Current Status of CIRCOR Tech™ Platform Development

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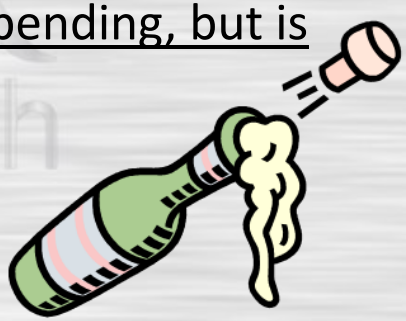
Background

- NeSSI™ GEN 1 has been in the market and in service in the field for almost ten years (if not longer)
- # of GEN 1 systems installed, compared to total available market, is no where near levels anticipated from "early days"
- GEN 2 bus (NeSSI™ intrinsically-safe (IS) digital communications) was thrown around in steering committees and different standards organizations for ~ 4 years
- Three bus topologies are now currently certified for U.S./Canada/IEC applications in Class 1, Div 1, and Zone 0,1 (ATEX is pending, but is eminent)
  - IS CANbus
  - Siemens I^2C
  - IS Modbus
  - ***ALL versions are commercially available today***



- Three installs at two different major petrochemical companies have been undertaken in various process or environmental monitoring, more install projects are currently imminent with refining, chemical, and pilot-plant/research facilities

Results as of Today

CIRCOR Tech has focused 4 years of development effort on gathering *V*oice *O*f *C*ustomer (VOC) (end user, analytical OEM's, and system integrators) and has introduced various manifestations of the following *(With a little help from our friends!! Of Course).*

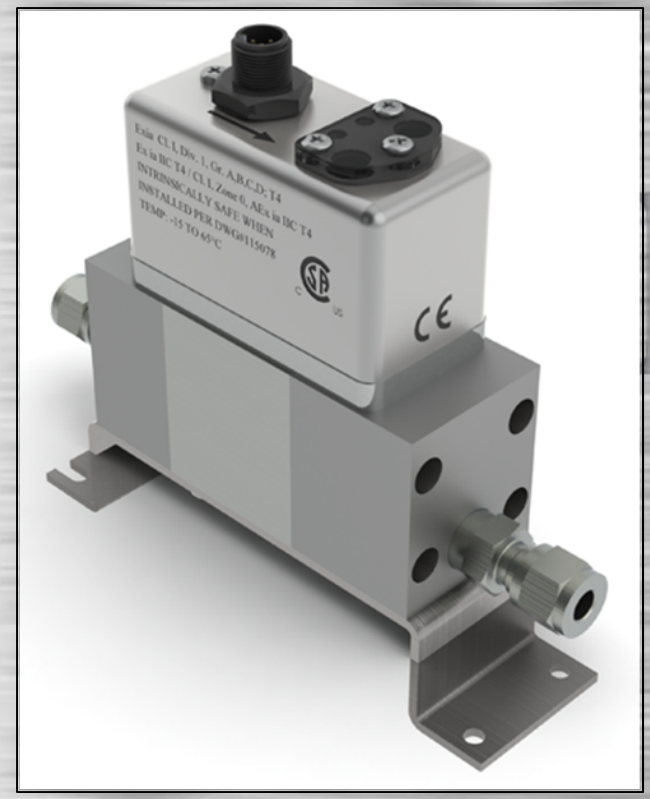
- ✓ *User friendly, CAD exportable, and flexible, design tool which will have applicability for GEN2 implementation*
- ✓ *Critical sensor points required (pressure, temp, flow)*
  - ➢ **Flow was indentified by CPAC-NeSSI steering teams as #1 need for product improvement solutions in petrochemical process sample systems**
- ✓ *Intrinsically Safe Communication Physical, Transport, and Application layer based on widely used or open standards*
- ✓ *Local, intrinsically safe, valve control for:*
  - ➢ **Pilot valves to actuate pneumatic isolation and stream select valves**
  - ➢ **Proportional control for closed loop pressure/flow**
- ✓ *Ability to integrate new IS bus and power topologies with existing or new "smart" analyzers as well as PLC/PC/DCS connectivity*

Team Effort

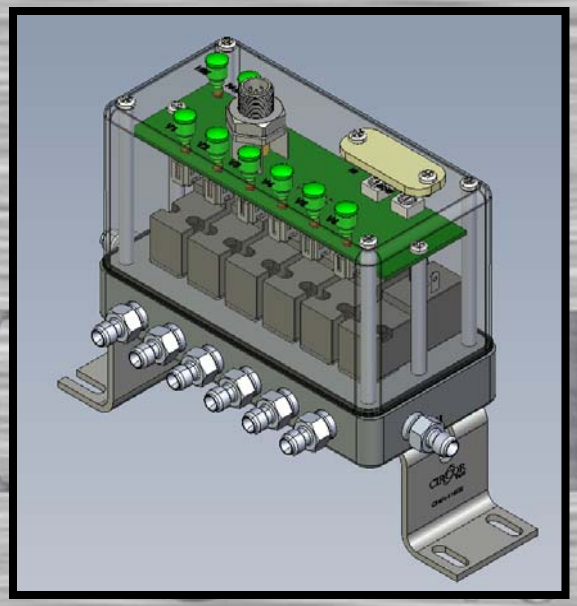
Many companies and organizations contributed in various ways (some very substantially) to the IS CANbus development, these companies include:

- CPAC and NeSSI steering team members and ISA
- Pepperl and Fuchs (the "gurus" of intrinsic safety power and communications, their power supply is a core enabling technology)
- Rockwell Automation (Allen Bradley), the P&F power supply was developed for the AB "Flex ExIO™" data acquisition system (i.e. with a CANbus data highway backbone).
- Texas Instruments (enabling CANbus microchip technology)
- CAN in Automation ("keeper" of the specification and standards for open fieldbus based on CANbus (originated by Robert Bosch corporation))
- ABB Analytics (the main driver behind IS CANbus)
- Swagelok (CANbus specs, I2C)
- Turck (IS CANbus cables and junction boxes)
- Siemens Applied Analytics (the inventor and main driver behind I2C bus)
- Parker Hannifin (ISA SP76 Porting and Schematic Legends for EDS sheets)
- IXAAT (German network automation technology provider)
- HMS Anybus (hazardous area gateway protocol converters)

New GEN2 Digital Products



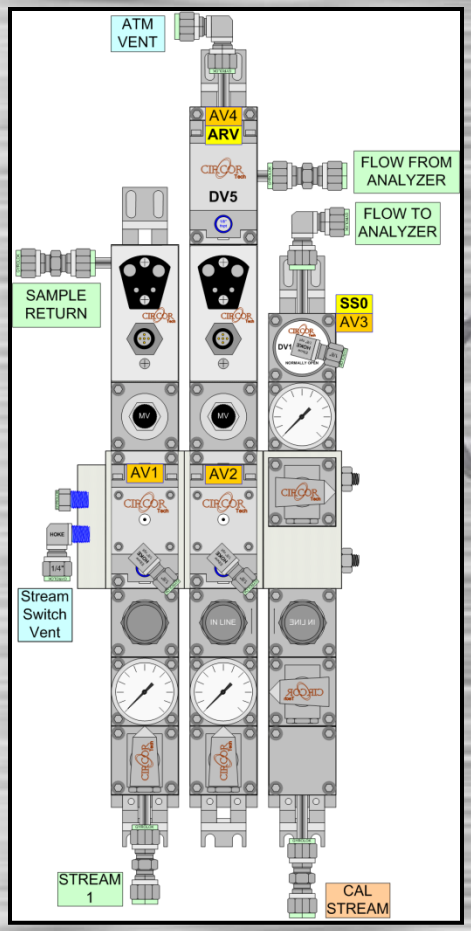
Multi-variable Flow Meter



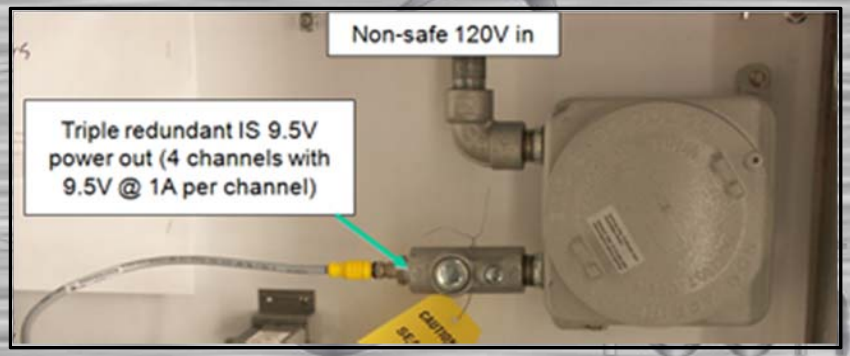
Intrinsically-Safe
Digital Pilot Manifold

CAN Interface Manager

Some Related Enabling Products or Technologies that are “Completing the Circle”



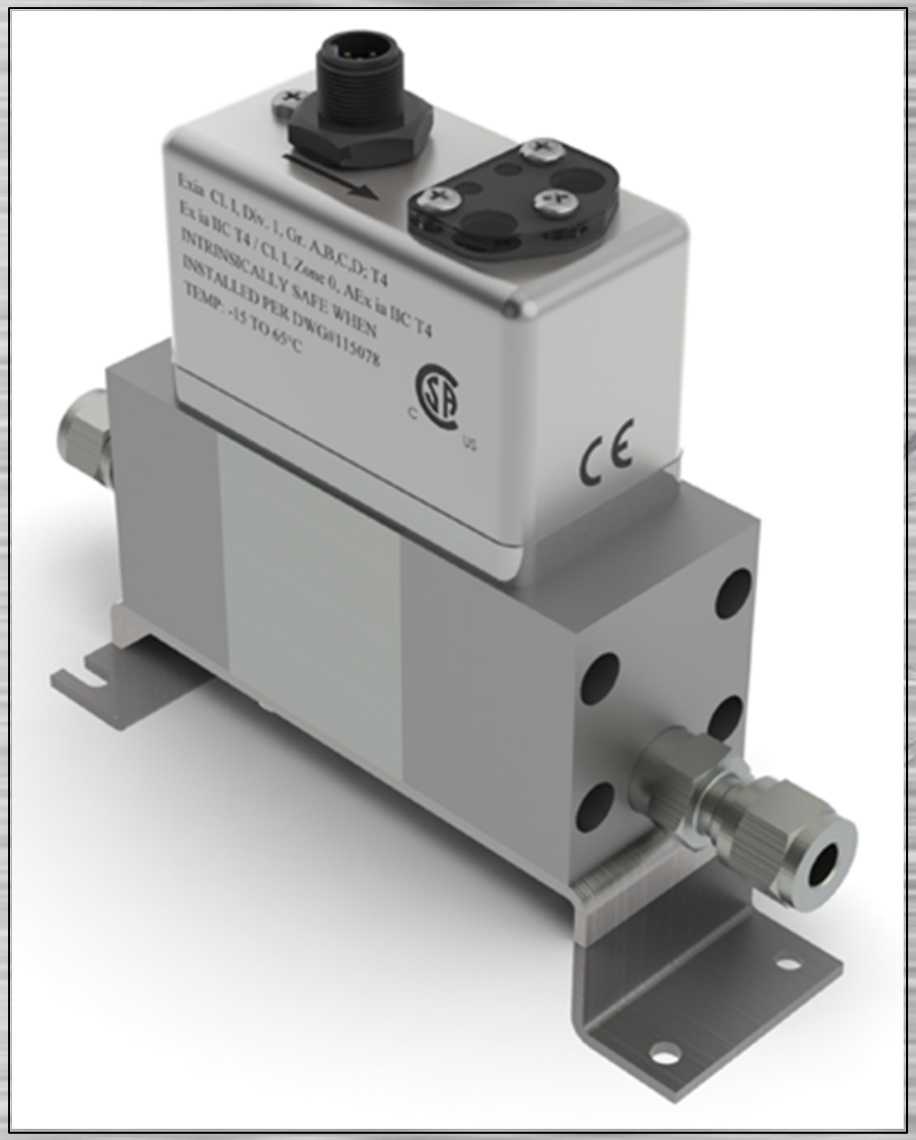
CT76 Visio Design Tool



P&F 9.5V IS power supply

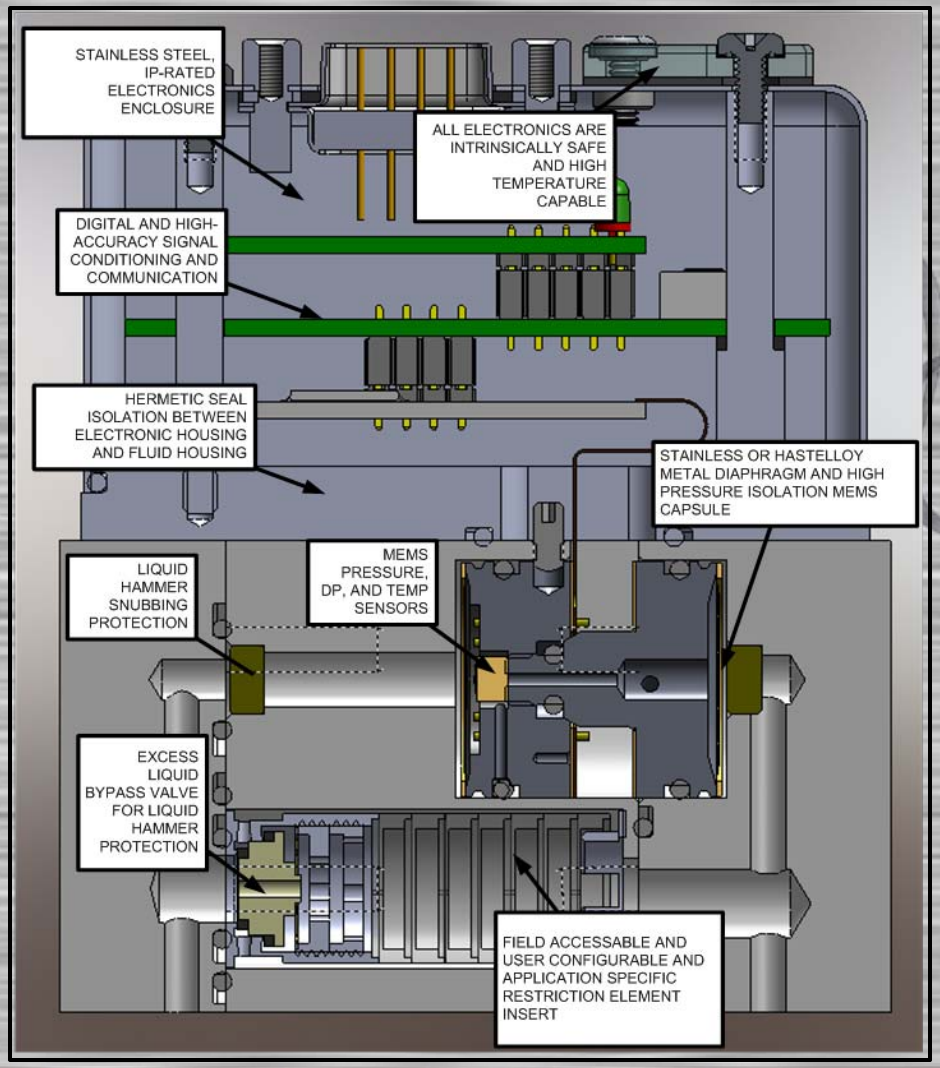
PSV Proportional Valve

Digital Bus allows Multi-variable



- **Multi-Variable Flow Meter**
  - Upstream and Downstream Pressures
  - Flow rate (Volumetric and Inferential Mass)
  - Fluid Temperature
  - Closed-loop Control Version Available in late Q1 (DMT-2500)
  - Intrinsically Safe CANbus, Siemens I^2C, and Modbus (Zone 0,1 certifications)
  - Electronic Data Sheet
  - Digitally re-scale of ranges
  - Field rescale of orifice pack
  - Integrated pressure relief valve
  - 1.5” x 3” x 4” (W x L x H) size
  - IP65, NEMA 4X package

New MVDP meter designed for SCS applications

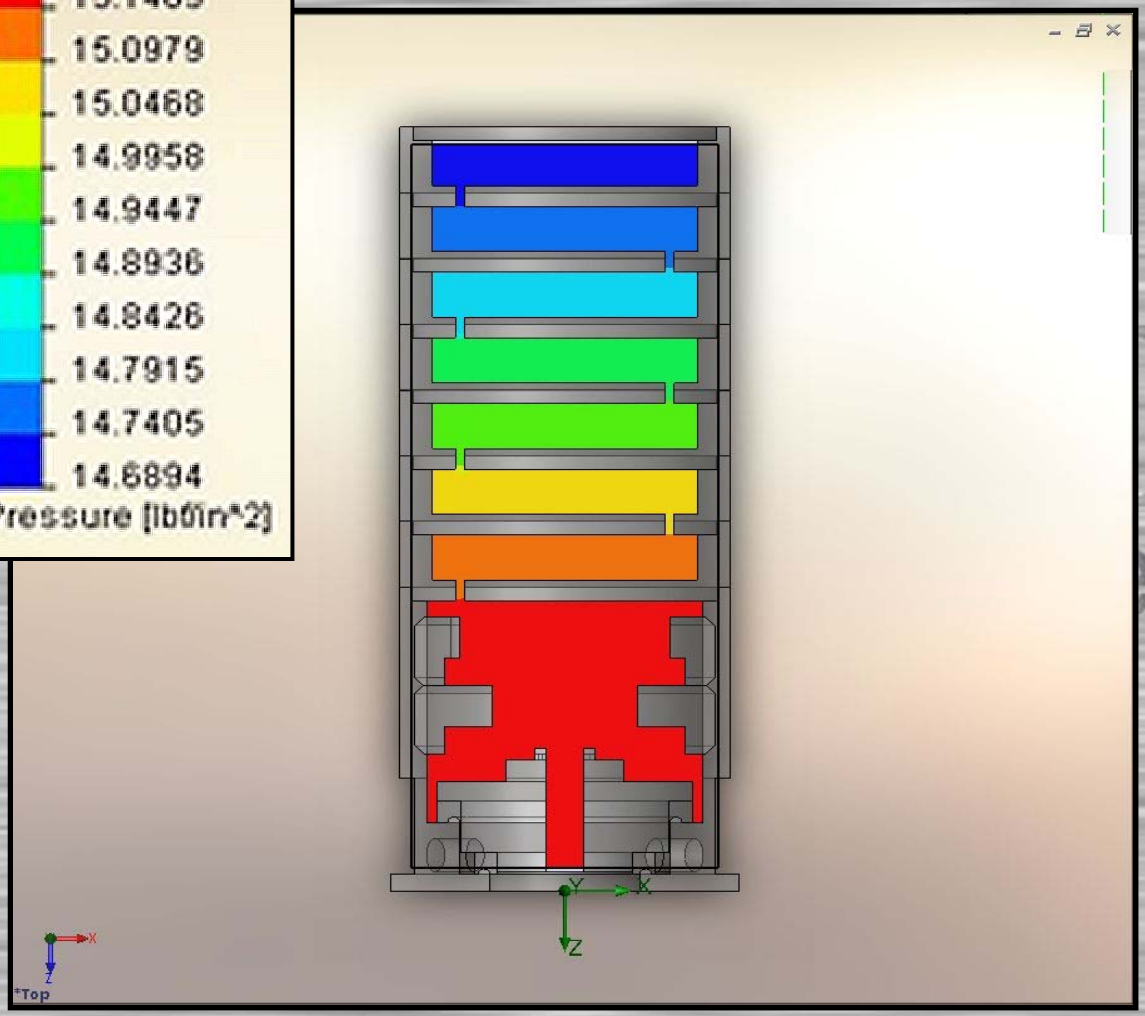


- Features designed exclusively for petrochemical sample systems
  - **Intrinsically Safe electronics**
  - **Pressure, temperature, and flow**
  - **Liquid or gas**
  - **High pressure and pressure shock resistant**
  - **Ingress/ environmental protection**
  - **Corrosion resistant (internally and externally)**
  - **High temperature capable**
  - **Visual Indication**
  - **Configurable flow module (CFM) for various applications and flow rates**

Flow Meter

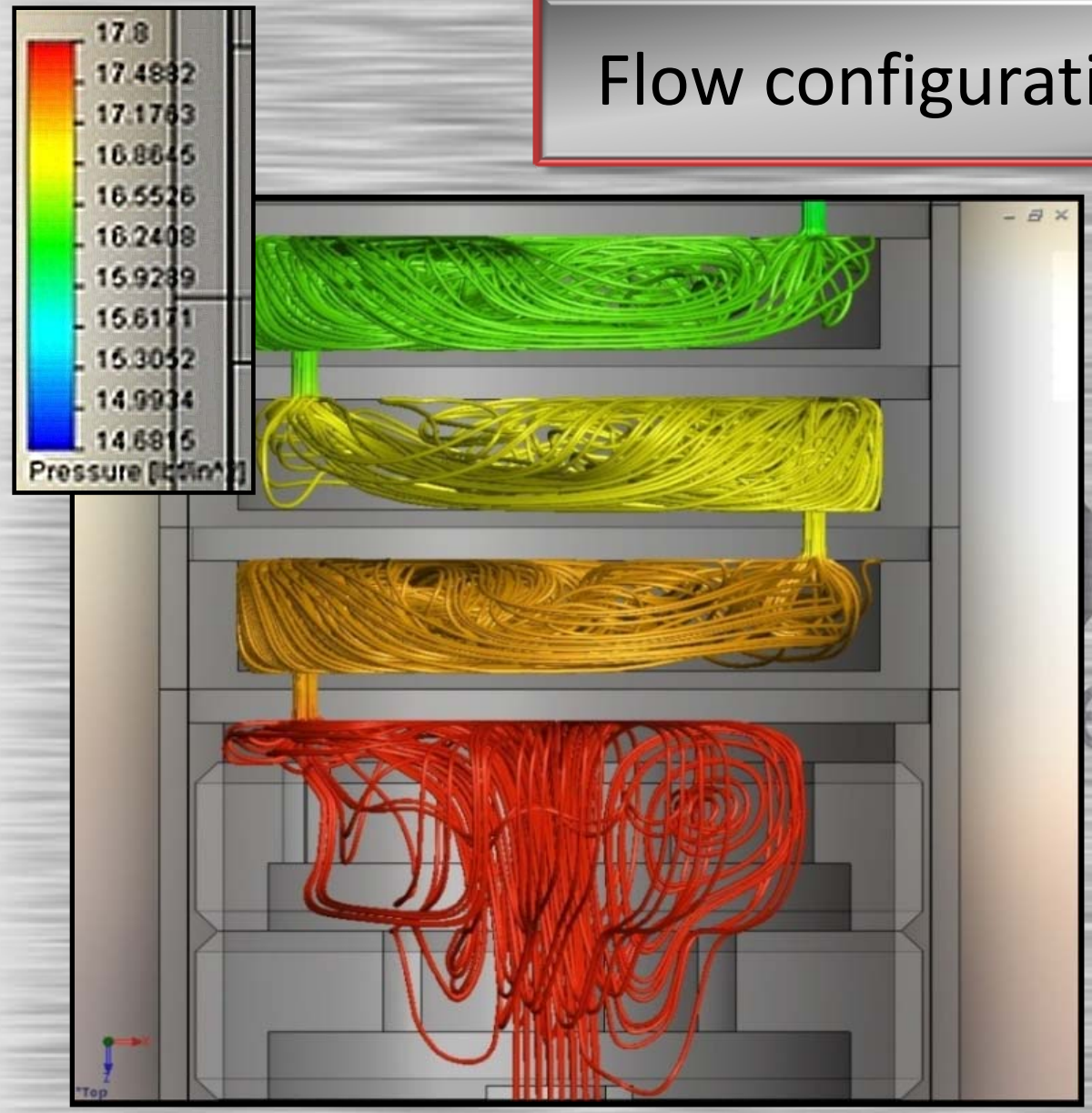
- Three “flavors” of multi-variable flow meters are available
  - IS CAN Bus
  - Siemens I^2C
  - Modbus/RS485
    - ProfibusDPV1 can also be implemented with this RS485 physical layer
    - Class 1, Div 1 installs require a C1D1 certified RS485 isolator/repeater/barrier
    - # of meters available for C1D1 applications is limited to 3 using the RS485 interface
- IS CANbus can theoretically accommodate up to 50 multi-variable devices on a single 1amp power channel,
  - *30 devices is CIRCOR Tech’s published specification when cable inductance, capacitance, and digital addressing/handshaking time lags are taken into consideration*
  - *Typical FISCO install (Foundation Fieldbus, Profibus PA) can accommodate around 3-10 devices on one power/communication segment in comparison*
- Design focus is on ruggedness, repeatability, and reliability
- Closed-loop version is undergoing final performance testing using the low powered, IS capable, PSV proportional solenoid

Flow configuration module (FCM)



- **FCM features:**
  - Multi-stage pressure drop minimizes JT effect on volatile applications
  - Pressure drop (# of stages) is configurable for the particular density/ viscosity and flow rate desired
  - Can maximize the “effective” passageway diameter for a given min pressure drop (lower probability for clogging)
  - Removable and cleanable/ consumable by end user
  - Can be removed and reconfigured by end user to mechanically re-range a given flow sensor

Flow configuration module (FCM)



- **Flow Dynamics:**
  - Figure shows fluid streamlines w/ different colors representing decreasing pressure
  - CFD results indicate that downstream of each pressure drop element, vortices or eddies are created
  - Localized low and high pressure zones in each cavity
  - Particles have high probability of “falling” out of main streamlines due to inertia
  - Analogous to “inertial filters” where particles are removed from stream by non-linear flow directions

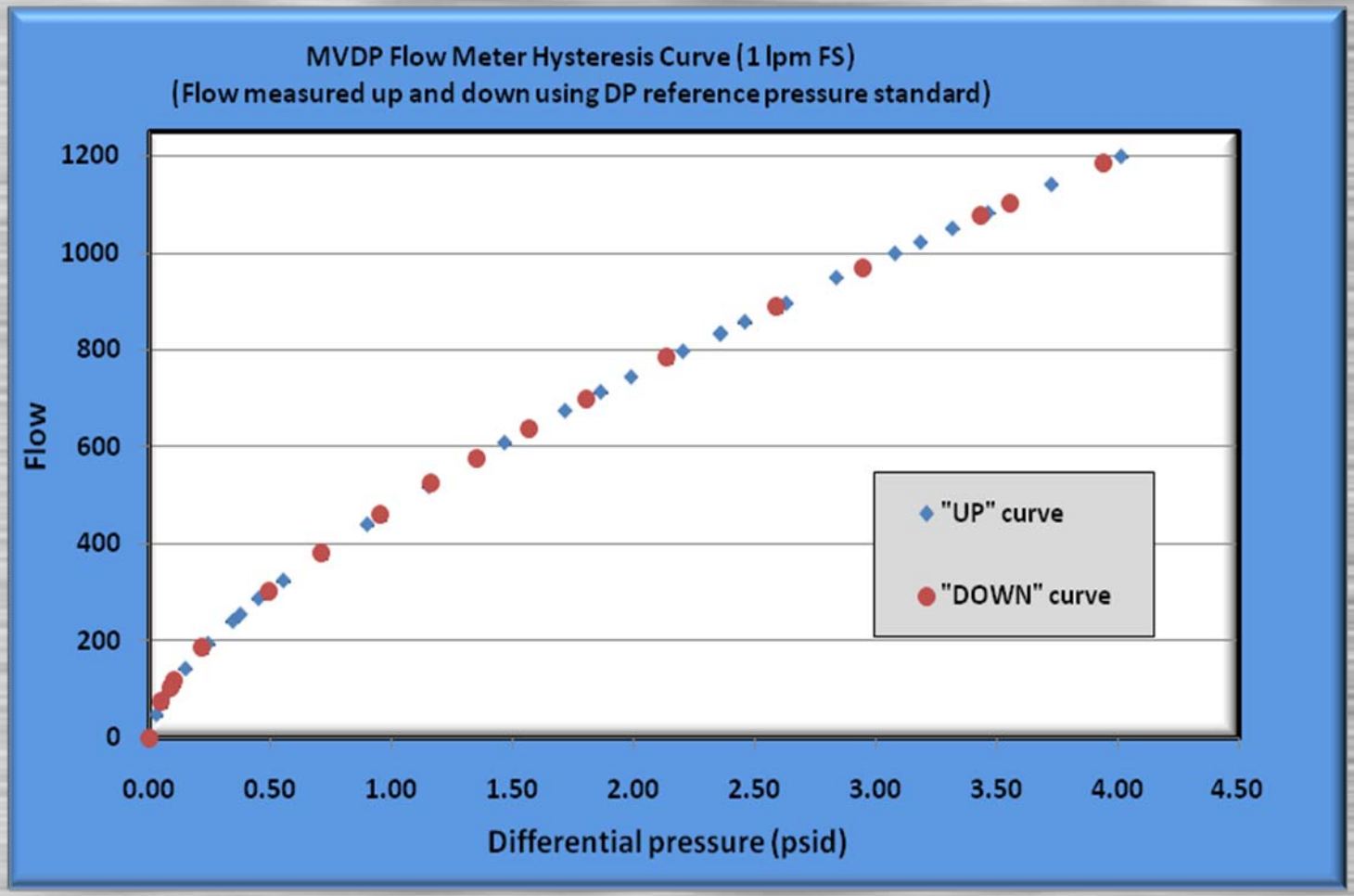
Flow configuration module (FCM)

	orifice stack size (in)	max flow@5 psid (lpm air)	Reynolds number	% increase in effective flow diameter
Zig-Zag	0.0150	0.750	428.61	38%
	0.0250	1.810	1034.39	47%
	0.0320	2.810	1605.88	51%
	0.0500	6.040	3451.77	51%
	0.0600	8.216	4695.33	66%
In-line	0.0150	0.800	457.19	25%
	0.0250	1.880	1074.39	45%
	0.0320	3.255	1860.19	40%
	0.0500	8.025	4586.17	40%
	0.0600	9.880	5646.28	51%

The FCM elements can be arranged in an “in-line” or “zig-zag” (180 deg opposite) configuration to maximize the desired pressure drop and effectively increase the orifice diameter that a particle would have to flow through

Reference: Typical particle filters filter down to 10 microns and thermal MFC’s have sensor tube diameters on the order of 0.010 inches

Repeatability

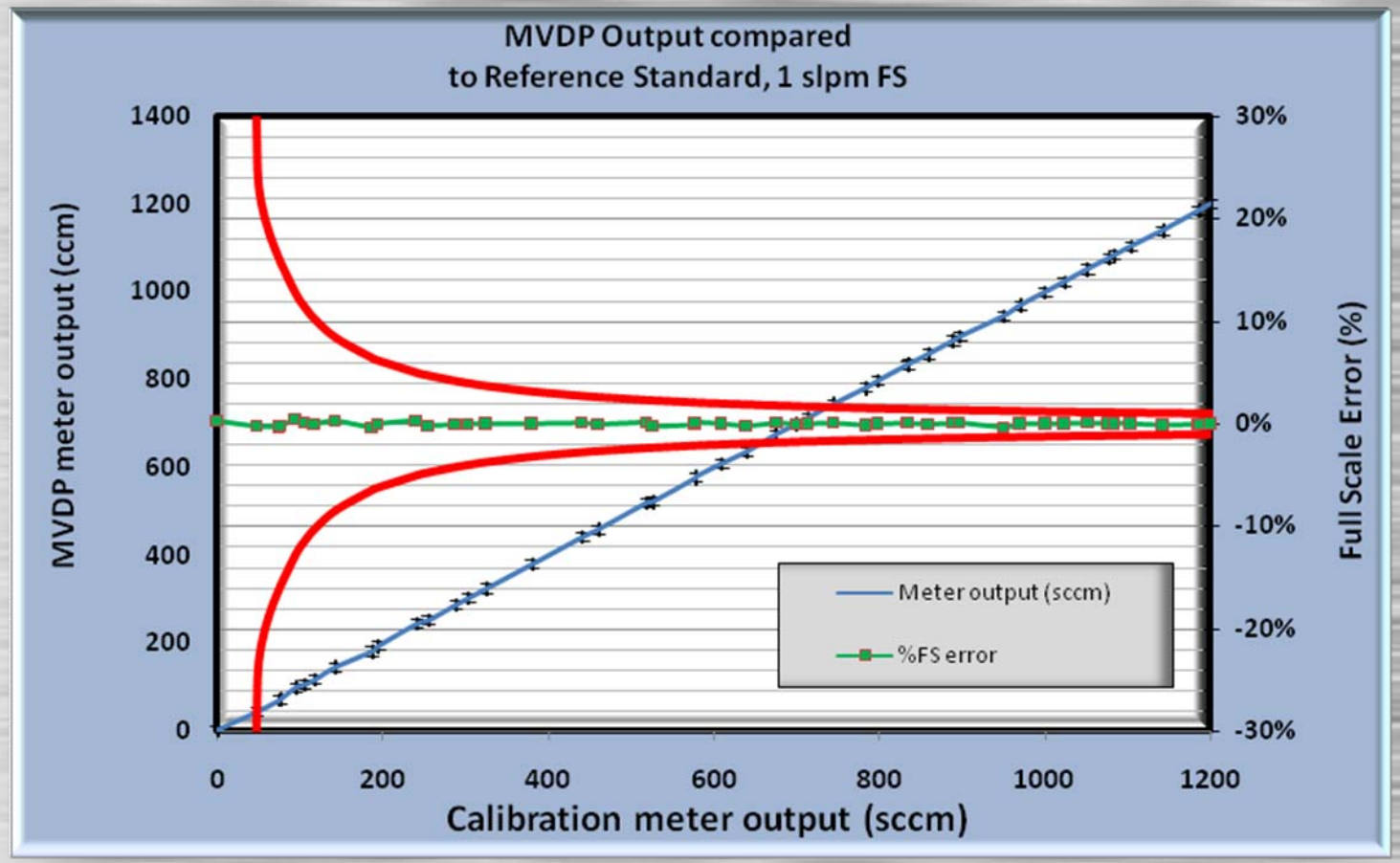


Flow rate was increased and then decreased over several cycles to see the effects of sensor hysteresis or mechanical instabilities.

Effective sensor repeatability exhibits less than 0.25% FS repeatability.

In most SCS applications (and process applications as well), repeatability is more important than pure accuracy.

Accuracy



Red lines indicate the +/- 1% full scale accuracy zone

Center (square) data points is the output from the sensor

<u>Accuracy was less than 0.25% FS and <1% of reading throughout the entire range</u>

DMT-2000 sensor low end stability was measured with 6 digit precision voltmeter and compared to highly sensitive hot-wire anemometer to measure ultimate precision

Accuracy

- One of the traditional disadvantages of DP measurements in general has been the low turndown ratio due to the square-root relationship between velocity (i.e. volumetric flow rate) and pressure drop
  - Turn down ratio is defined as min flow rate output divided by max flow rate output, at stated accuracy specifications.
- Due to repeatability, accuracy, and low-end sensor output stability, the DMT-2000 sensor has a turn-down ratio that exceeds 100:1 (theoretically), practical turn-down would be in the 50:1 range
- Implications of this large turn-down are:
  - A MVDP flow meter calibrated for 1 liter/min can be used for applications down around 20 cc/min (if density/ viscosity is similar)
  - One flow meter can be digitally re-ranged for a wide variety of flow rates and fluid specific gravities
  - <u>One core model of flow meter can meet the entire plant's SCS monitoring needs (fast loop or analyzer flows) with simple FCM restriction element inventory</u>

“Ruggedness”

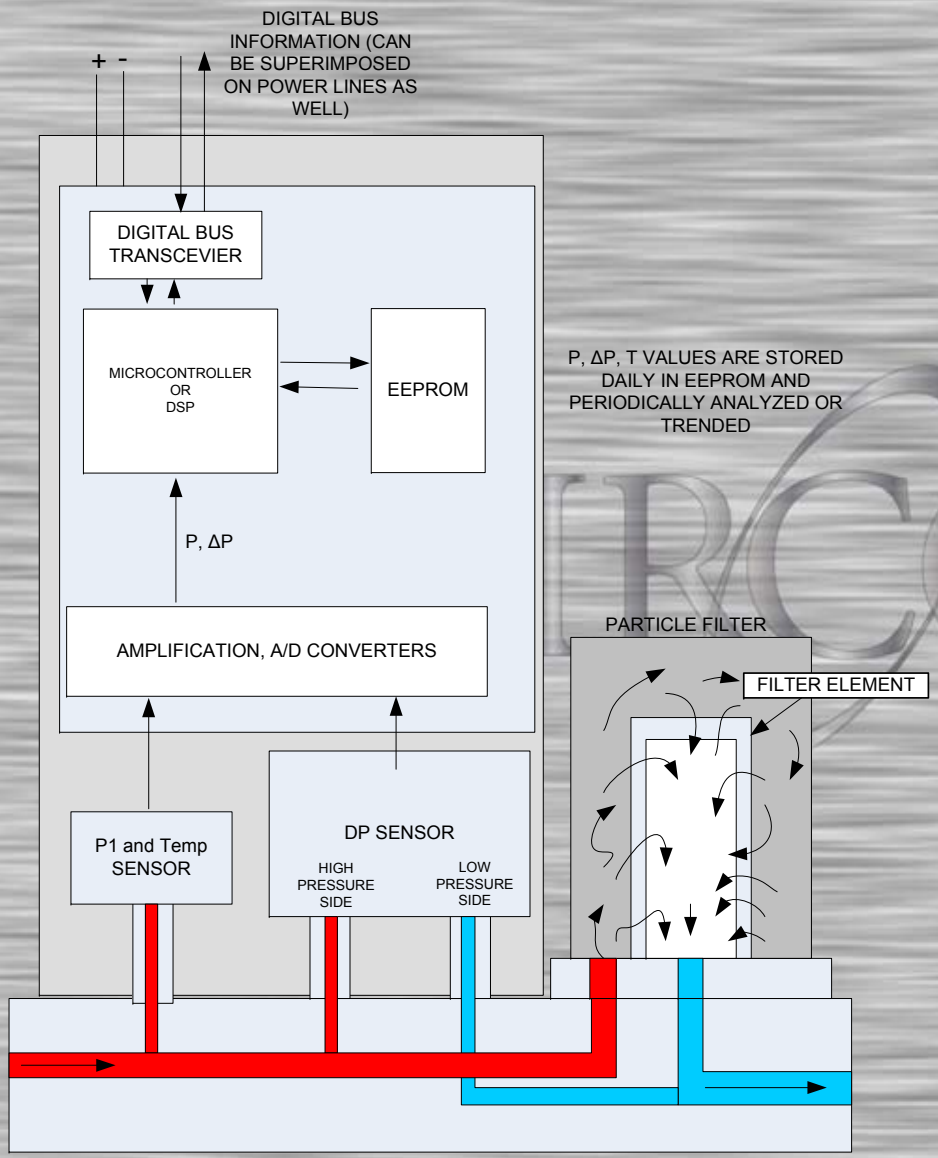
CUMULATIVE CYCLES	OUTPUT 1 (mV)	OUTPUT 2 (mV)	OUTPUT 3 (mV)
0	-0.4300	-0.6600	6.2900
1253	-0.5300	-0.9200	6.2100
10947	-0.0800	-0.3400	6.6100
37142	-0.5000	-0.8600	5.8900
76127	-0.3500	-0.8700	6.2700
110240	-0.1800	-0.4000	6.5200
120000	-0.5200	-0.9700	6.4800
130294	-0.3500	-0.7200	5.4700
257288	-0.2600	-0.4600	6.3900
MIN	-0.5300	-0.9700	5.4700
MAX	-0.0800	-0.3400	6.6100
STDDEV	0.1580	0.2382	0.3562
NET CHANGE	0.1700	0.2000	0.1000
NET %FS READING CHANGE	0.004%	0.005%	0.002%

Max operational pressure of 1500 psig was applied to both inlet and outlet side of sensor simultaneously for over 250,000 cycles

DMT-2000 sensor outputs did not drift more than 0.01% on average after cycles.

This test was intended to show that “ruggedness” or damage protection was the original primary design specifications in development.

Filter Monitor



Using the same DMT sensor and circuitry, we can now use a particle filter as the flow restriction element. With intelligent sub-routines, the device can self-calibrate.

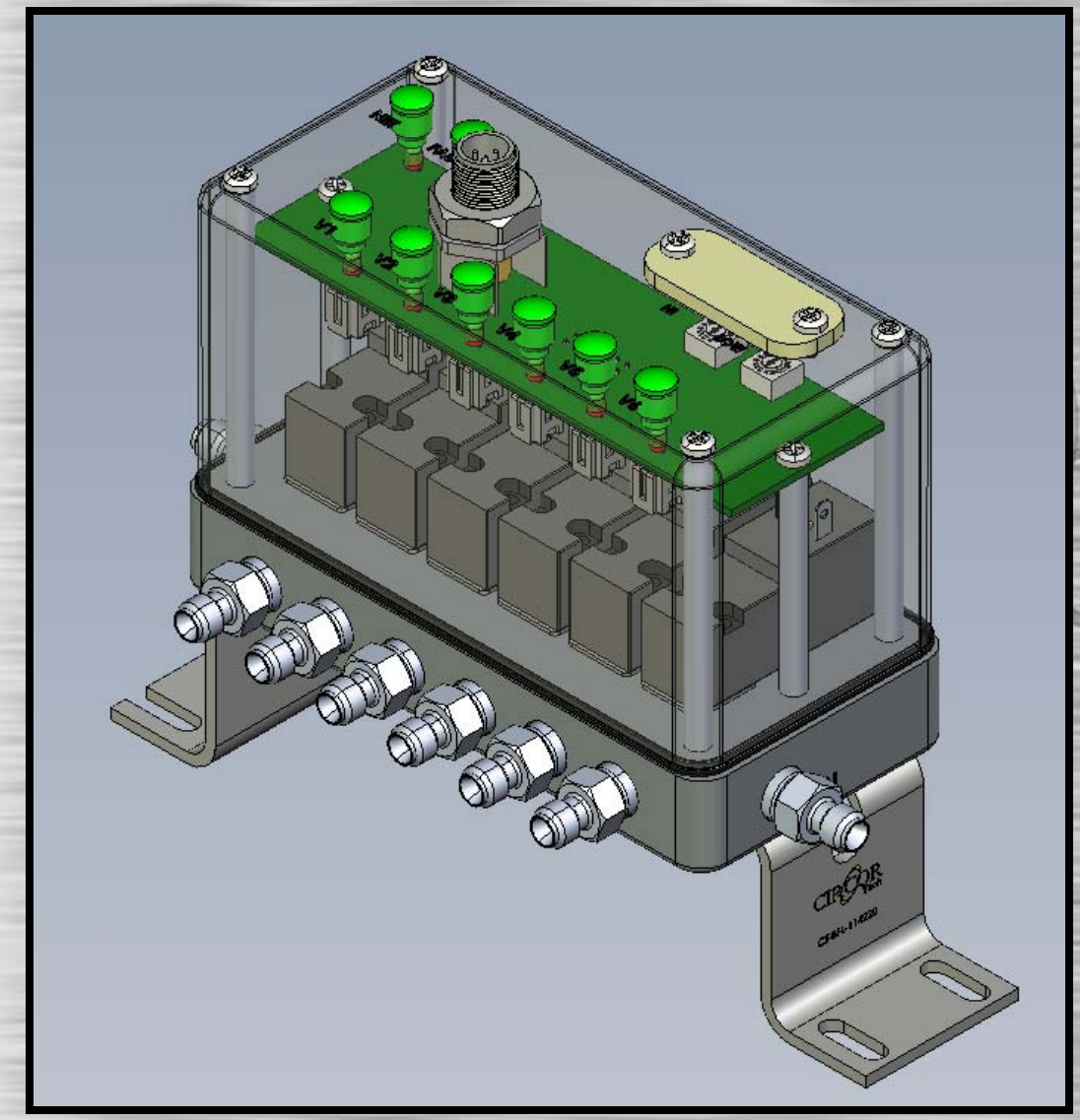
The device can monitor the status of the filter over time and tell the operator or a computer when the filter is clogged to a critical point.

Contrary to common practice, need two pieces or info to determine filter health, P1 and dP or flow and dP, dP by itself will be misleading.

Can be operated in “reverse mode” to infer a gas/mixture viscosity using Darcy’s Law and an accurate flow calibration

$$\dot{Q} = -\kappa \frac{\Delta P}{\mu} \frac{A}{L}$$

Valve Solutions: DVM Pilot Manifold DVM-6PAK

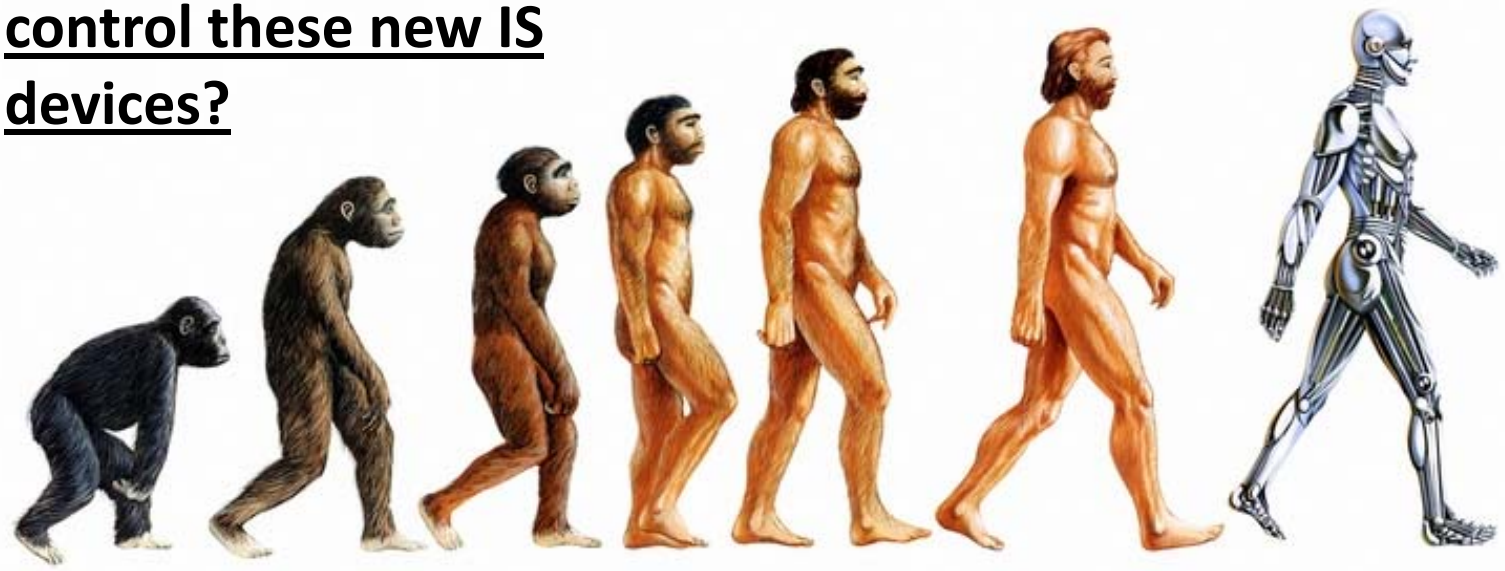


- Ultra Low powered solenoid valve manifolds
- Intrinsically safe targeted, C1D2 approval pending
- Multiples of six per bus node to save on cabling cost
- Up to 85 deg C
- Can go inside the sample cabinet with C1D1 certification
- IP65 protection, SS enclosure
- Less 0.2 watts per valve (minimize power budget)
- Must pay attention to inductance on IS power/signal cable
  - **Only 8mH of inductance is allowed for IS applications ≈ 15 meters of bare copper cable have this much inductance**
- **<u>HOW can we get solenoids onto the bus?!</u>**

The “Missing link”

- SAM stands for **S**ensor **A**ctuator **M**anager
- G… …vice
  w…

How do we get all of this data somewhere else and control these new IS devices?



  - Software Applets for Sample System Repetitive Tasks (Application Interface)
  - Provides “Open” Development Space for Custom Software”

CAN Interface Manager

CIM76™

HMS INSIDE

PROFIBUS PROCESS FIELD BUS

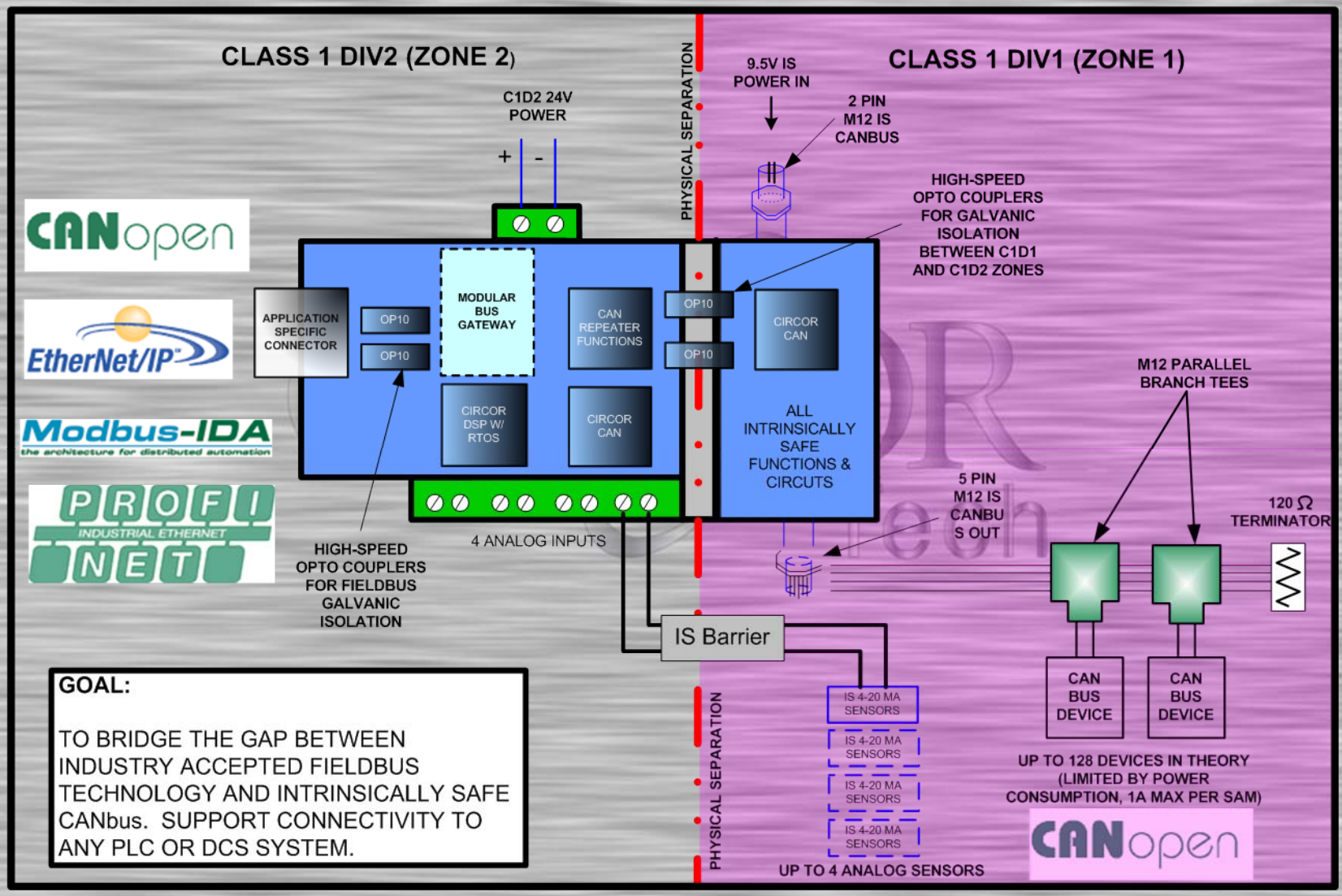
CANopen

Modbus-IDA
the architecture for distributed automation

CSA

Ex

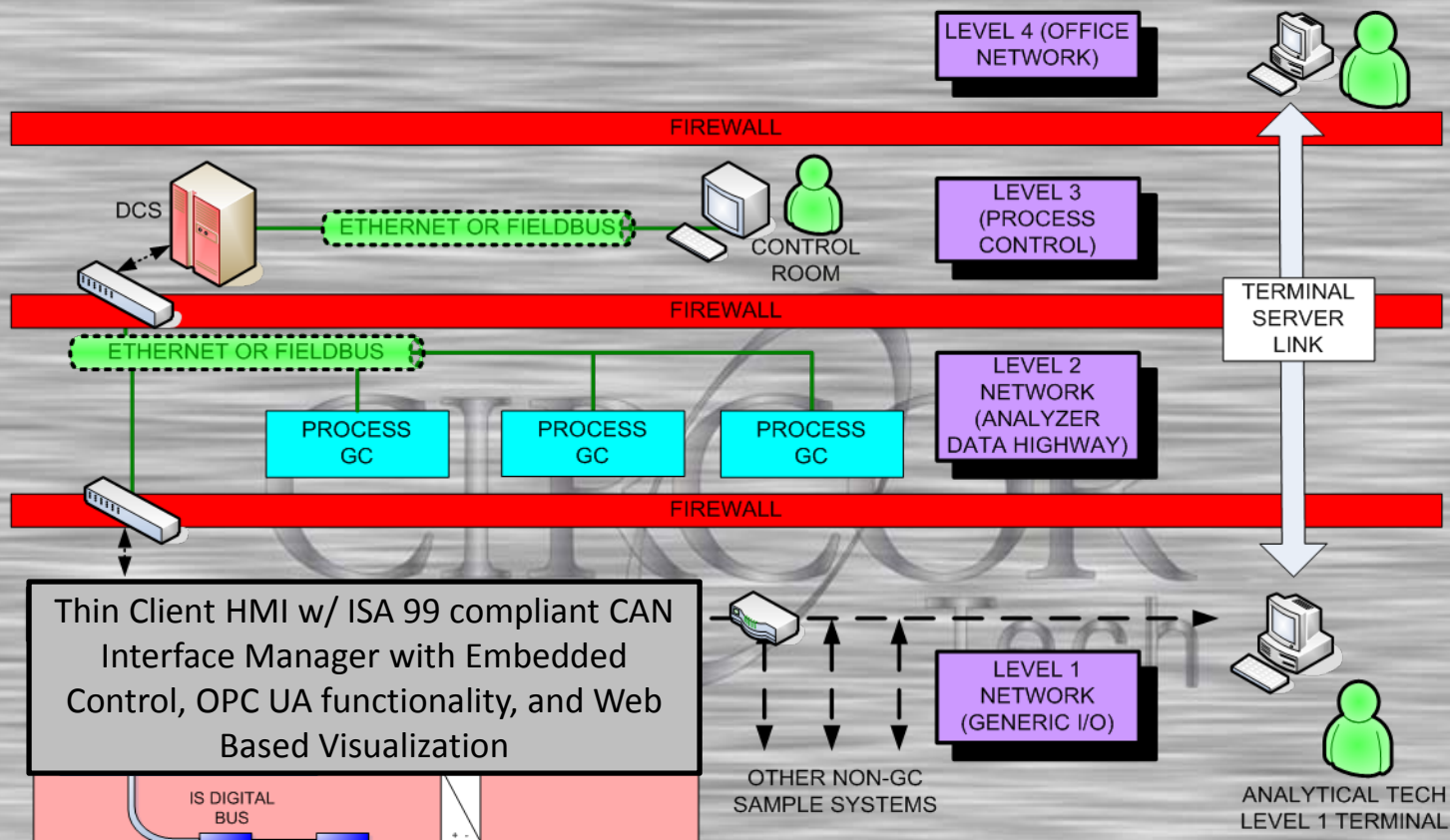
CIM76™ CAN Interface Manager



What does the CAN manager do, why do we need it?

- Mission Critical Functions:
  - High-speed optical communication between C1D1 (Zone0,1) and C1D2 (Zone2, General Purpose) for digital communication integrity (optical links ensure safety factor at high bus speeds (baud rate))
  - Galvanic isolation between zones/areas for power isolation (very stringent requirement)
  - "Gateway" functions (bus protocol conversion) between CANbus and "any" other common C1D2 serial or Ethernet (or fiber optic) communications
  - Extend networking functionality past a "one to one relationship" (analyzer-sample system OR PLC to sample system)
  - Overcome the 15m cable length limitation (due to capacitance/inductance) by using the CAN manager as a repeater and network hub
  - Web-enabled visualization functions using JAVA, AJAX, XML, XHTML, HTML (any mix and match will work with any thin client HMI or WMI (web machine interface)
- Value Added Functions
  - Data/alarm "mini-historian" with non-volatile (USB) memory storage
  - Minimal "truth table" functionality for "if-then" control functions (can replace PLC on simple system configurations)
  - Gives the user extreme flexibility to use with both new and legacy communication schemes

Where does CIM76 reside without SMART Analyzer?

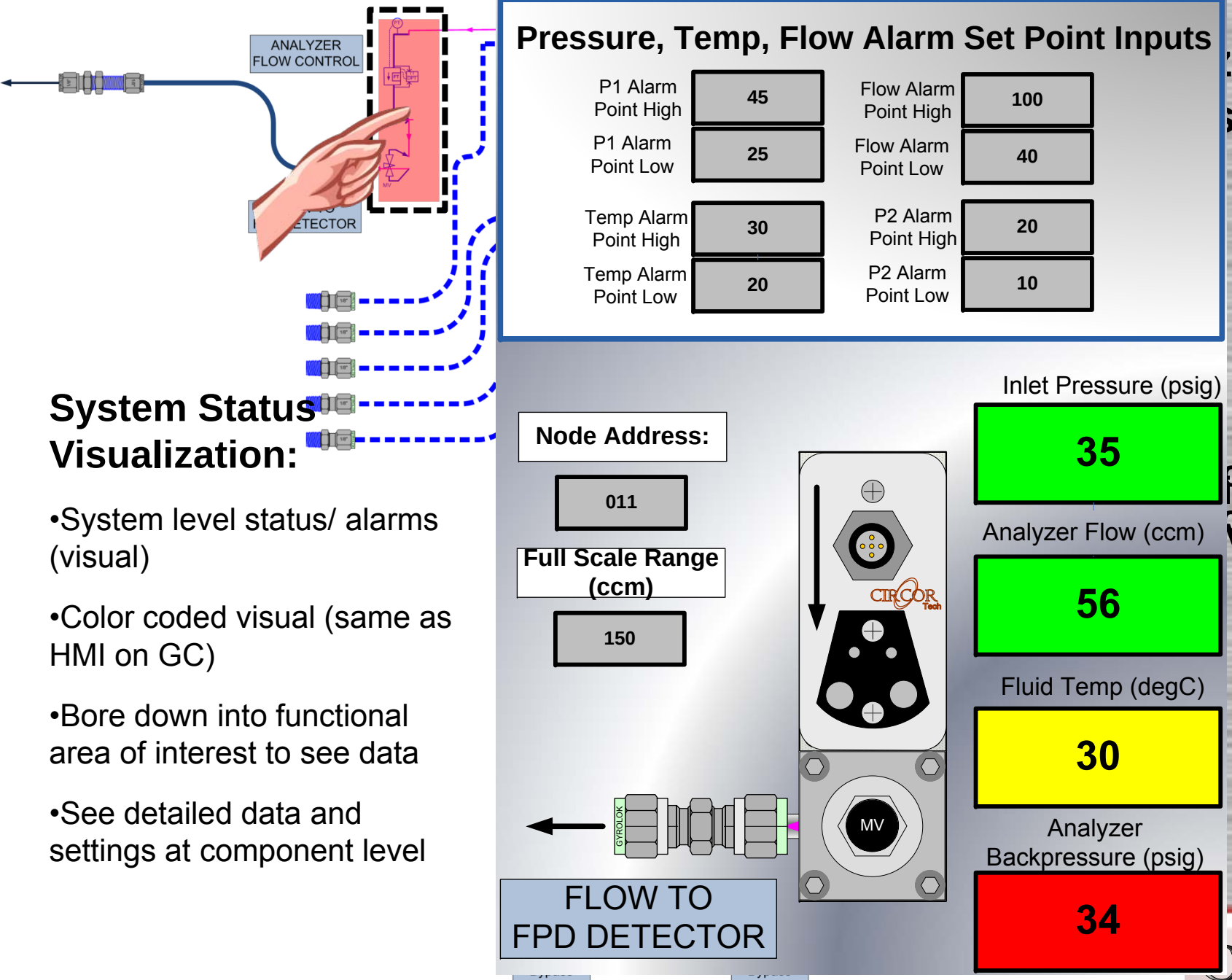


Current Scheme w/o a SMART Analyzer

"Near Future" Communication Scheme

Importance of Visualization and Remote Monitoring

- Fate of NeSSI™ relies on delivering the value proposition that is missed with GEN1 and GEN 1.5 (analog sensors with PLC automation)
  - More and more companies are realizing the value of absolutely minimizing maintenance time in the field (human impact and cost of potential accident/ liability), not just “do more with less”
  - Technicians are confused by the non-intuitive flow paths of modular systems, need both ease of looking at intuitive flow paths mechanically and electronically
  - Process analytical engineers, techs, specialists want to focus on better analysis, not becoming process automation/networking specialists, so spend less time sending data on sample system and more time letting them look at chromatograms and spectrographs
  - Data and sample validation for regulatory environmental monitoring is becoming more and more critical each year, system automation concepts are becoming increasingly difficult with multi-analyzer systems and automation products combined with controlling sample systems
  - End user value of reducing time spent on “scheduled maintenance intervals” is much smaller than the value of performing “maintenance only when needed”
  - Must avoid feature “creep” that could make digital bus “too complicated” to manage for existing users
  - **Need a “USB for Process Analytical Chemists” (KISS methodology seems to work for new disruptive technologies)**



System Status Visualization:

- System level status/ alarms (visual)
- Color coded visual (same as HMI on GC)
- Bore down into functional area of interest to see data
- See detailed data and settings at component level

Summary

- GEN 2 is ready to go, GEN3 is also primed for launch due to breadth of silicon-based and related micro sensors that use transistor level voltages (3.3 -5V), which are perfect for NeSSI bus
- Full compliment of digital solutions are available today, certified and in production, with a variety of vendors and major analytical OEMs needing end users.
- Near term future plans include:
  - *Providing Intelligent heat and in-situ phase control (vaporization) to the sample system*
  - *Moving some of the sample conditioning and monitoring back to the probe/extraction point*
  - *Active barrier technologies to reduce reliance on one large power supply, which may be overkill for some applications*
- Must gain some traction quickly, **but do not assume that you must have GEN1 to deliver benefits of GEN2 and GEN3 to the market**, the large % of the value relies in robust data, visualization, and flexibility to maneuver around all kinds of corporate and site level specs and preferences
- Time for discussion, debates, and committees on NeSSI GEN1 vs. 2 vs. 3 must STOP and we must implement, or millions of dollars and years of many companies hard work and time could evaporate and fall forever into “the chasm” (think Betamax, DAT, Apple Newton!)