-Fault*” output will be clear if a fault is detected. The Status outputs CR2 will be cleared when the next weld is detected.

The SmartSensor will count each valid weld and will internally load new Process limits for each weld event. The “*INP1-New Part*” signal is used to synchronize the weld counts. A min arc time for a valid weld is used to verify valid completion of a specific weld event. At the end of each weld event the SmartSensor will summarize and store the results of the previous weld to include average Volt, Amp, Wire Speed, Arc Time and Weld Number.

When the “*INP1-New Part*” input is cleared the SmartSensor will calculate the total wire volume, work applied, spot heat and total number of welds on part. The result of the previous part data will be verified to the part control limits and the Part Status will be asserted on the Status outputs “*CR2-PASS/Fault*”. The status condition will remain until the next “*INP1-New Part*” input is asserted.

The following is the SmartSensor I/O timing diagram:



4.7 SETTING PROCESS CONTROL LIMITS

The SmartSensor has a learn mode that is used to establish the Part and weld process control limits. This mode is used to calculate the required AAD limits and to establish the base-line weld data limits. The user must first validate the weld process parameters and be assured that the welded parts are conforming to applicable codes and design specification.

To activate the learn mode, assert and maintain the INP 2 input during the complete learn cycle. This input is a 24 VDC input and is an active high input. Weld 5 parts using the normal interface sequence

The SmartSensor will assert the “CR2-Pass/Fault” indicate the learn mode (if the output is low prior to the start of the Learn Process). When the “INP1- New Part” input is asserted the “CR2-Pass/Fault” output will clear to indicate that the Smart Sensor received the “INP1- New Part” signal. At ARC ON the SmartSensor will assert the “CR2-Pass/Fault” to indicate that the sensor is learning the part. When the “INP1- New Part” is reset at the end of the part the “CR2-Pass/Fault” output will remain high unless a fault is detected during the learn process. When this occurs the user needs to evaluate/fix errors in the weld process and restart the Sensor Learn Process.

The “CR1-Ready” output will be cleared (set low) during the ARC ON to ARC OFF period then asserted (set high) when the arc is off. After processing 5 parts the SmartSensor will assert and hold the “CR1-Ready” which will indicate completion of the Learn cycle. The user should then clear the “INP2-Learn” input. To terminate a learn cycle before completing the 5 parts the user will clear the “INP2-Learn” Input. If the “CR2-Pass/Fault” output is reset at the end of the Learn Process this will indicate a learn mode fault.

Warning: *Clearing the learn mode prior to completing the 5 parts will result in an incomplete Learn process.*

At the end of the last part in the Learn Process the Part Input must be set low before the Learn Input is set low.

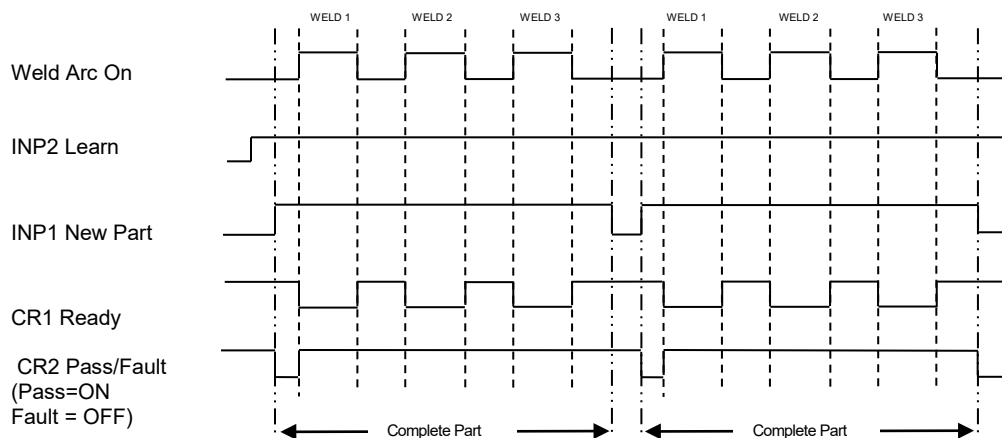
During the Learn Process the SmartSensor will build a profile for each weld conducted on the Part and a profile for the entire Part. This profile includes the *Number of Welds per Part* and the *total ARC Time* for each weld and the entire Part. This Profile is used during the Learn to ensure that the weld process used to “Learn the Part” is repeated for all 5 parts.

When all 5 Parts for the Learn Process are completed and the Learn Input is set low the Fault output will transition high to indicate that the Learn Process was GOOD.

If, during the Learn process, something changes the process (such as too few welds or too many welds on one of the 5 parts) the “CR2-Pass/Fault” output will remain low when the Learn Input is set low to indicate that the Learn Mode is not set. When this happens the user should fix or adjust the welding process to meet user established standards for the Part and then re-start the Learn Process.

After a Fault the “CR2-Pass/Fault” is asserted when a new weld is detected (ARC On) or when the “INP2-Learn” input is asserted. After completing the “Learn” the SmartSensor will not begin testing until the “INP1- New Part” has been cleared then asserted indicating a new part.

The following is the SmartSensor Learn Mode I/O timing diagram:



5.0 SmartSensor MODBUS MEMORY MAP

5.1 General Description

This document provides the basic Modbus memory map and command structure for the SmartSensor RS-485 communications port. The SmartSensor supports the Modbus Protocol as specified in the Modicon Technical publications "Modbus Protocol" ([intr7.html](#)). The SmartSensor control does not support the Broadcast mode. The controller provides the slave side communications routines for the RTU mode. The user must define the Slave ID to a unique ID number from 1 – 247. Default Baud rate is 19.2 K baud.

5.2 Supported Modbus Commands

The following ModBus commands are supported:

| CODE | DESCRIPTION | ADDRESS RANGE |
|------|---------------------------|---------------|
| 01 | Read Coil Status | 0-31 |
| 03 | Read Holding Registers | 0-21 |
| 05 | Force Single Coil | 0-15 |
| 06 | Preset Single Register | 0-21 |
| 15 | Force Multiple Coils | 0-15 |
| 16 | Preset Multiple Registers | 0-21 |
| 17 | Report Slave ID | 5 bytes |

5.3 Memory Map for Sensor

The following is the Coil definitions address 0-31:

| COIL | ADDRESS | DESCRIPTION |
|------|---------|---|
| 1 | 0 | Arc Active – Set when Weld Arc is detected |
| 2 | 1 | Save Average Data – When set Weld Summary Data is stored in NVRAM |
| 3 | 2 | Clear Weld Counter – When set the Weld Counter will be reset to 1 |
| 4 | 3 | Clear Summary Counter – When set the Average Data Counter is reset to 0 and Average Memory is cleared |
| 5 | 4 | Clear Arc Timer – When set the Accumulative Arc Timer is reset to 0 |
| 6 | 5 | Disable Auto Arc Detect – When set the Arc On condition must be set by the user supplied input CR1 |
| 7 | 6 | Read Memory – When set the Weld Summary data specified by Register 19 will be read into Register 2-12. Coil will be reset when summary has been loaded. Function is executed only when the arc is off. |
| 8 | 7 | Set Clock – When set the Date and Time values set in Register 7 – 12 will be loaded to the Real Time Clock. The Coil will be reset after the RTC is set. This function will only execute when the arc is off. |
| 9 | 8 | Enable Metric units of measure (1=Metric, 0=Imperial) |
| 10 | 9 | "PART" Input 1 (1 = On, 0 = Off) |
| 11 | 10 | "LEARN" Input 2 (1 = On, 0 = Off) |

| | | |
|-------|-------|---|
| 12 | 11 | "PASS/FAULT" Output (1=Pass, 0=Fault) |
| 13 | 12 | Volume Fault (1=Fault, 0=Pass) |
| 14 | 13 | AAD Fault (1=Fault, 0=Pass) |
| 15 | 14 | Arc Time Fault (1=Fault, 0=Pass) |
| 16 | 15 | Weld Count Fault (1=Fault, 0=Pass) |
| 17 | 16 | Auto Null Current Sensor (1=Auto Null Active) |
| 18 | 17 | Travel Sensor Type (1=A3A0112,0=A3A0263) |
| 19-32 | 18-31 | Not Defined |

The following is the Register definitions address 0-26:

| REGISTER | ADDRESS | DESCRIPTION |
|----------|---------|---|
| 1 | 0 | Arc On Status – When the arc is active the value will be 1 when the arc is off the value will be 0 |
| 2 | 1 | Arc Time – Weld on timer in 0.1-second intervals. Value is incremented during a weld cycle and measures the Arc On time for each weld. When the weld cycle is complete the total time for the weld will be set. (Note 100 = 10.0 sec) |
| 3 | 2 | Volts – During the Arc on Time the value represents the actual arc voltage. The value is in 0.1-volt increments (100=10.0 volts). When the weld cycle is complete the value will be the statistical average for the last weld. |
| 4 | 3 | Amps- – During the Arc on Time the value represents the actual arc current. The value is in 1amp increments (100=100 amps). When the weld cycle is complete the value will be the statistical average for the last weld. |
| 5 | 4 | Gas Pressure - – During the Arc on Time the value represents the actual gas pressure. The value is in 1KPa increments (100=100KPa). When the weld cycle is complete the value will be the statistical average for the last weld. |
| 6 | 5 | Wire Speed - – During the Arc on Time the value represents the actual wire feed speed. The value is in 1-mm/sec increments (100=100 MM/Sec). When the weld cycle is complete the value will be the statistical average for the last weld. |
| 7 | 6 | Hour – The value is the arc start Hour based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 8 | 7 | Minute - The value is the arc start minute based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 9 | 8 | Second - The value is the arc start second based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 10 | 9 | Day - The value is the arc start day based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 11 | 10 | Month - The value is the arc start month based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 12 | 11 | Year – The value is the arc start year based on the Real Time Clock. This value is set when an arc on condition is detected. |
| 13 | 12 | Total ARC Hours – This value is the accumulative arc on hours since the last arc time reset. |
| 14 | 13 | Total ARC Minutes - This value is the accumulative arc on minutes since the last arc time reset. |

| | | |
|----|----|---|
| 15 | 14 | Total Arc Seconds - This value is the accumulative arc on seconds since the last arc time reset. Value is in 0.1 second increments (100=10.0 seconds). |
| 16 | 15 | Weld Count – Total number of weld since last reset. If weld counter reaches the max count of 65535 the counter will reset to 0. |
| 17 | 16 | Weld Summary Count – Value indicates the number of weld summaries stored in memory (Max Count = 500). |
| 18 | 17 | Sample Count – Value indicates the number of raw data samples to average to produce a single sample value as stored in Register 3-5. |
| 19 | 18 | Read Weld Number – the value is used to select the stored Summary data to be read from memory to Register 2-12. Range of Value 1-500. |
| 20 | 19 | Arc On Amps – The value set in this Register is the welding current that must be exceeded to establish an arc on condition. Value is in 1-amp increments (10 = 10 amps). |
| 21 | 20 | Arc On Volts - The value set in this Register is the welding voltage that must be exceeded to establish an arc on condition. Value is in 0.1-volt increments (100 =10.0 volts). (Not used in SmartSensor) |
| 22 | 21 | Mean Time - This is the calculated Weld ARC TIME Mean value for testing. |
| 23 | 22 | Mean Volts - This is the calculated Weld ARC Volts Mean value for testing. |
| 24 | 23 | Mean Wire - This is the calculated Weld ARC Wire Feed Speed Mean value for testing. |
| 25 | 24 | Mean AMPS - This is the calculated Weld ARC AMPS Mean value for testing. |
| 26 | 25 | DELAY : MIN ETM Sigma – The MSB byte sets the start/end Test delay time. The value is in 0.1 second increments and sets the delay time from arc start to begin testing and the end time, prior to arc off, to stop testing. The LSB byte sets the MIN Arc Time sigma value used by sensor for process limits. Setting the Sigma value to 0 will disable the test function. (Arc Time Sigma = LSB/24; i.e. 55 =2.29) |
| 27 | 26 | VOLUME : AAD Sigma – The MSB byte sets the Volume sigma value used by the SmartSensor for Volume Deposited process limits when a wire feed speed sensor is used with the system. The LSB byte sets the ARC Applied Density (AAD) sigma value used by sensor for process limits. Setting the Sigma value to 0 will disable the test function. (Sigma = MSB, LSB/24; i.e. 55 =2.29) |
| 28 | 27 | WELDS : ETM Sigma – The MSB byte sets Number of welds per part used by the SmartSensor for process limits. The LSB byte sets the Maximum ARC Time sigma value for a given weld on a part for sensor process limits. Setting the Sigma value to 0 will disable the test function. (Sigma = MSB, LSB/24; i.e. 55 =2.29) |
| 29 | 28 | PART COUNT TOTAL - Displays the total Part Count number. |
| 30 | 29 | SPARE 1 – Not Assigned |
| 31 | 30 | Vzero : Azero - Manufacture Calibration value. Do not change this value unless instructed to do so by CWT. |
| 32 | 31 | CONFIG : DEVID - The Device ID function provides the user with a way to change the Sensor NODE Number. All Smart |

| | | |
|----|----|--|
| | | Sensors are set to Node 1 prior to shipment. If multiple units are connected to a Network, each Sensor must have a different Device ID. After loading a new ID the Sensor must be powered OFF and back ON to activate and save the new ID. Attach a label with ID number to the Sensor Enclosure. |
| 33 | 32 | AMP NULL VALUE - Manufacture Calibration value. Do not change this value unless instructed to do so by CWT. |
| 34 | 33 | AGAIN : VGAIN - Manufacture Calibration value. Do not change this value unless instructed to do so by CWT. |
| 35 | 34 | Low Current Test Value - Manufacture Calibration value. Do not change this value unless instructed to do so by CWT. |
| 36 | 35 | Travel Speed - Actual Travel Speed when Travel Speed Sensor is used with Smart Sensor (Reg Value must have a 0 loaded at start of weld for the Sensor to use the Travel Speed Sensor) or Manual Travel Speed. The user may load a Travel Speed in the Reg for Heat Calculation when not using a Travel Speed Sensor. |
| 37 | 36 | Arc Power #.## Kj |
| 38 | 37 | Heat Input #.## Kj / in |
| 39 | 38 | Raw AMP Sample (Factory Use Only) |
| 40 | 39 | Raw Volt Sample (Factory Use Only) |
| 41 | 40 | Raw Gas Sample (Factory Use Only) |

The following is a summary of the Report Slave ID and Status (Code 17) Response Data fields:

| Byte | Contents |
|------|---|
| 1 | Sensor ID Number =10 Hex (Version 1, Rev0) |
| 2 | Run Indicator (0=OFF, FF=On) |
| 3 | Status Byte Bit 0 = Ram Full Bit 1 = Battery Ok Bit 2 = Self Test Ok Bit 3-7 = 0 |
| 4 | Firmware Version Number – BCD Format (MSB = Major: ISB = Minor) |
| 5 | Firmware Version Number – BCD Format (MSB+LSB = Release) |

5.4 Coil Definitions and Operation

The SmartSensor has 32 simulated output coils. These coils are used as internal bit flags to perform specific functions. Only 1-19 of the simulated coils is used. Setting the coils 20-32 will not have any effect on the SmartSensor controller. However, they are reserved for future expansion. The SmartSensor support both single and group force coil commands. Refer to Section 4.3 for summary of the Coil functions.

To clear the SmartSensor weld and average counters or reset the total arc timer, force the specific coil to the “ON” condition. The SmartSensor will clear the requested counter or timer and then reset the coil to the “OFF” condition signifying a successful operation.

To disable the auto arc on detection mode force coil 6 to the “OFF” condition. When reset the SmartSensor will only log data when the remote on input CR1 is asserted. To allow normal arc on detection Coil 6 must be in the “ON” condition.

To set the Real time clock perform the following steps:

1. Set Coil 6 to the “ON” condition to disable automatic arc detection.
2. Load the BCD formatted Time and Date into the value Registers 6-12.
3. Set Coil 8 to the “ON” condition. The SmartSensor will clear the coil after completing the function.
4. Enable Coil 6 to resume automatic arc detection.

To read a stored weld data summaries perform the following steps:

1. Set Coil 6 to the “ON” condition to disable automatic arc detection.
2. Load the desired weld summary number into Registers 19. This value must be equal to or less than the total number of saved welds as indicated by Register 17.
3. Set Coil 2 to the “ON” condition. The SmartSensor will load the stored data into Registers 2-12 and will clear the coil after completing the function. The data will remain in the register until the next arc on or stored weld request.
4. Enable Coil 6 to resume automatic arc detection.

5.5 Register Definitions

Register 1: Used to indicate when a welding arc has been detected. When this register is a 1 the SmartSensor controller is updating the welding parameters with new measured values.

Register 2–6: Contains the current value for each of the welding parameters: The following table shows the value and units of measure for each weld parameter register:

| REGISTER | MEASURED PARAMETERS | UNITS OF MEASURE |
|----------|--|-------------------------|
| 2 | Arc On time – Time in 0.1 seconds from arc detection | (Value /10) sec. |
| 3 | Arc Voltage – Voltage measured by Volt sensor | (Value/10) vdc |
| 4 | Arc Current – Welding amps measured by Hall Sensor | Value = Amps DC |
| 5 | Gas Flow Rate – Shielding Gas flow from GFM sensor | Value = CFH (lpm) |
| 6 | Wire Speed – Linear wire speed measured by encoder | Value = In/Min (mm/sec) |

When the Arc is in the off condition the Registers will display the statistical average for the last weld.

Register 7-12: Contains the Time and Date at the start of the last weld. These registers will only update when a new weld is detected or a weld summary is loaded from memory. The Time and Date parameters are in BCD format. The low nibble is the 1's units and the upper nibble is the 10's units. Only the lower byte is used for all parameters except the year. The MSB byte holds the BCD value for the century value.

Note: When setting the Real time Date and Time the values loaded into the Registers 6-12 must be in a BCD format.

Register 13–15: Used to indicate the accumulative arc time. The value is an integer value and represents the total arc on time sense the last reset. At the end of each weld the accumulated arc timer will be updated. Writing to these registers will have no effect on the total arc time. When the next weld occurs the new value will be written.

Register 16: The current weld count sense the last weld count reset. This counter is incremented when the total arc time for a weld is greater then 0.5 seconds. This prevents false arc starts from being counted as a valid weld.

Register 17: Indicates the number of weld summaries stored in the weld memory. The maximum number of welds stored is 1365. Writing a new value to this register will cause the next collected weld to be written to that weld number location. The Welds will only be saved if the Save Weld summary coil (2) has been set and the minimum weld time is greater than 0.5 seconds.

Register 18: This register sets the number of raw data points to be averaged to generate a single sampled value. The minimum value is 1 and the maximum value is 255. Setting this value to 0 will disable the Analog Data collection routines.

Register 19: This register is used to read a previously stored weld summary from memory. Set the desired weld summary number in this register then set the Read Weld Memory Coil 7. The value will be written to Register 2 – 12. Maximum value is 1365.

Register 20-21: These registers are used to specify the conditions required to establish an arc on signal. To set the auto arc on signal the Voltage and current sensor values must exceed both values stored in the these registers. If any single sensor input drops below this level the arc on signal will be reset.

Register 22-25: These registers are used to display the calculated mean values for Time, Volts, Wire and AMPS.

Register 26-28: These registers are used to specify the process control limits used for in process monitoring. The MSB and LSB bytes are used as independent byte size variables and have a Byte size decimal range of 0-255.

Register 29: This Register display the Total number of Parts welded from previous reset of counter.

Register 31: Manufacture Calibration value. Do not change this value unless instructed to do so by CWT.

Register 32: Device ID Number

Register 33-35: Manufacture Calibration value. Do not change this value unless instructed to do so by CWT.

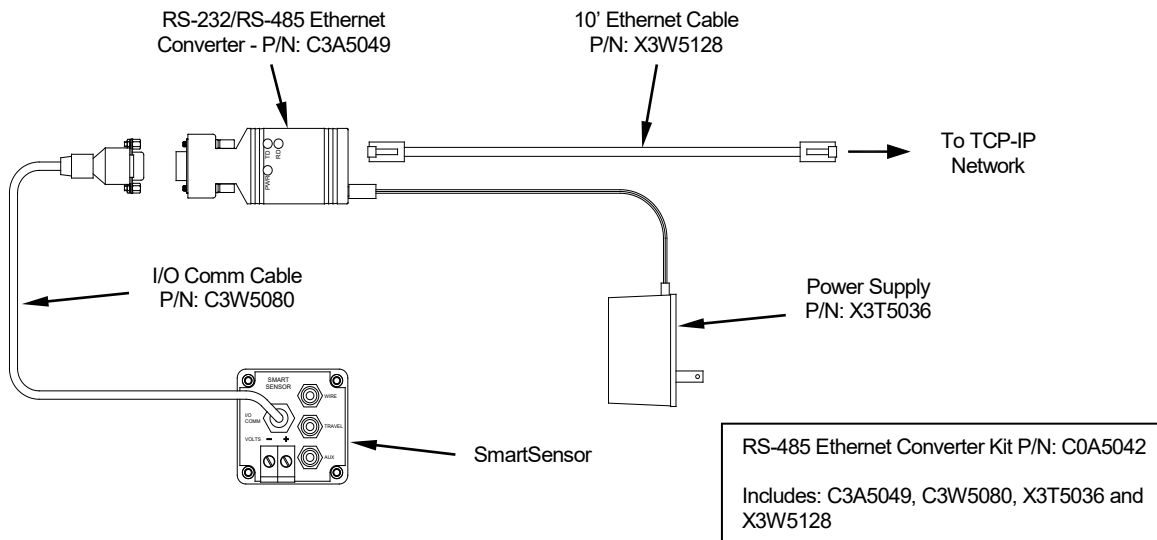
Register 36: Travel Speed Value.

Register 37-38: Sensor Calculated Arc Power and Heat Input.

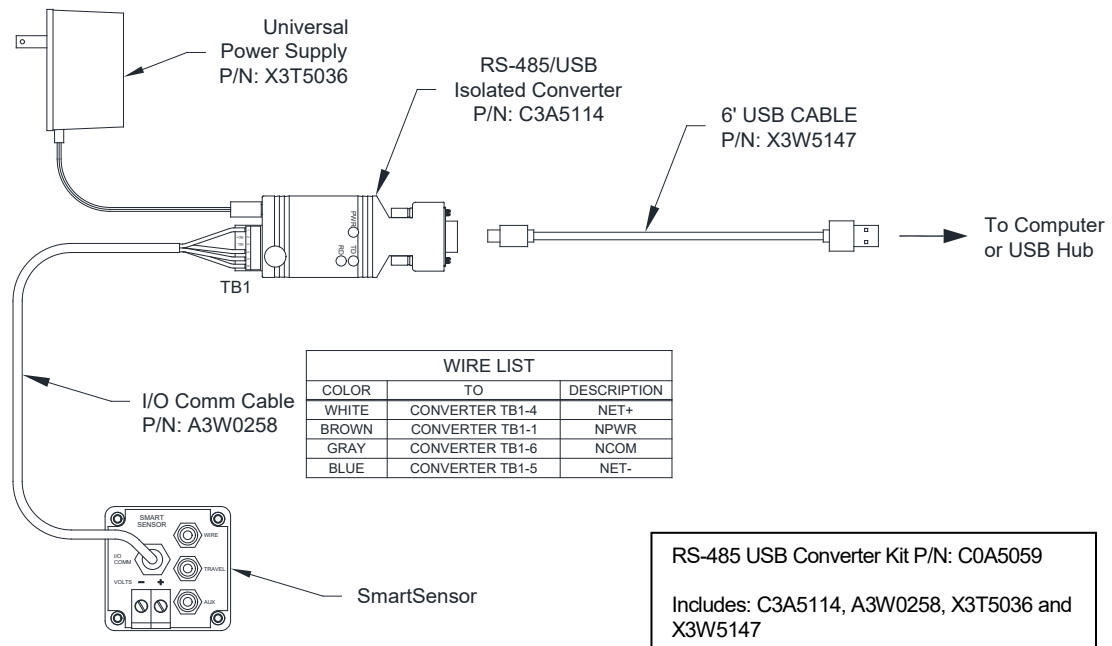
Register 39-41: Raw AMP, Volt and Gas sample (For Factory Used Only).

6.0 DRAWINGS

6.1 Single SmartSensor with Ethernet Communications

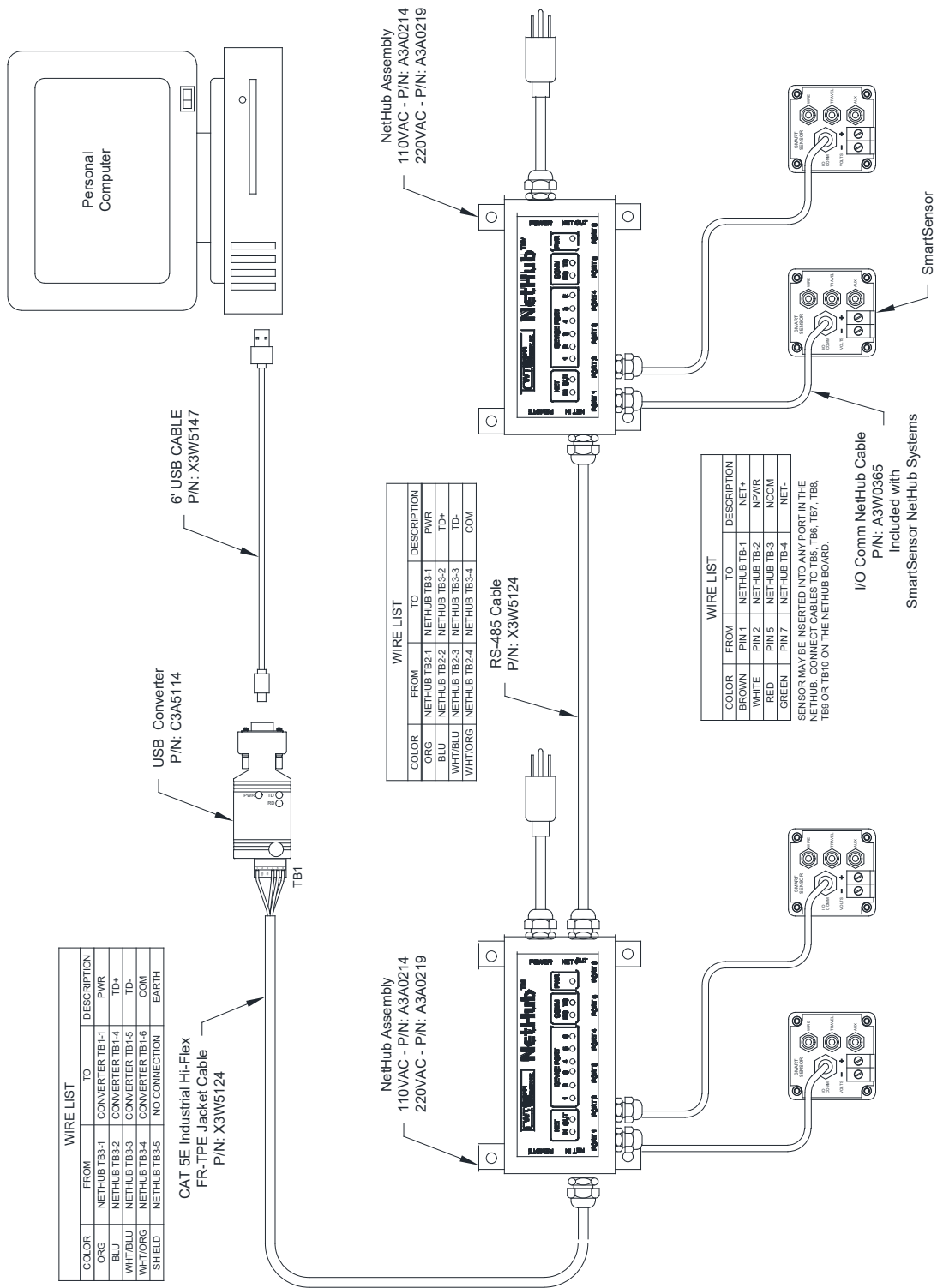


6.2 Single SmartSensor with USB Communications

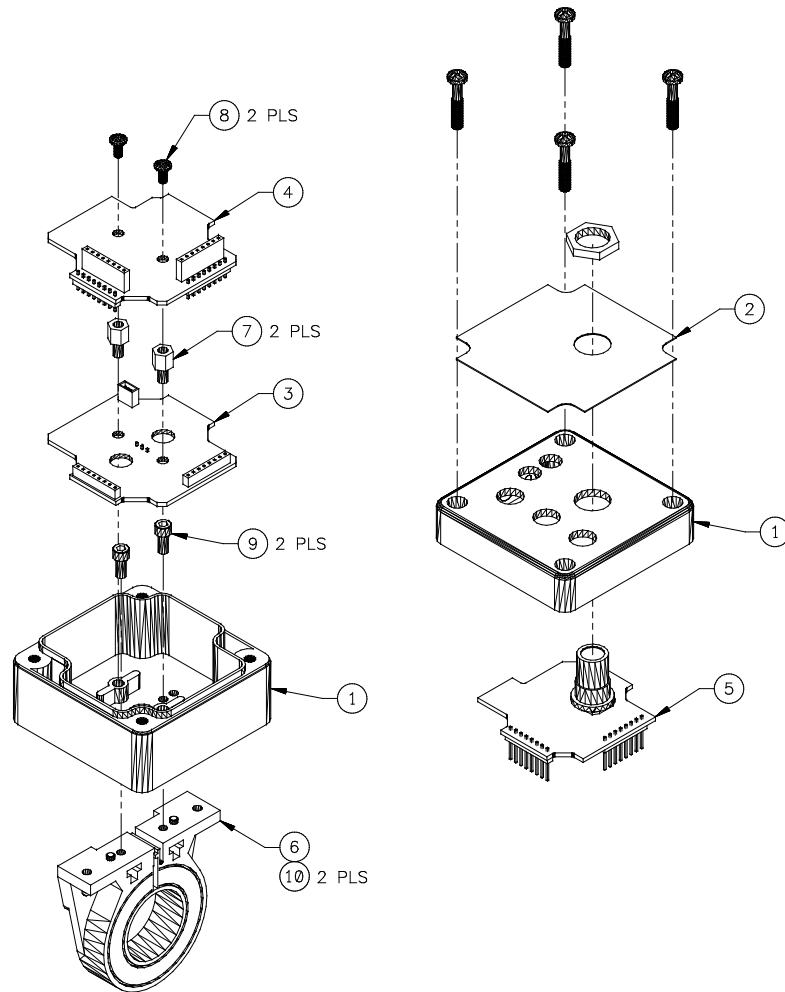


[illegible]

6.4 Multiple SmartSensor with USB Communications

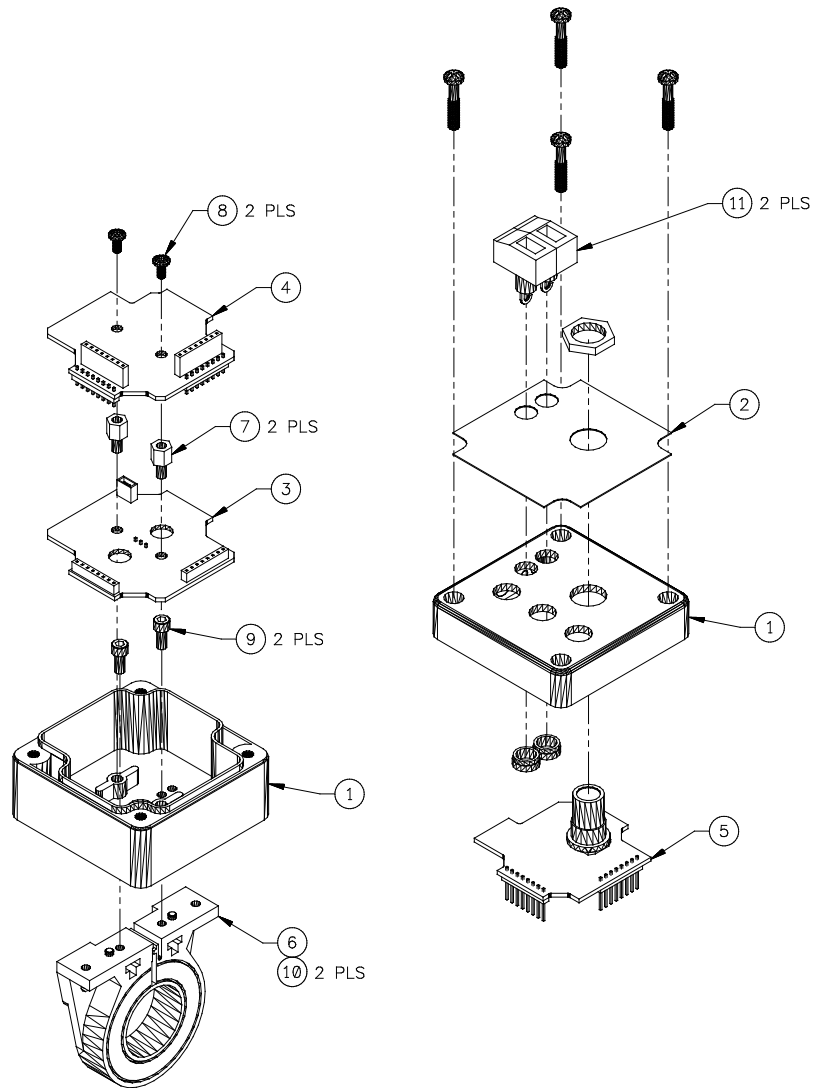


6.5 SmartSensor – Amp Assembly (P/N: A3A0250)



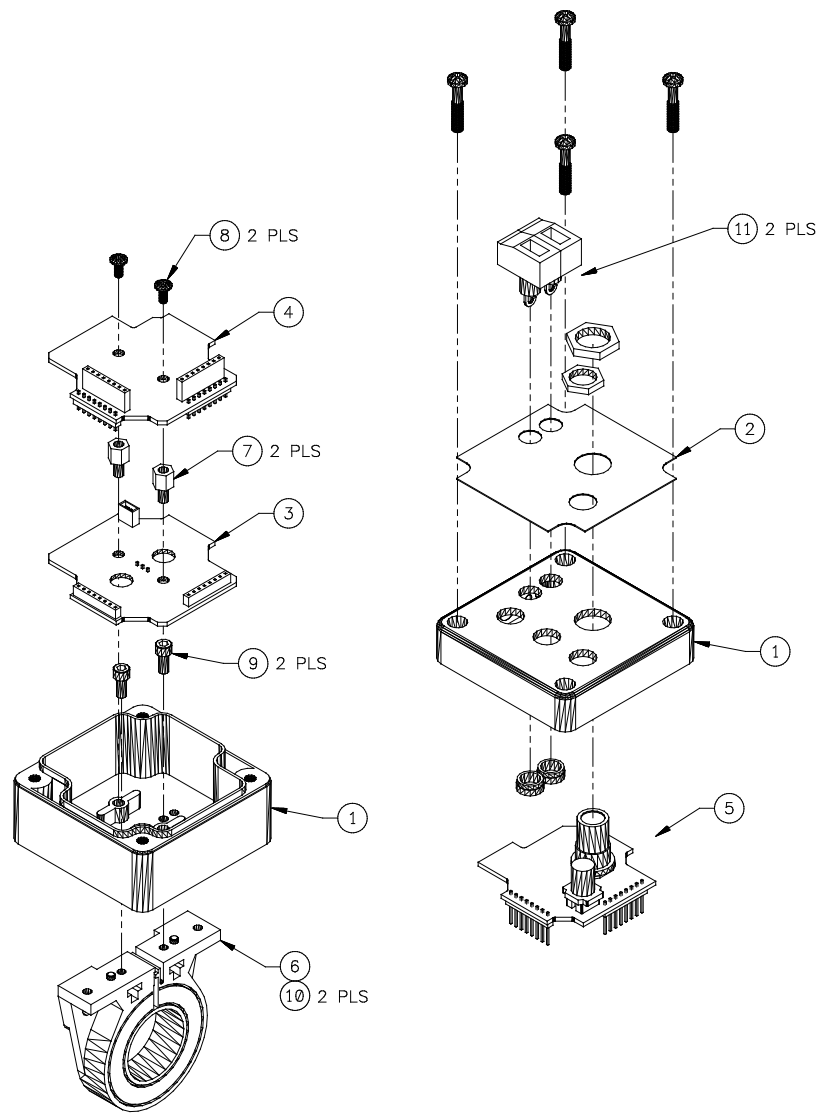
| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149 | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |

6.6 SmartSensor – Amp/Volt Assembly (P/N: A3A0251)



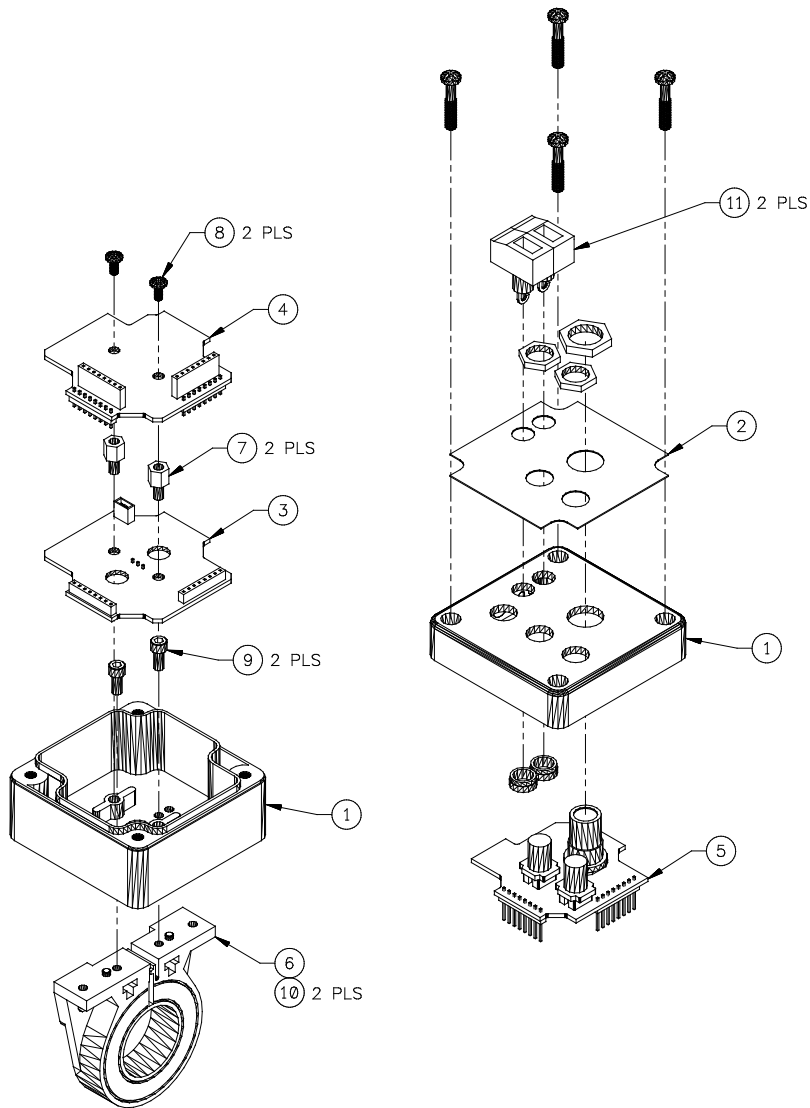
| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149 | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |
| 11 | 2 | X3P5767 | Block, Terminal |

6.7 SmartSensor – Amp/Volt/WFS Assembly (P/N: A3A0252)



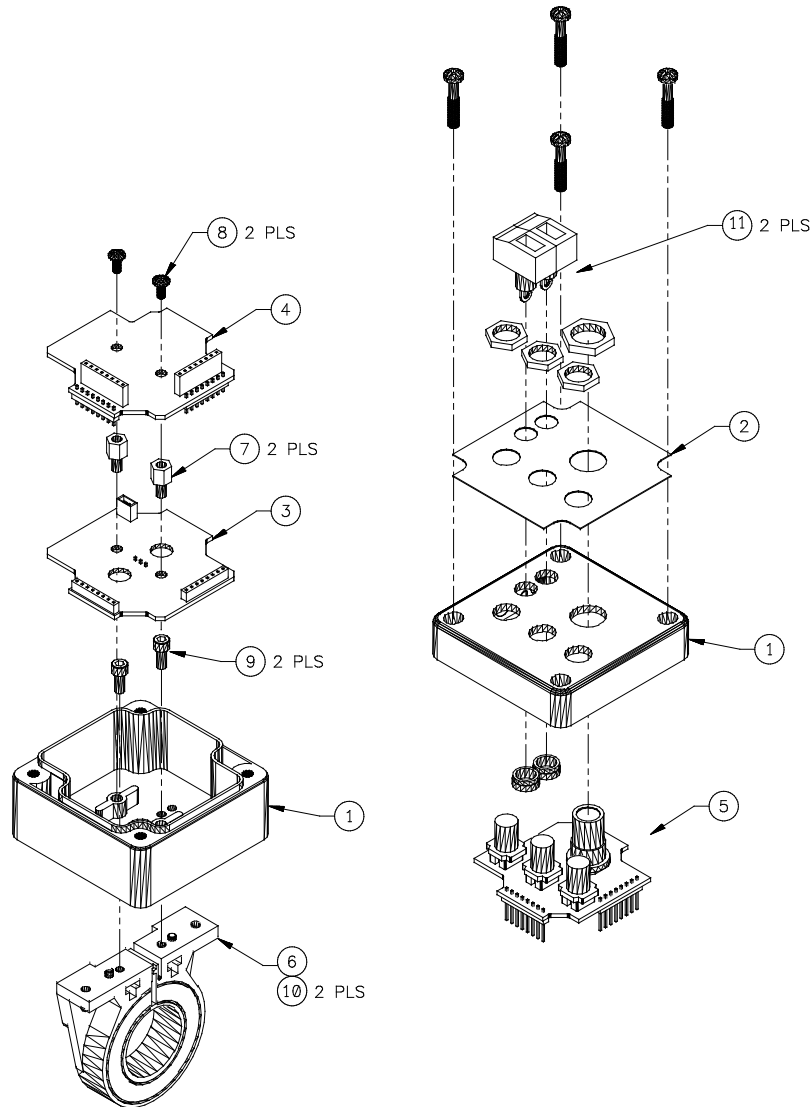
| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|-----------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149-W | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |
| 11 | 2 | X3P5767 | Block, Terminal |

6.8 SmartSensor – Amp/Volt/WFS/TVS Assembly (P/N: A3A0272)



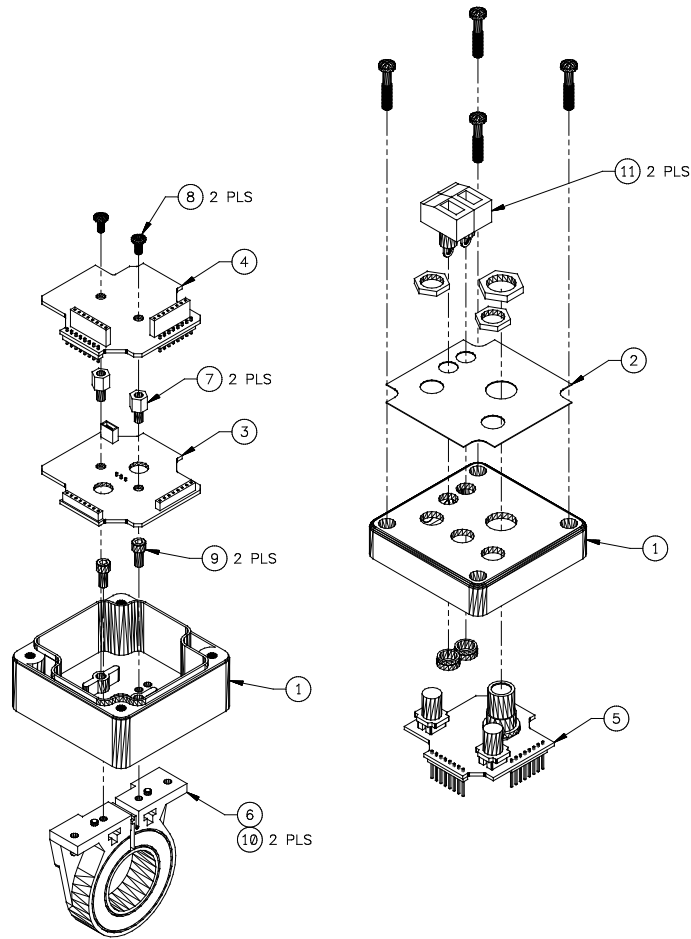
| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|------------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149-WT | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |
| 11 | 2 | X3P5767 | Block, Terminal |

6.9 SmartSensor – Amp/Volt/WFS/TVS/ANL Assembly (P/N: A3A0273)



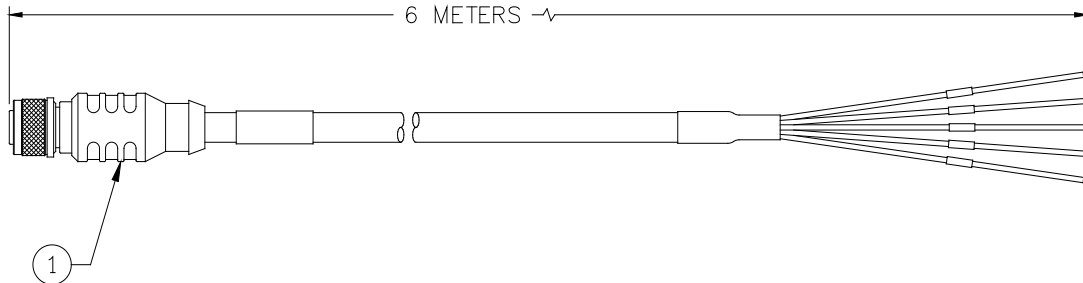
| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|-------------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149-WTA | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |
| 11 | 2 | X3P5767 | Block, Terminal |

6.10 SmartSensor – Amp/Volt/WFS/ANL Assembly (P/N: A3A0274)



| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|------------|---|
| 1 | 1 | A3E0174 | Enclosure |
| 2 | 1 | A3E0180 | Overlay |
| 3 | 1 | A5A0147 | PCB Assy., SmartSensor CPU |
| 4 | 1 | A5A0148 | PCB Assy., SmartSensor Interface |
| 5 | 1 | A5A0149-WA | PCB Assy., SmartSensor Connector |
| 6 | 1 | X3Q5024 | Sensor, Current |
| 7 | 2 | X6S5057 | Spacer, 6-32 x 1/4" Long M-F |
| 8 | 2 | | Screw, 6-32 x 1/4" Pan Head Screw w/ Washer |
| 9 | 2 | | Screw, 4-40 x 3/8" Socket Cap Head |
| 10 | 2 | | Nut, Hex 4-40 |
| 11 | 2 | X3P5767 | Block, Terminal |

6.11 I/O Comm Cable (P/N: A3W0358)



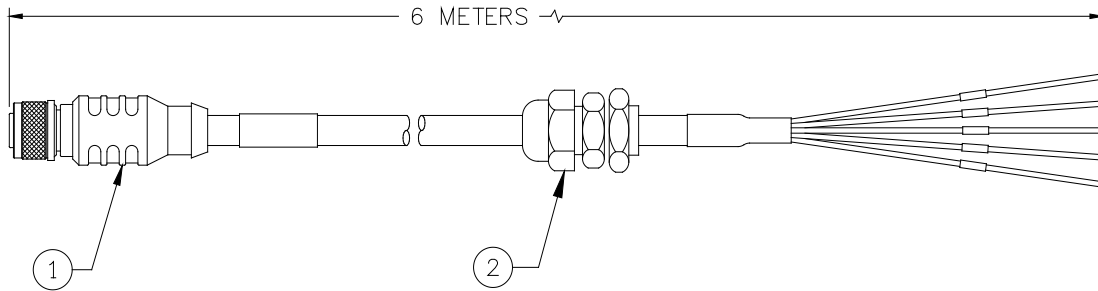
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|---|
| 1 | 1 | X3W5118 | Cable, 8 Conductor M12 Male Straight Single Ended |
| | | | |

WIRE LIST

| WIRE TYPE | FROM | DESCRIPTION |
|-----------|--------------|-------------|
| White | Item 1 Pin 1 | PWR+ |
| Brown | Item 1 Pin 2 | NET+ |
| Green | Item 1 Pin 3 | NET- |
| Yellow | Item 1 Pin 4 | Part |
| Gray | Item 1 Pin 5 | Learn |
| Pink | Item 1 Pin 6 | Ready |
| Blue | Item 1 Pin 7 | Fault |
| Red | Item 1 Pin 8 | Com |
| Shield | Item 1 Shell | Earth |

6.11 NetHub I/O Comm Cable (P/N: A3W0365)



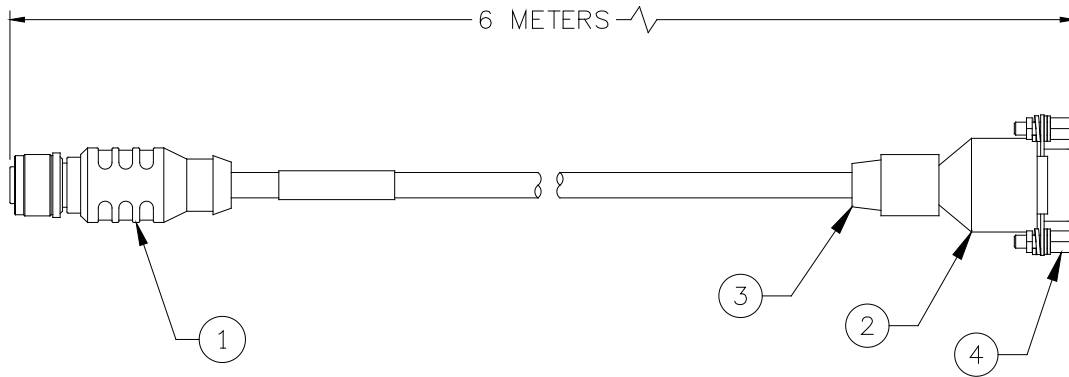
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|---|
| 1 | 1 | X3W5118 | Cable, 8 Conductor M12 Male Straight Single Ended |
| 2 | 1 | X3Z5088 | Relief, Strain |

WIRE LIST

| WIRE TYPE | FROM | DESCRIPTION |
|-----------|--------------|-------------|
| White | Item 1 Pin 1 | PWR+ |
| Brown | Item 1 Pin 2 | NET+ |
| Green | Item 1 Pin 3 | NET- |
| Yellow | Item 1 Pin 4 | Part |
| Gray | Item 1 Pin 5 | Learn |
| Pink | Item 1 Pin 6 | Ready |
| Blue | Item 1 Pin 7 | Fault |
| Red | Item 1 Pin 8 | Com |
| Shield | Item 1 Shell | Earth |

6.12 RS-485 Comm Cable (P/N: C3W5080)



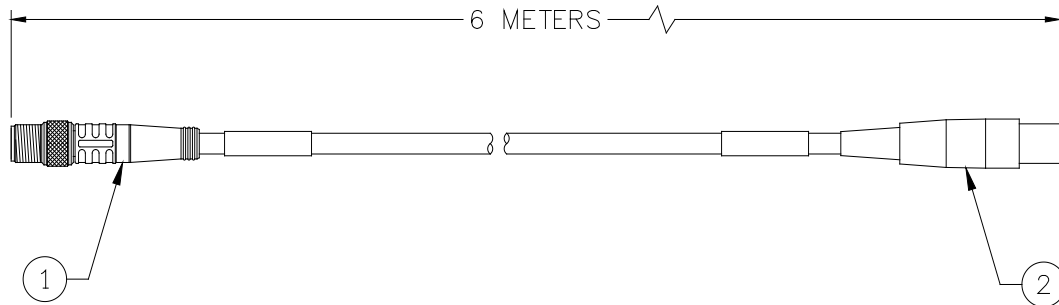
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|---|
| 1 | 1 | X3W5118 | Cable, 8 Conductor M12 Male Straight Single Ended |
| 2 | 1 | X3P5484 | Connector, D-Sub 9 Circuit Female |
| 3 | 1 | X3Z5081 | Shell, D-Sub |
| 4 | 1 | X3Z5027 | Kit, D-Sub Screwlock |

WIRE LIST

| WIRE TYPE | FROM | TO | DESCRIPTION |
|-----------|--------------|--------------|-------------|
| White | Item 1 Pin 1 | Item 2 Pin 9 | NET PWR |
| Brown | Item 1 Pin 2 | Item 2 Pin 7 | NET+ |
| Green | Item 1 Pin 3 | Item 2 Pin 3 | NET- |
| Yellow | Item 1 Pin 4 | | |
| Gray | | | |
| Pink | | | |
| Blue | | | |
| Red | Item 1 Pin 8 | Item 2 Pin 5 | NET COM |
| Shield | Item 1 Shell | Item 3 Shell | Earth |

6.13 Wire Speed Sensor Cable (P/N: A3W0360)



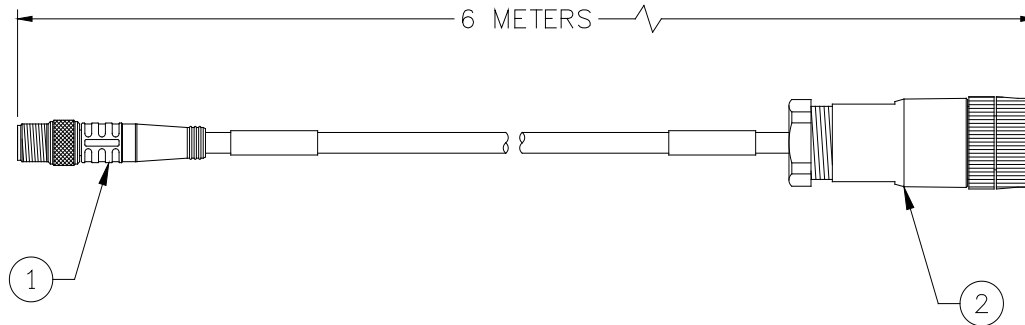
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|--|
| 1 | 1 | X3W5120 | Cable, 3 Conductor M8 Male Straight Single Ended |
| 2 | 1 | X3P5377 | Connector, 4 Circuit Female |

WIRE LIST

| WIRE TYPE | FROM | TO | DESCRIPTION |
|-----------|--------------|--------------|-------------|
| Brown | Item 1 Pin 1 | Item 2 Pin 2 | Pulse |
| Blue | Item 1 Pin 3 | Item 2 Pin 1 | ENC+ |
| Black | Item 1 Pin 4 | Item 2 Pin 3 | ECOM |
| Shield | Item 1 Shell | Item 2 Pin 4 | Earth |

6.14 Wire Speed Sensor Cable (P/N: A3W0361)



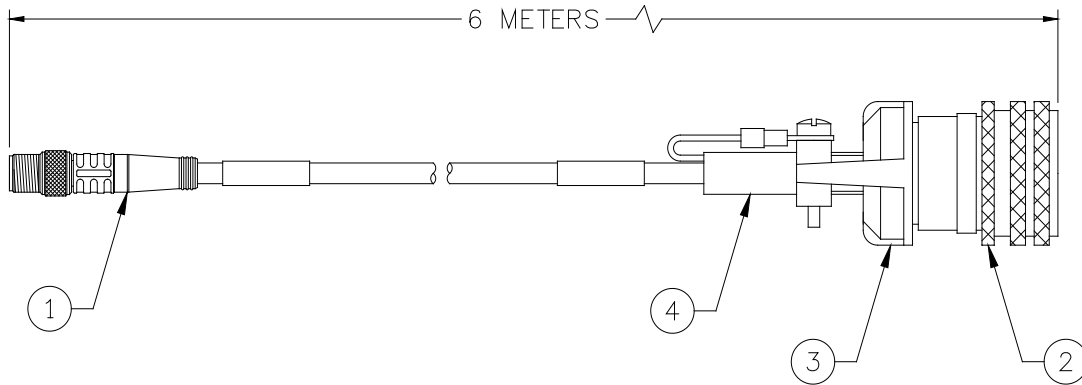
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|--|
| 1 | 1 | X3W5120 | Cable, 3 Conductor M8 Male Straight Single Ended |
| 2 | 1 | X3P5869 | Connector, 5 Circuit Female |

WIRE LIST

| WIRE TYPE | FROM | TO | DESCRIPTION |
|-----------|--------------|---------------|-------------|
| Brown | Item 1 Pin 1 | Item 2 Pin 2 | Pulse |
| Blue | Item 1 Pin 3 | Item 2 Pin 1 | ENC+ |
| Black | Item 1 Pin 4 | Item 2 Pin 3 | ECOM |
| Shield | Item 1 Shell | No Connection | Earth |

6.15 Travel Speed Sensor Cable (P/N: A3W0362)



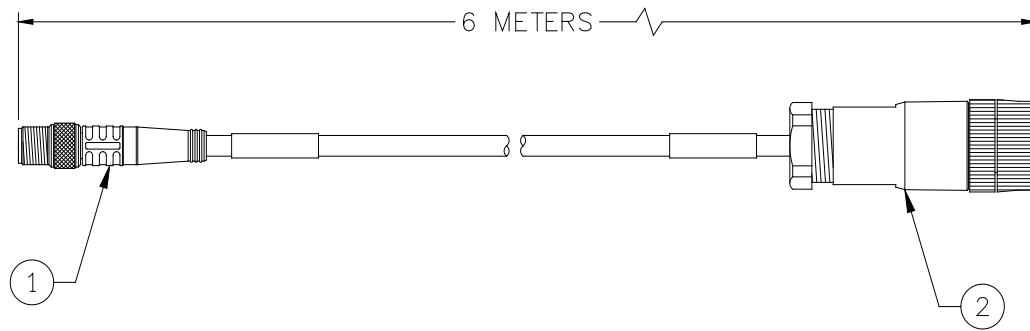
PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|--|
| 1 | 1 | X3W5120 | Cable, 3 Conductor M8 Male Straight Single Ended |
| 2 | 1 | X3P5020 | Connector, 5 Circuit Female |
| 3 | 1 | X3P5126 | Clamp, Cable |
| 4 | 1 | X3P5519 | Boot, Cable Clamp |

WIRE LIST

| WIRE TYPE | FROM | TO | DESCRIPTION |
|-----------|--------------|------------------|-------------|
| Brown | Item 1 Pin 1 | Item 2 Pin A | Pulse |
| Blue | Item 1 Pin 3 | Item 2 Pin D | ENC+ |
| Black | Item 1 Pin 4 | Item 2 Pin E | ECOM |
| Shield | Item 1 Shell | Item 2 Pin Shell | Earth |

6.16 Gas Flow Sensor Cable (P/N: A3W0363)



PARTS LIST

| ITEM | QTY | CWT P/N | CWT P/N |
|------|-----|---------|--|
| 1 | 1 | X3W5125 | Cable, 4 Conductor M8 Male Straight Single Ended |
| 2 | 1 | X3P5871 | Connector, 8 Circuit Female |

WIRE LIST

| WIRE TYPE | FROM | TO | DESCRIPTION |
|-----------|--------------|---------------|-------------|
| Brown | Item 1 Pin 1 | Item 2 Pin 2 | PWR |
| White | Item 1 Pin 2 | Item 2 Pin 8 | VOUT+ |
| Blue | Item 1 Pin 3 | Item 2 Pin 6 | VOUT- |
| Black | Item 1 Pin 4 | Item 2 Pin 5 | COM |
| Shield | Item 1 Shell | No Connection | Earth |

6.17 Typical I/O Connection and Control Cable Schematics

