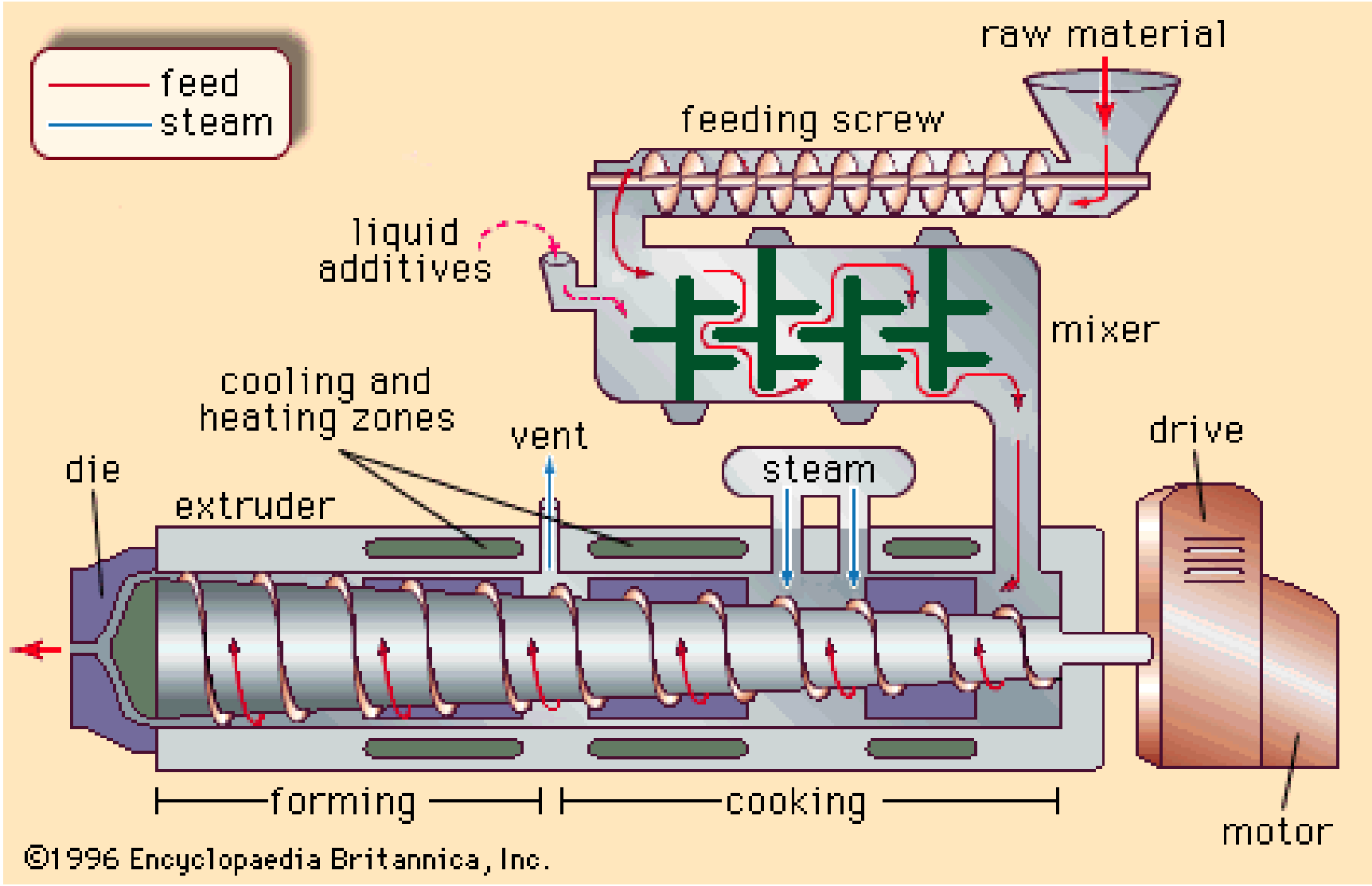
Making the IoT Smarter

Zynq® Enhanced Sensor Based Systems

Accelerating Your Success™

Example Plastic Extrusion Machine



Objective

- Understand that smarter devices are possible today because of
  - Better and lower-cost sensors enable sensor fusion
  - Better and lower-cost processing with Zynq

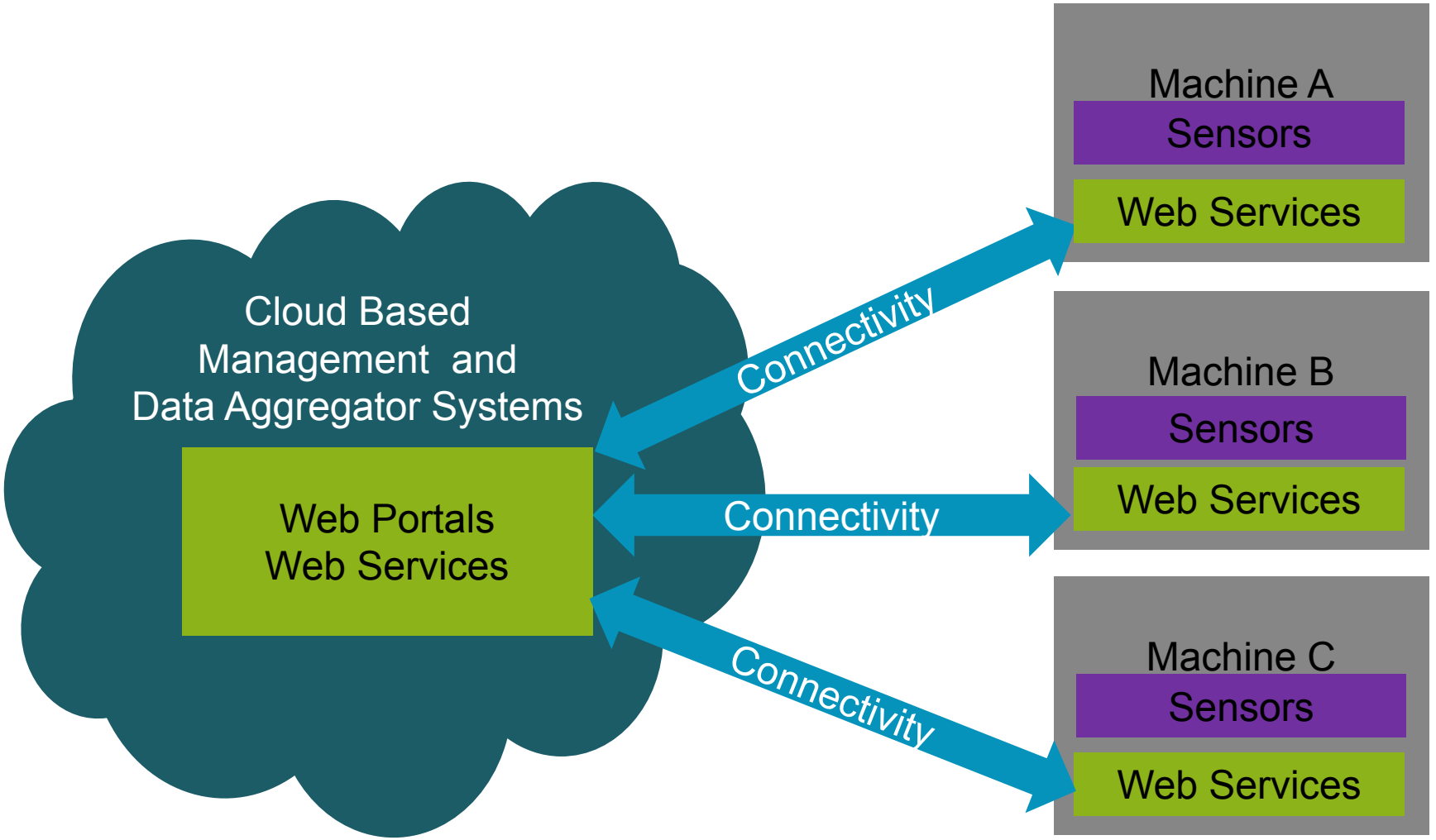
- Show how smarter devices in the IoT will
  - Reduce failures with efficient preventative maintenance
  - Save time by deciding for themselves
  - Limit amount of data to pass to the cloud
  - Reduce dependencies on the network

Agenda

- Components in the Internet of Things
- Making a smarter device
- Processing the data in the smarter device
- Connecting to the cloud
- Where to find more information

Components in the Internet of Things

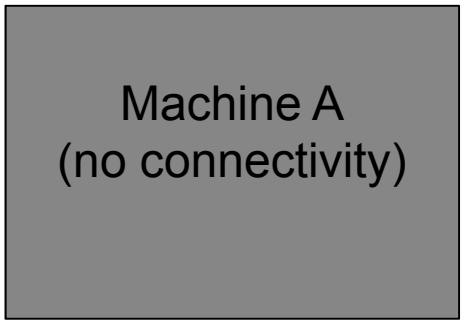
IoT: Enabling Networks of Smarter Machines



Making a Smarter Device

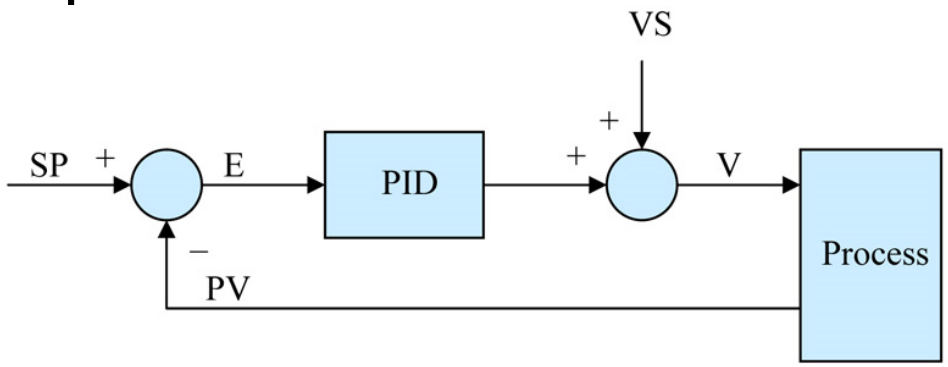
Legacy Manufacturing

- Single or Multiple Machines
- Aside from being in the same building, they had nothing to do with each other
- Performed actions ONLY as their operator directed them
- Requires highly skilled operator with high degree of training to operate



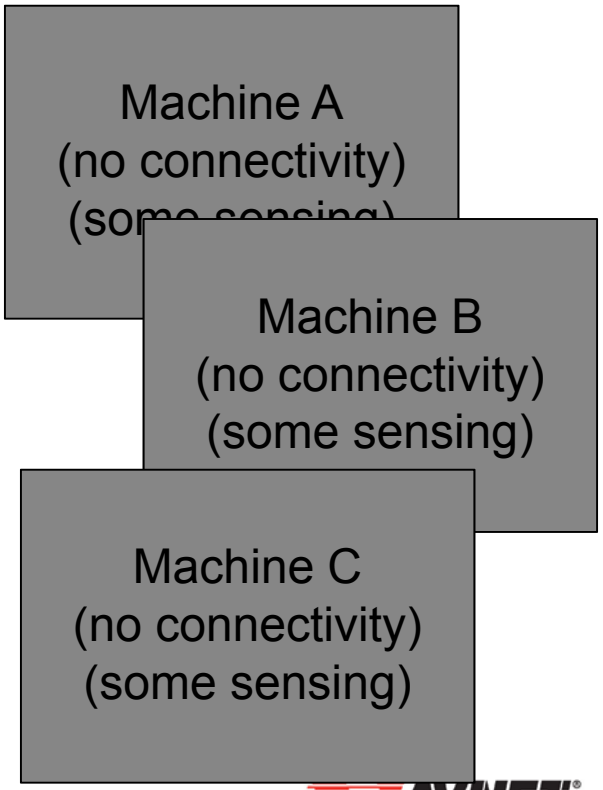
“Smart” Machines Today

- Today we have devices that have control loops
- Today we have (in the context of control loops) devices that can correct a process
- Fewer highly skilled operators required



Closed loop control where:

○	=	Summing point	PV	=	Process variable
PID	=	Proportional/Integral/ Derivative algorithm	E	=	Error
			V_S	=	Output Set Point
SP	=	Set point	V	=	Control variable

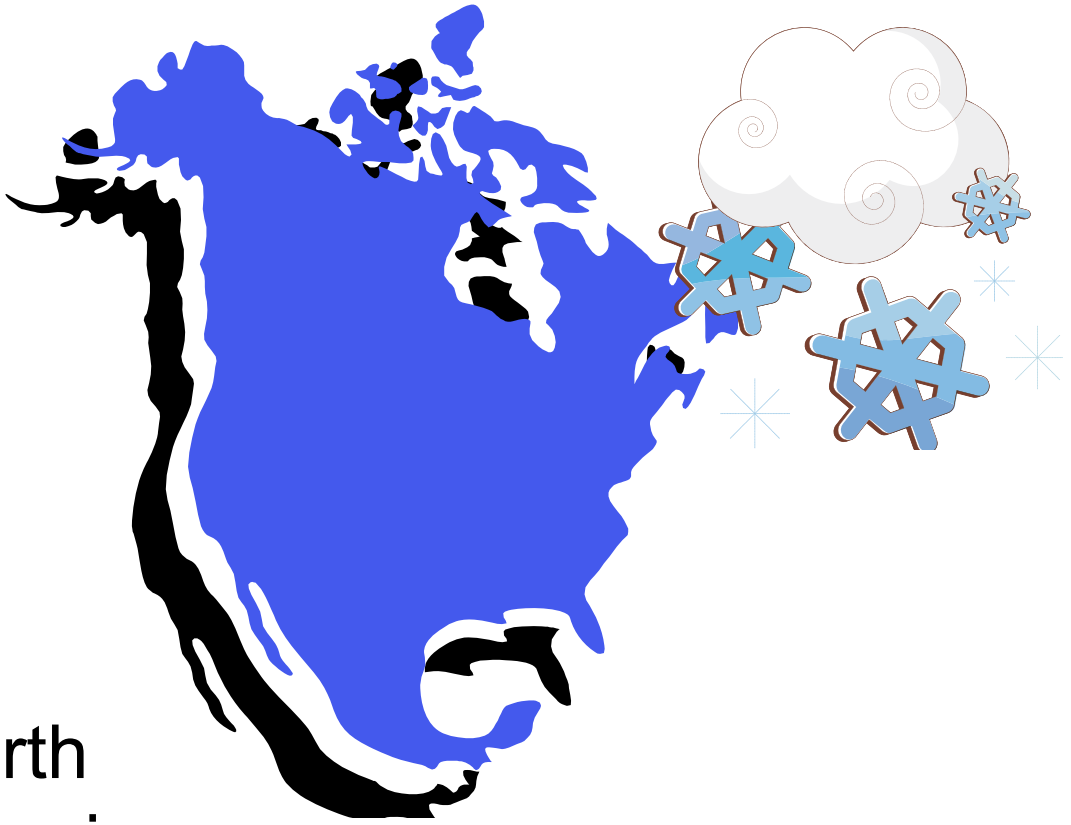


Making a Smarter Device

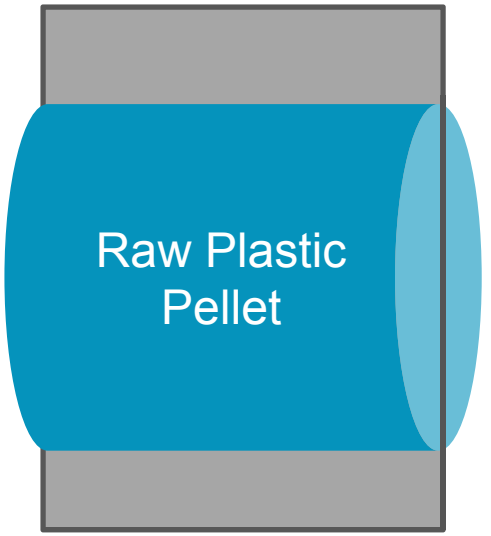
- What would it take to make the device smart enough to be autonomous?
  - Add more feedback / input data
    - Sensors, IO
  - Add more processing power
    - More efficient processing, more complex algorithms
  - Add ability for reporting
    - Feedback to a data aggregator; “cloud”
    - Enable the system for more complete decisions
    - Yes / No / Mostly Yes / Mostly No

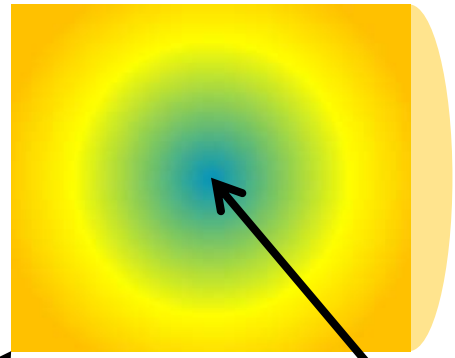
Plastics Manufacturing Today

Issues in Plastics Manufacturing



North America

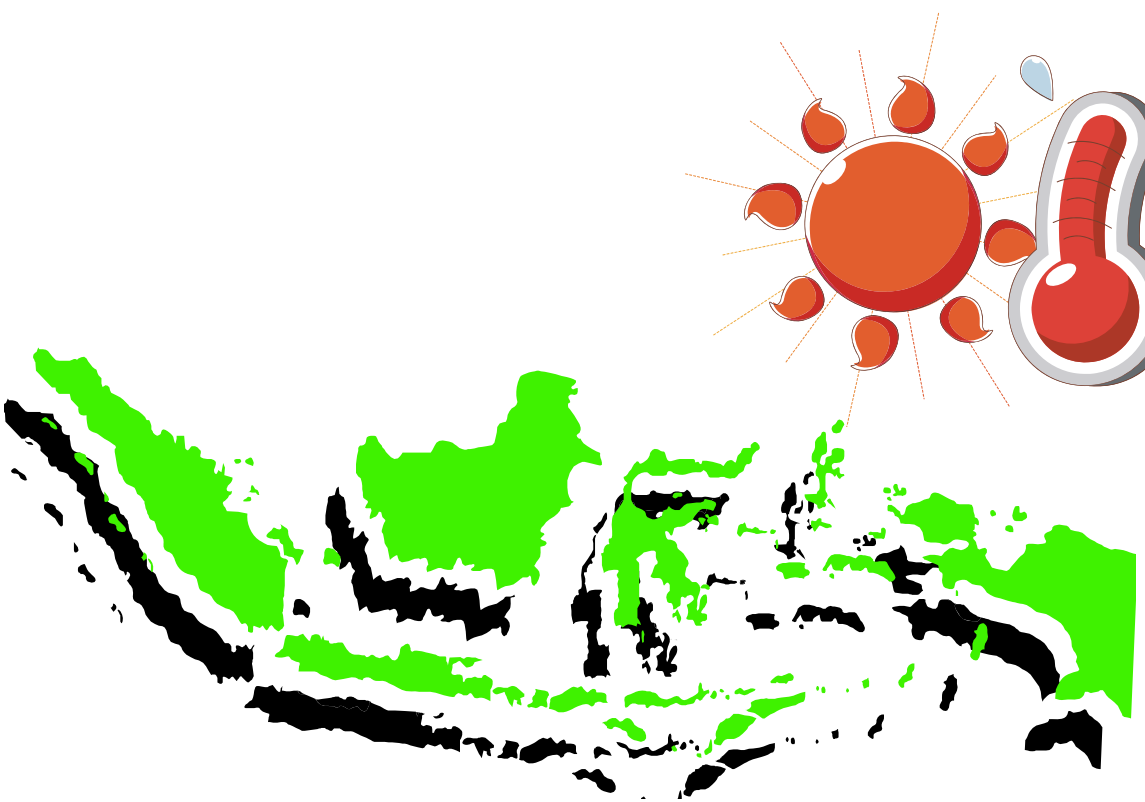




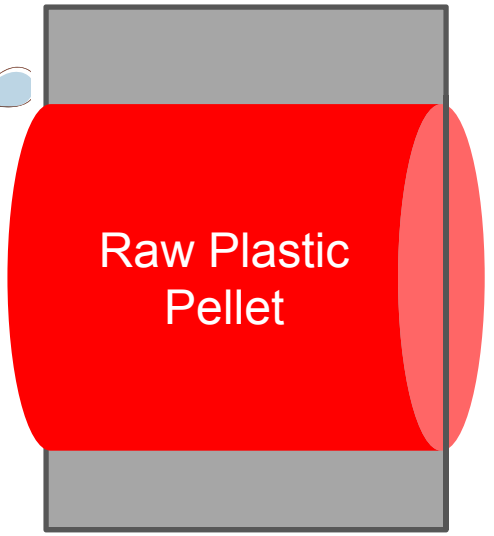
Room Temperature Outer Surface

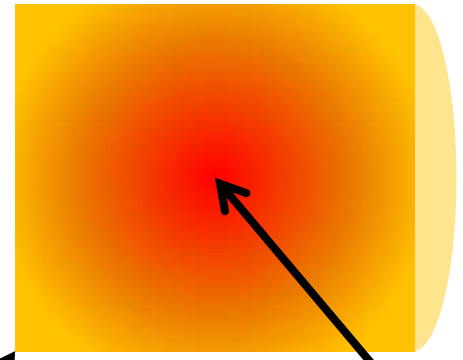
Cool Inner Volume

Issues in Plastics Manufacturing



Indonesia





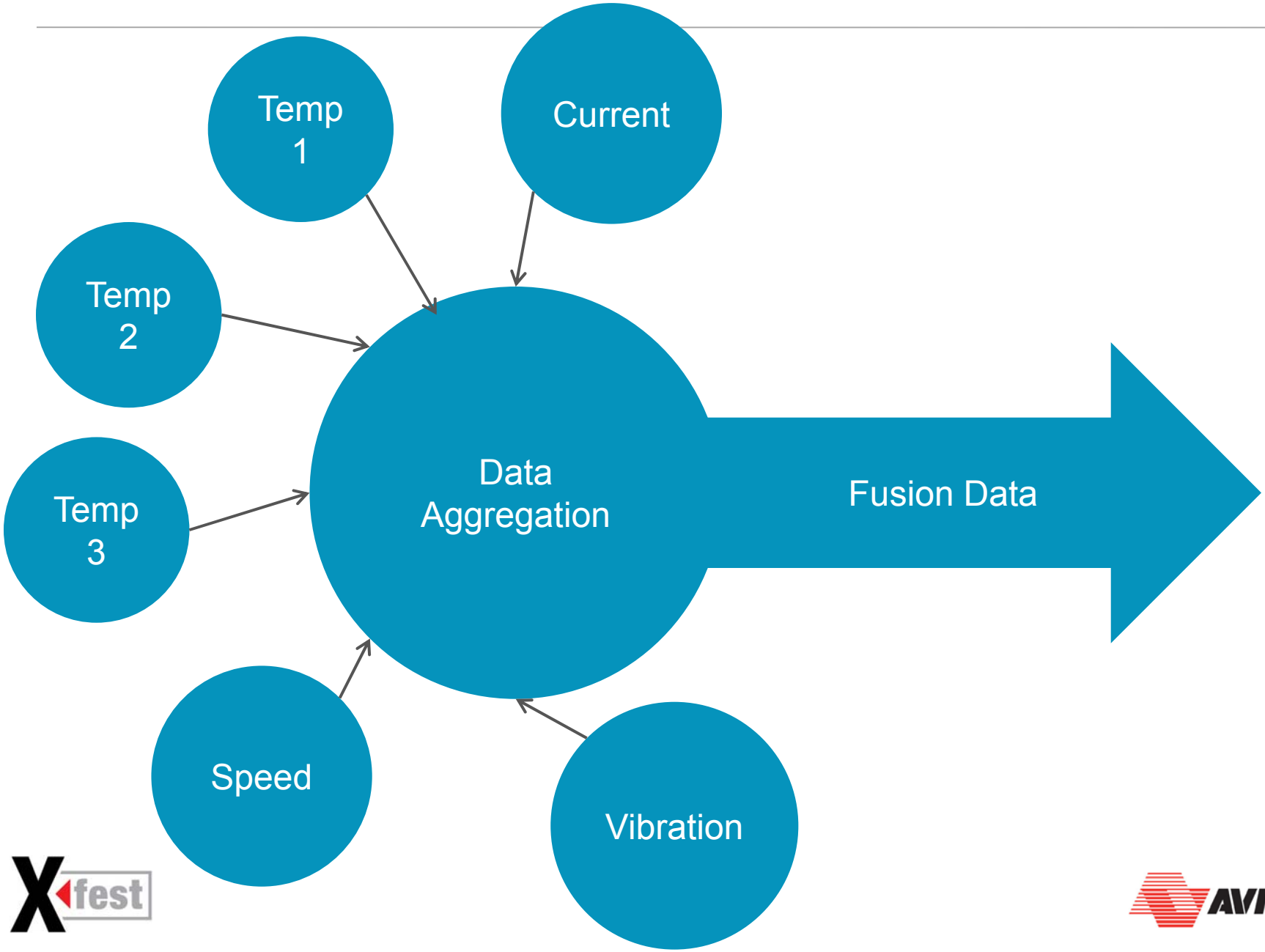
Room
Temperature
Outer Surface

Hot
Inner
Volume

Issues in Plastics Manufacturing

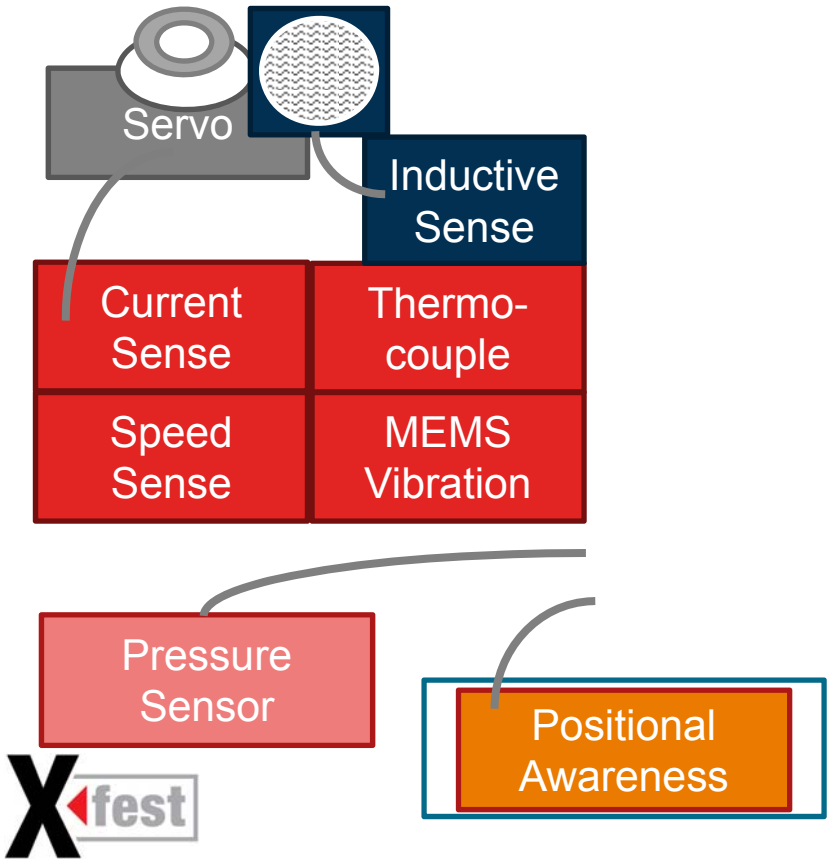
- How can we resolve these issues?
  - Add humidity sensors
  - Add multiple temperature sensors
  - Add a mixer inside the surge bin

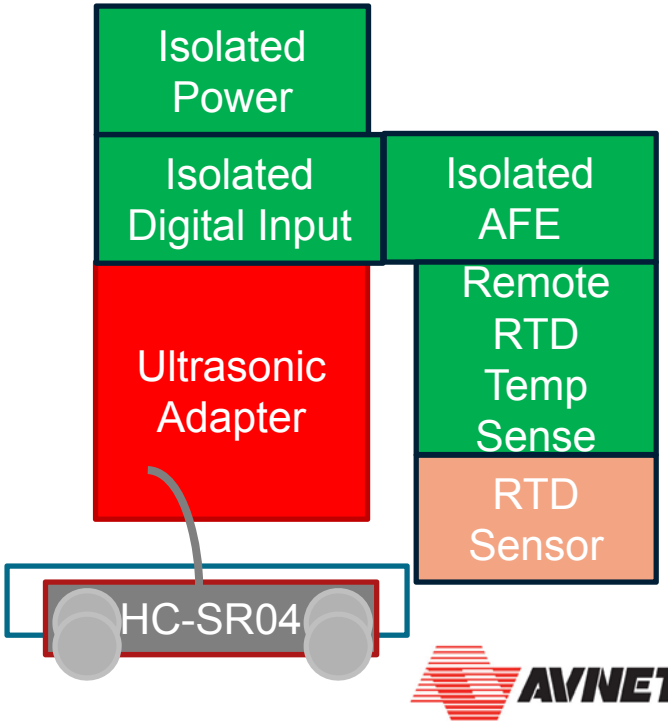
More Sensors!



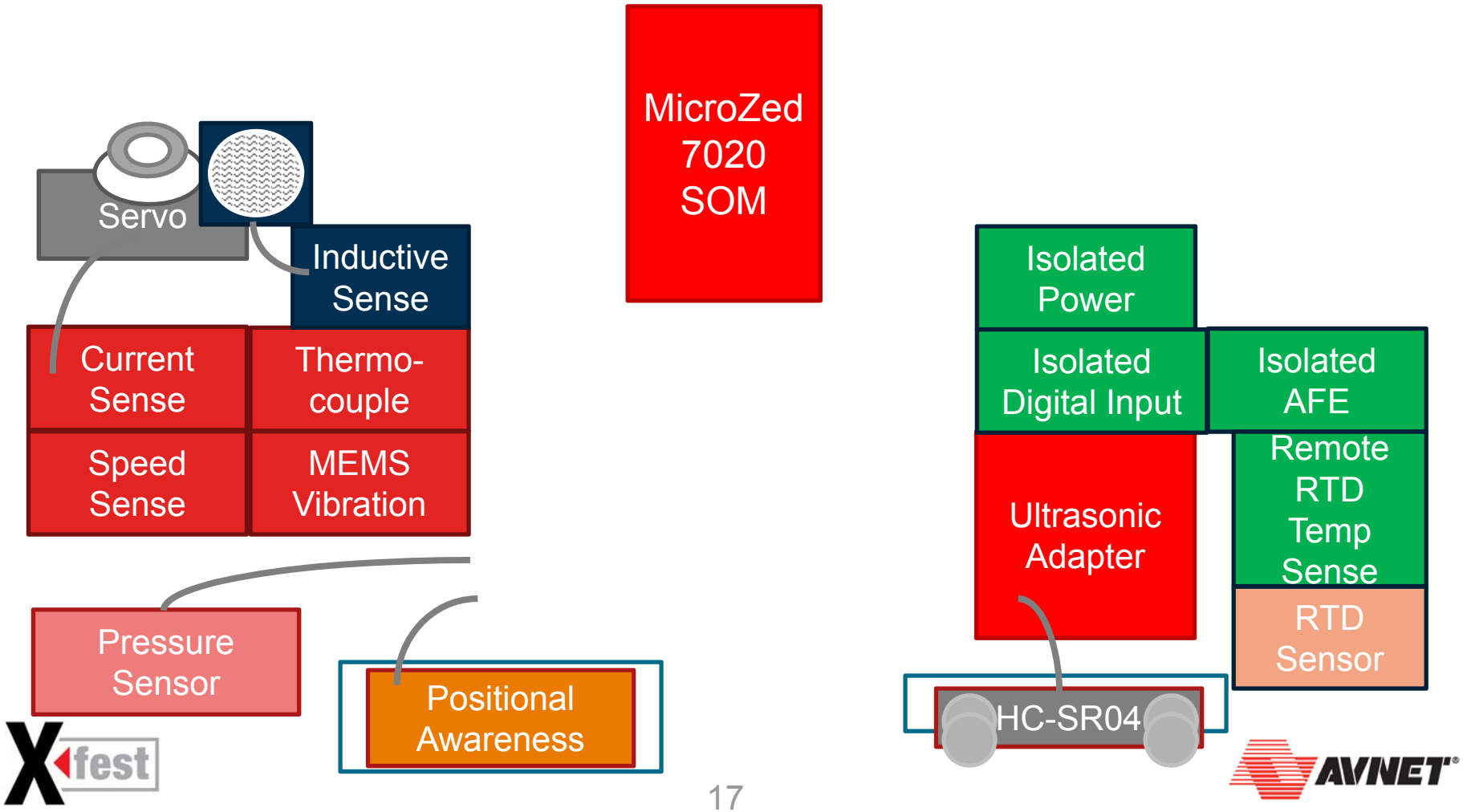
Demo Sensors

- So many sensors!

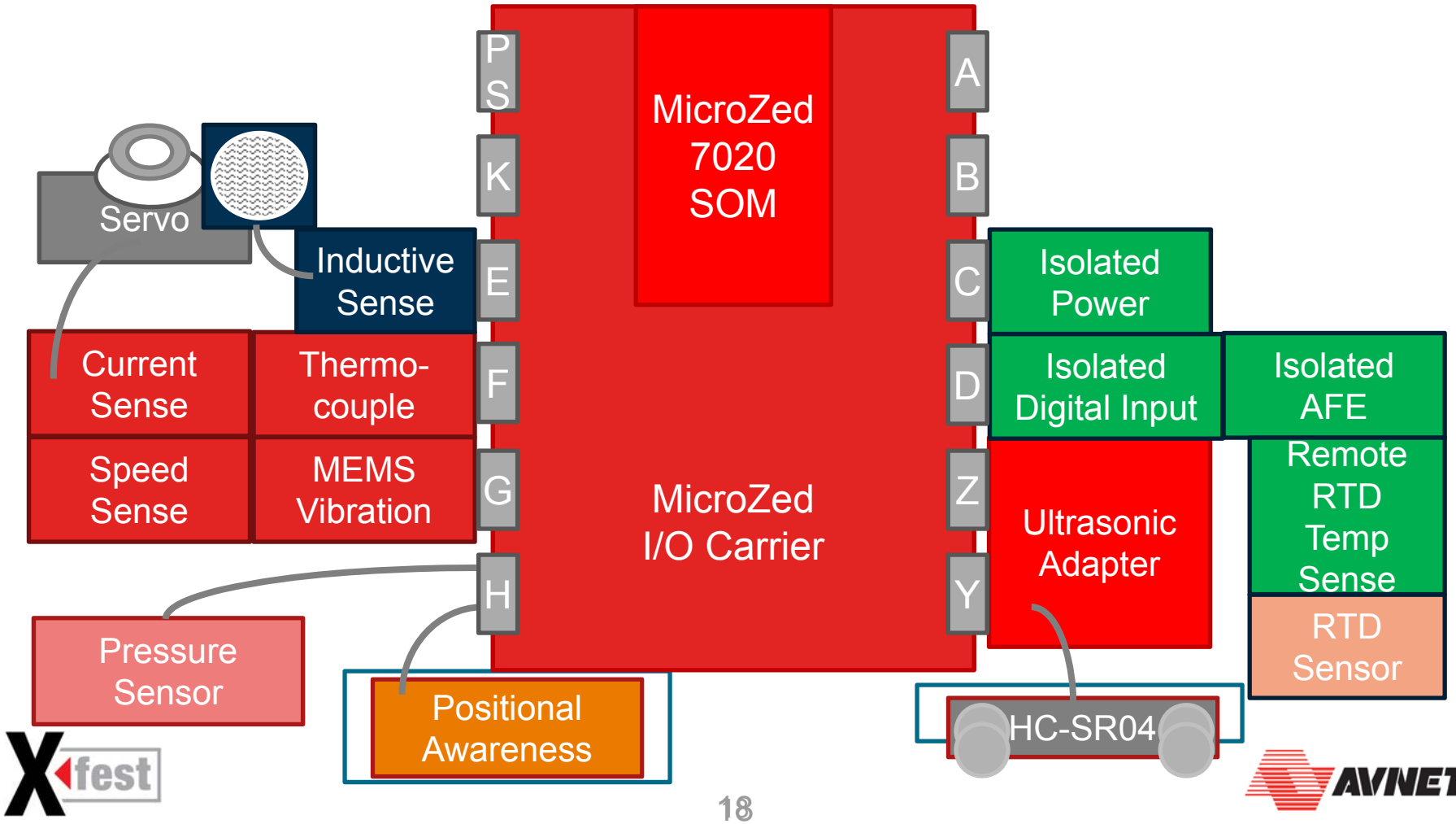




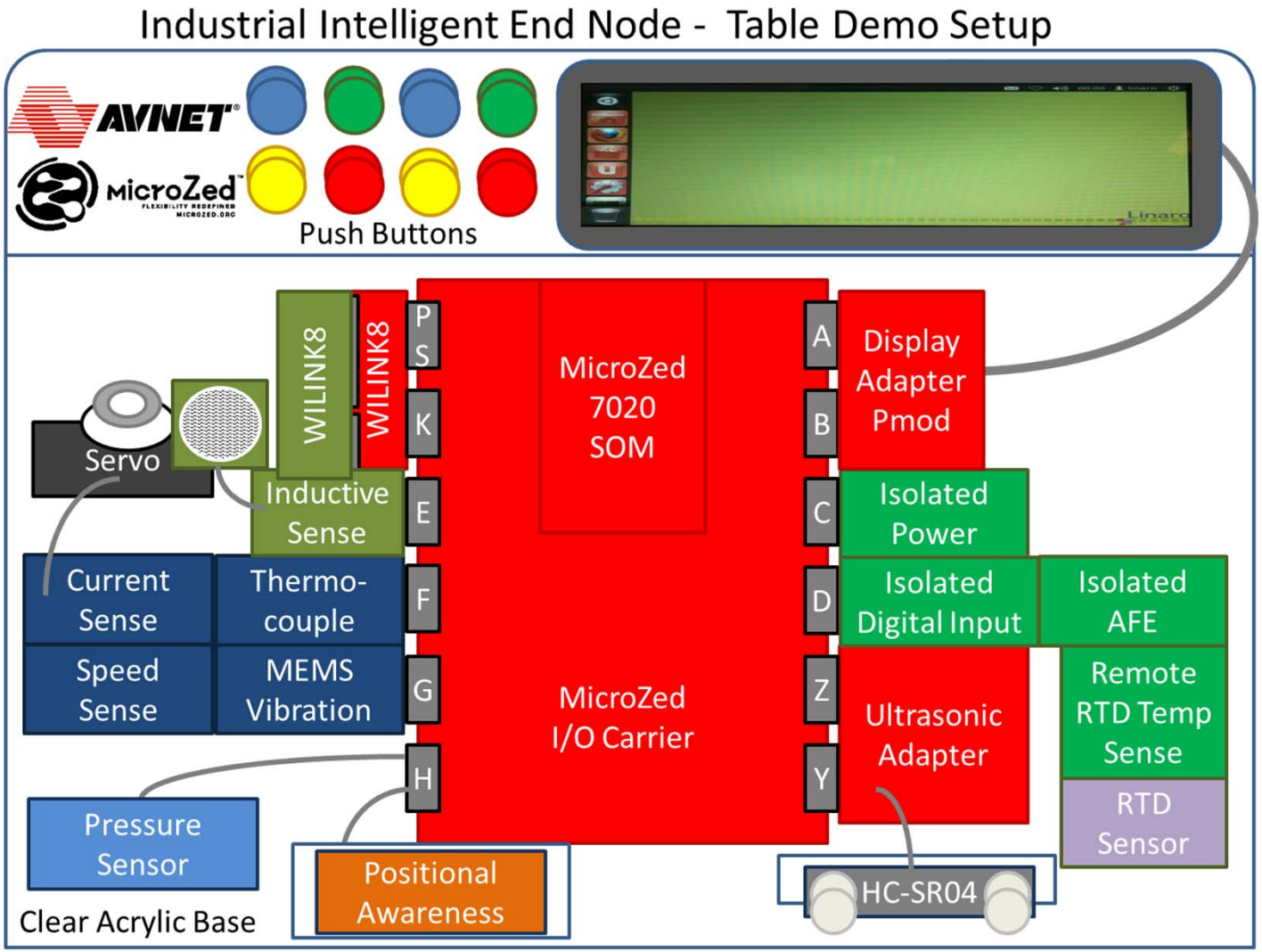
Demo Controller



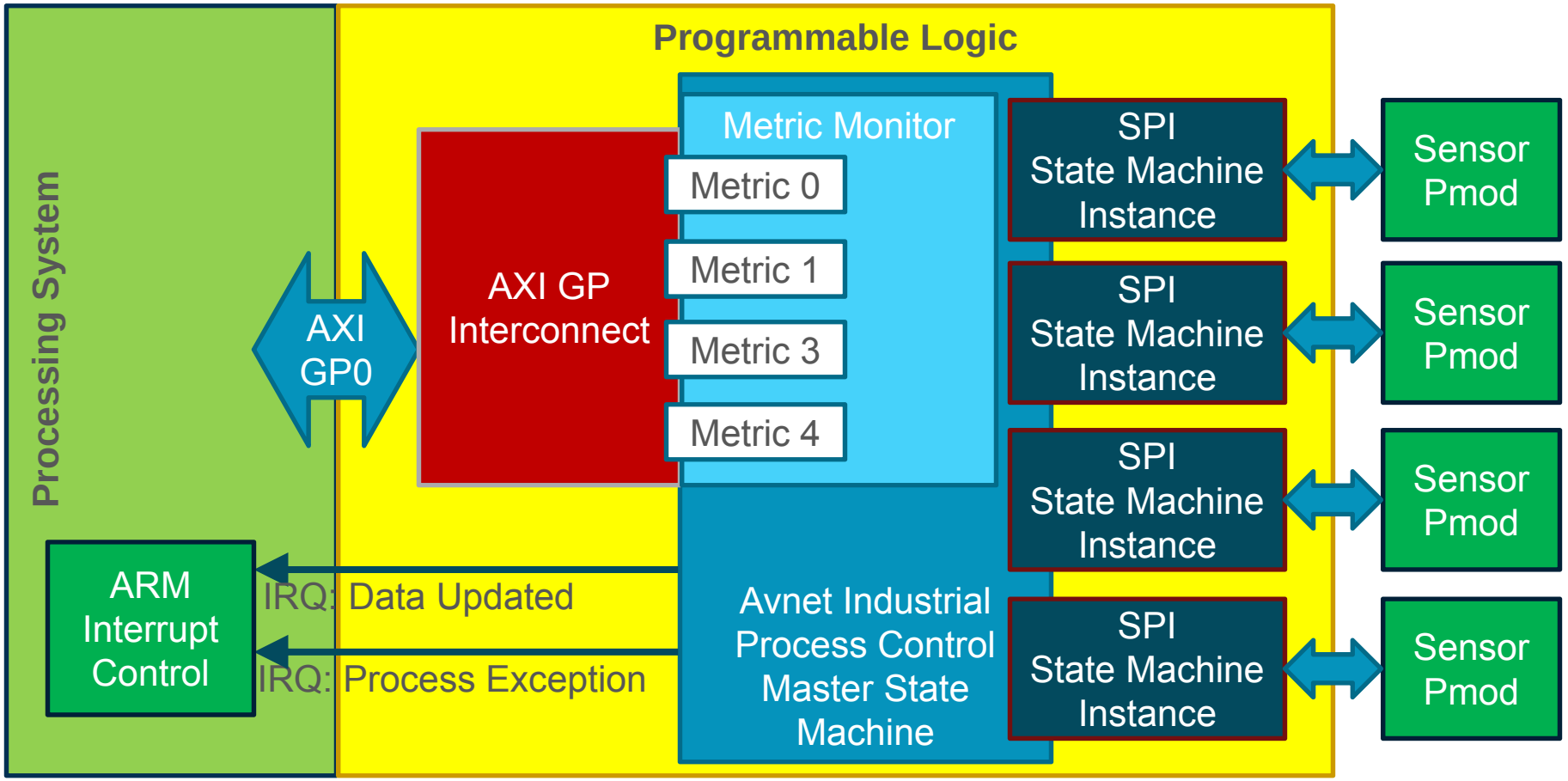
Interfacing to the Sensors



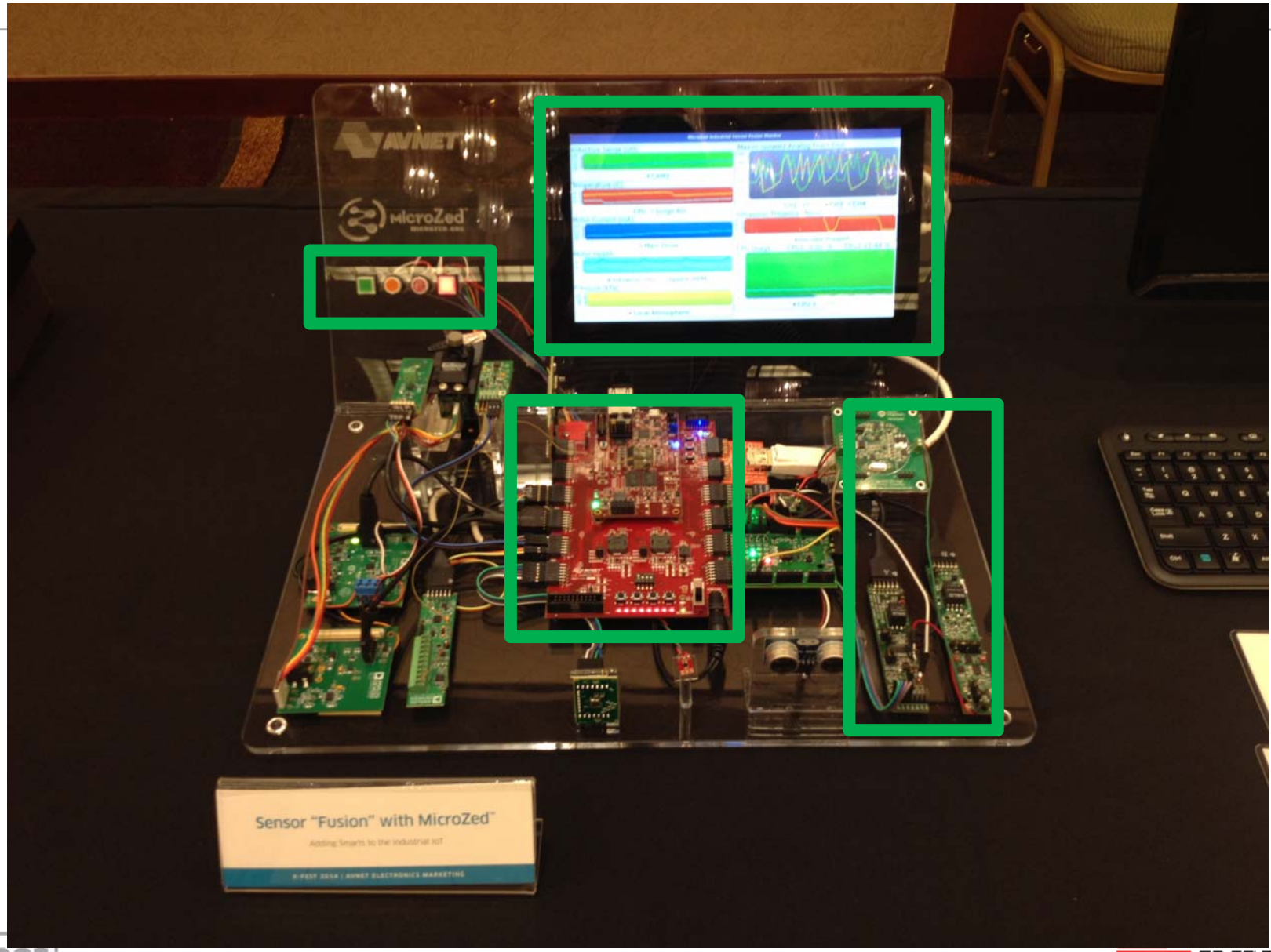
Demo Setup


Industrial Intelligent End Node - Table Demo Setup
AVNET
microZed
Push Buttons
Linaro
WILINK8
WILINK8
P
S
K
E
F
G
H
A
B
C
D
Z
Y
MicroZed
7020
SOM
MicroZed
I/O Carrier
Servo
Inductive
Sense
Current
Sense
Thermo-
couple
Speed
Sense
MEMS
Vibration
Pressure
Sensor
Clear Acrylic Base
Positional
Awareness
Display
Adapter
Pmod
Isolated
Power
Isolated
Digital Input
Isolated
AFE
Remote
RTD Temp
Sense
RTD
Sensor
Ultrasonic
Adapter
HC-SR04

Firmware Diagram

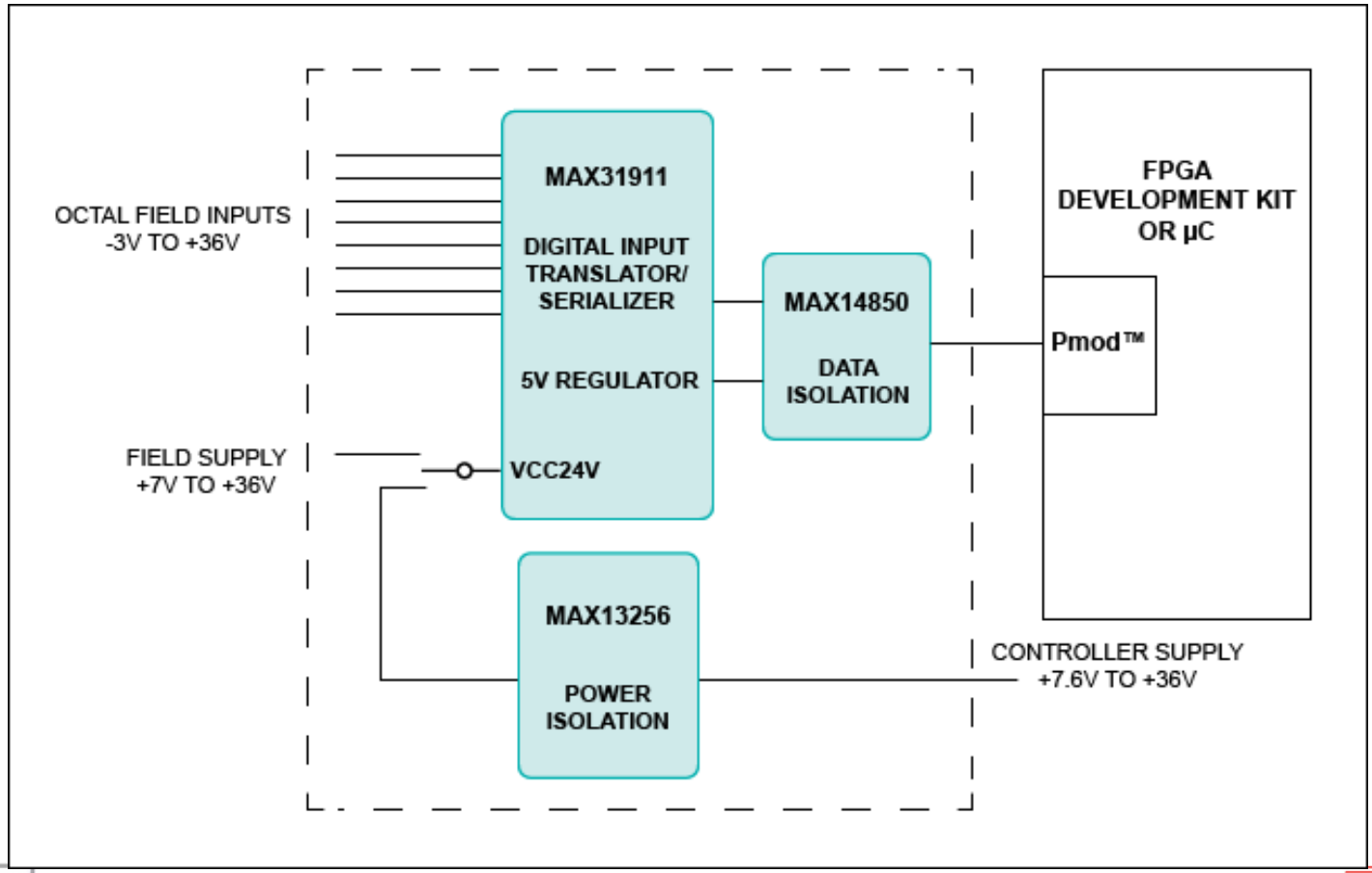


The Demo itself!



Adding more feedback (Corona)

- MAXREFDES12# Isolated industrial octal digital input translator/serializer



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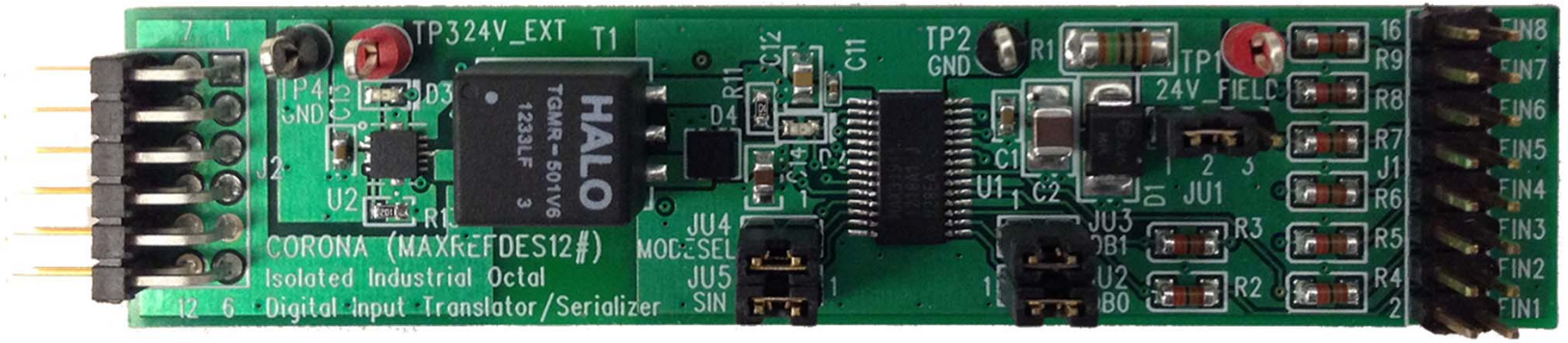
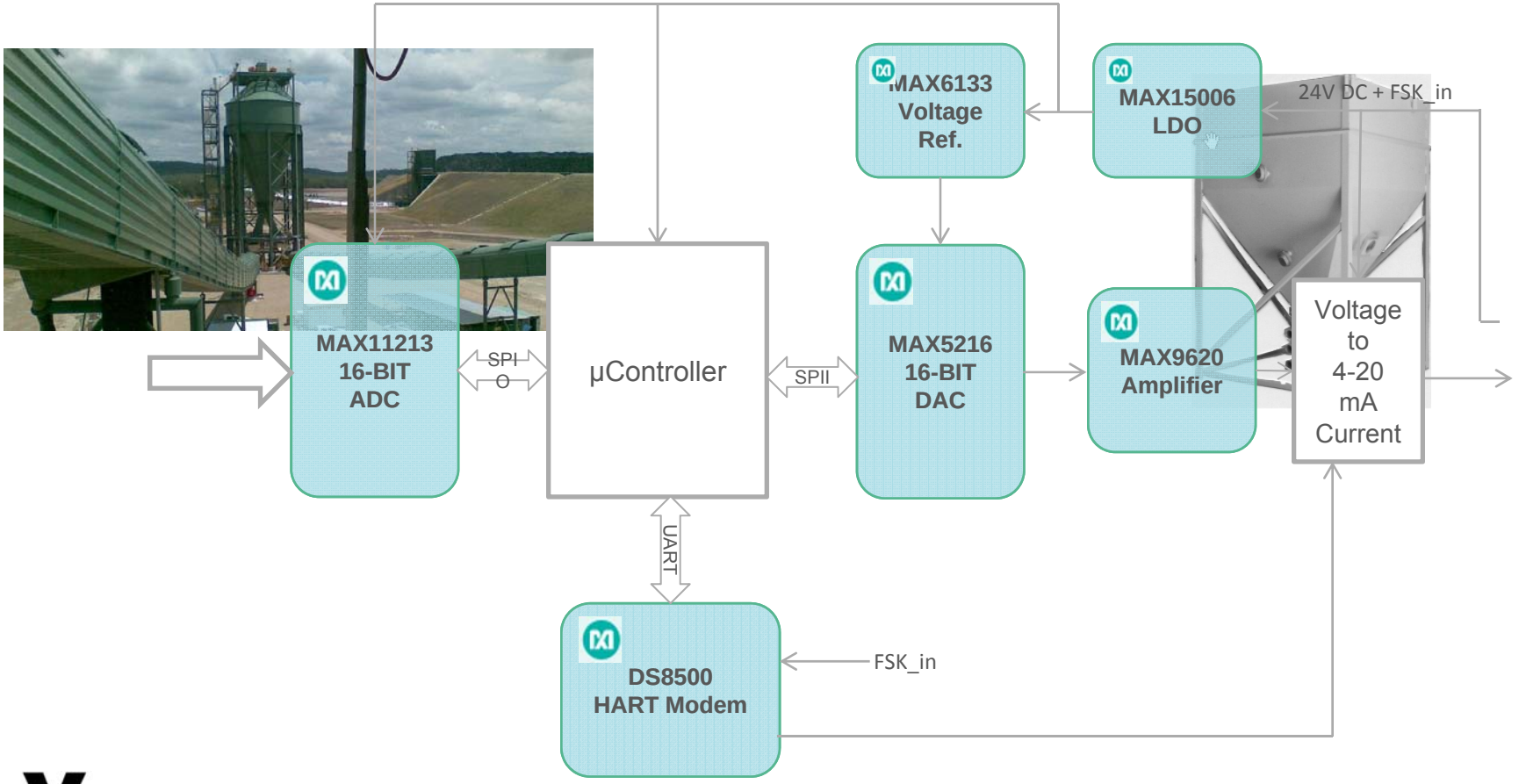


Adding more feedback (Novato)

- MAXREFDES16# 4-20mA loop-powered temperature sensor with HART



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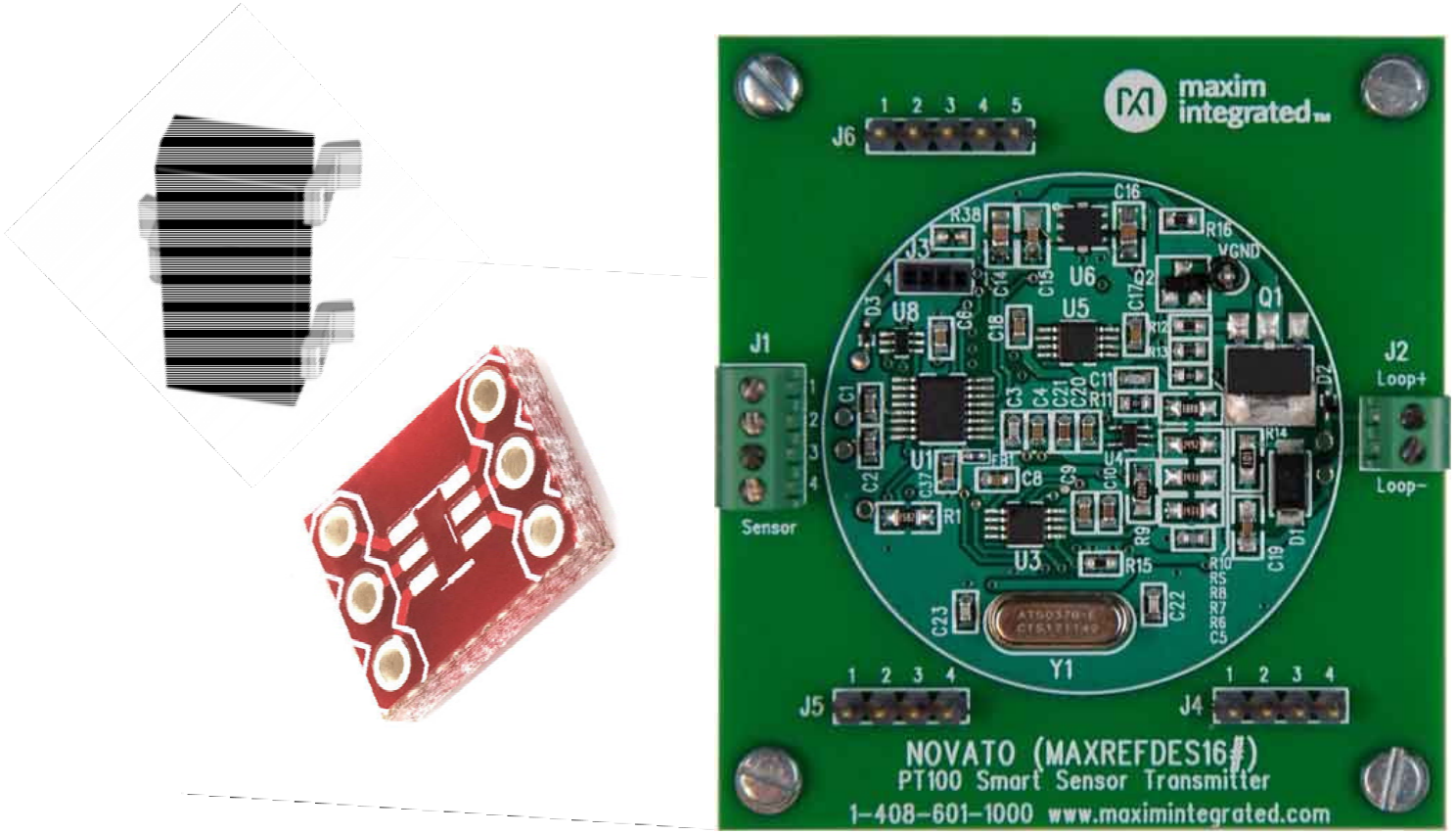
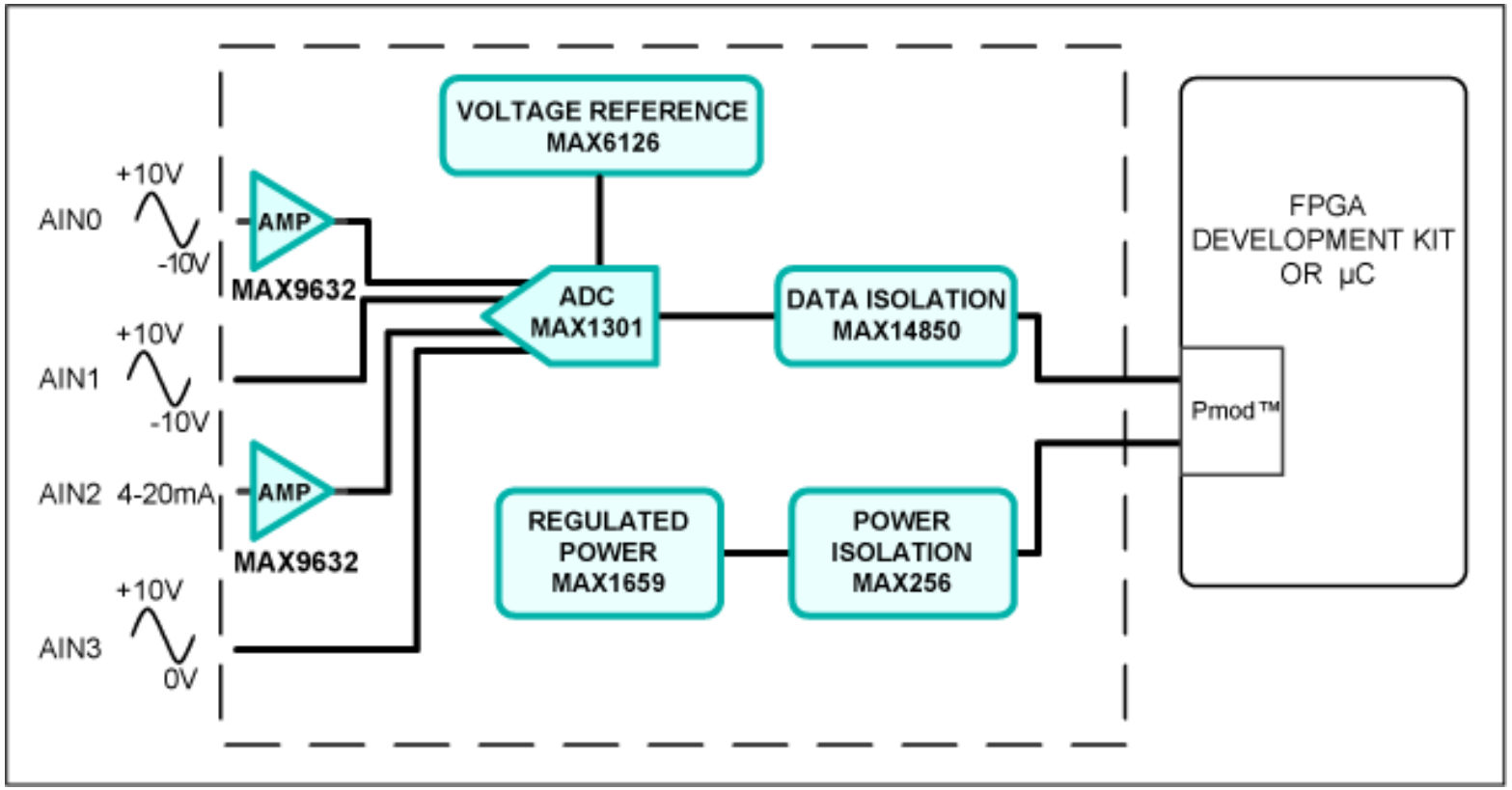


Adding more feedback (Santa Fe)

- MAXREFDES5# 16-BIT High accuracy multi-input isolated Analog Front End (AFE)

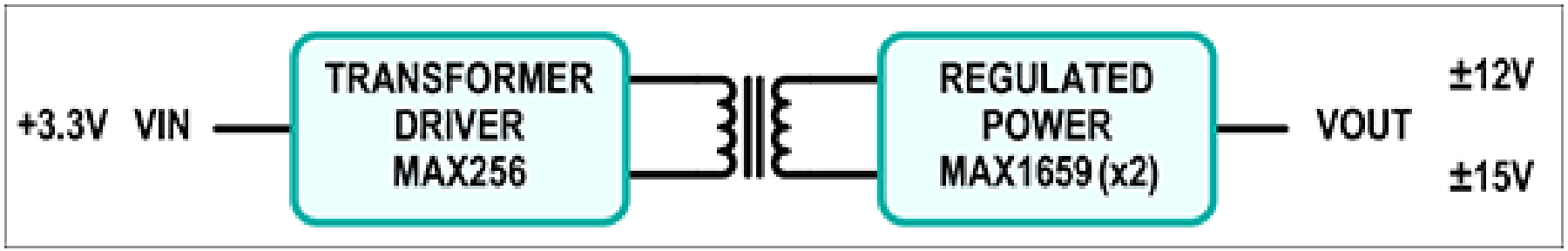


Adding more feedback (Santa Fe)

- MAXREFDES5# 16-BIT High accuracy multi-input isolated Analog Front End (AFE)

Adding more feedback (Lakewood)

- MAXREFDES7# Industrial 3.3V input, ±12V (±15V) output isolated power supply



Adding more feedback (Lakewood)

- MAXREFDES7# Industrial 3.3V input, ±12V (±15V) output isolated power supply

Adding more feedback (MPL115A)

- MPL115A
  - Integrated ADC
  - SPI or I²C Interface
  - Factory calibrated
  - 50 kPa to 115 kPa abs. pressure
  - 1 kPa accuracy
- KITMPL115A1EVB
  - SPI Evaluation Board
- Pin compatible
  - MPL3115A (20kPa to 110kPa)

Adding more feedback (MPL115A)

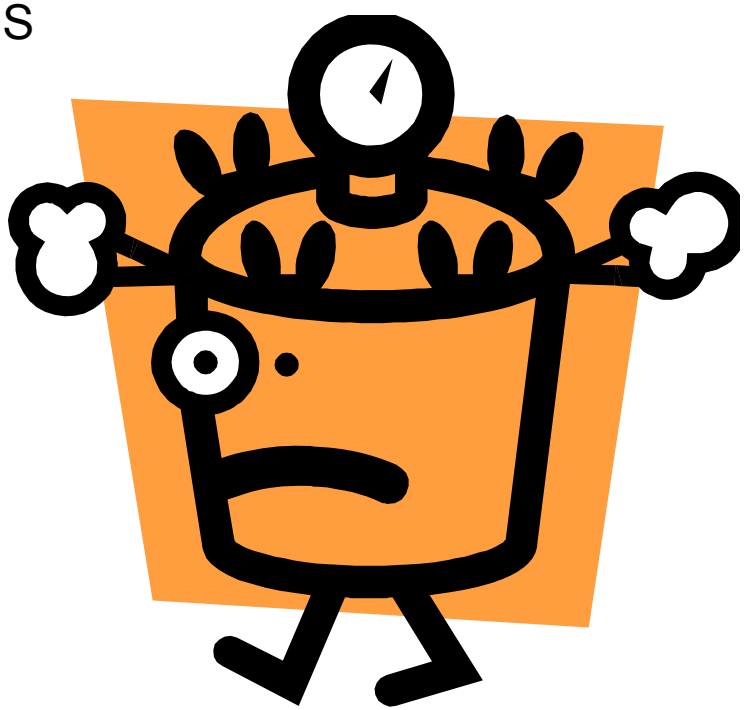
1kPa ~ 0.15 PSI
101.3 kPa ~ 14.7 PSI ~ 1 ATM
50 kPa ~ 7PSI ~ 1/2 ATM
1 ATM = 0ft or 0m above sea
1/2 ATM = 18,000 ft or 5486.3m

115kPa ~ 16 PSI

Usually when a pressure cooker is done!

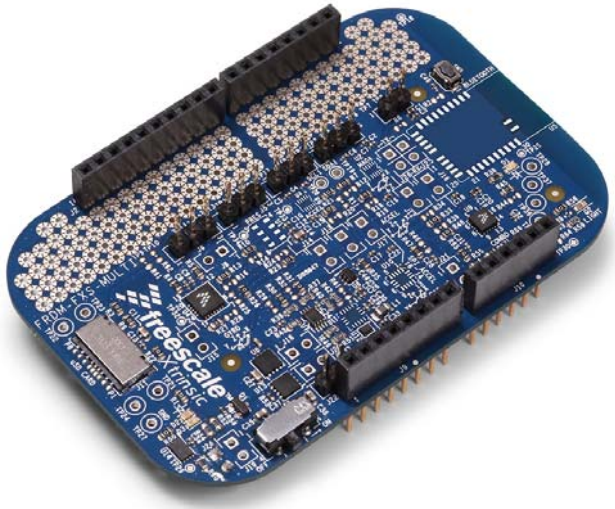
Peak of Mt. St. Elias 4th tallest mountain in the US
18008ft / 5488.84m

Photo from NOAA library
Photographer: Mr. David Sinson

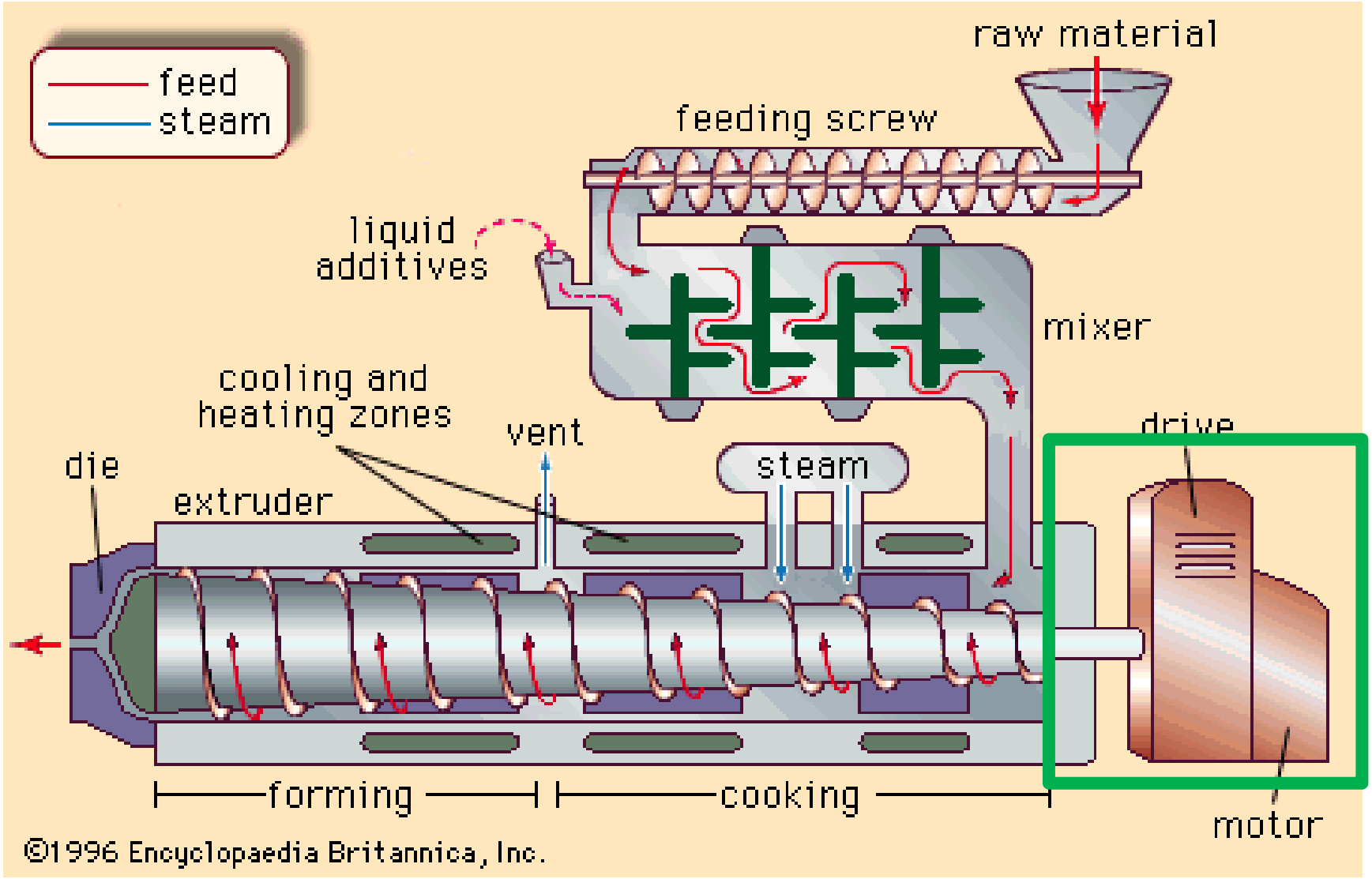


Visit the Freescale booth

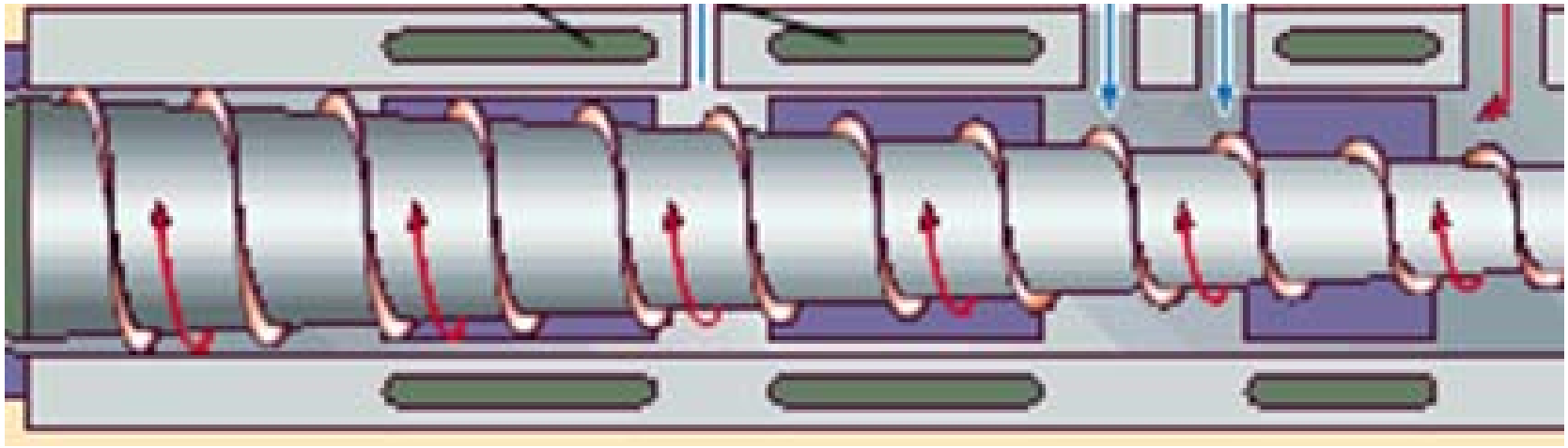
- See Sensor Fusion in action
- Sensor Fusion on Kinetis and MicroZed
  - Freescale Platform for Xtrinsic Sensors
  - Freescale Platform for Kinetis MCUs
  - Avnet MicroZed™ SOM featuring Xilinx® Zynq®
  - Sensor Fusion Toolbox for Android and Windows
  - Multiple fusion options, incl. 9-axis Kalman filter
  - Highly optimized for low power consumption



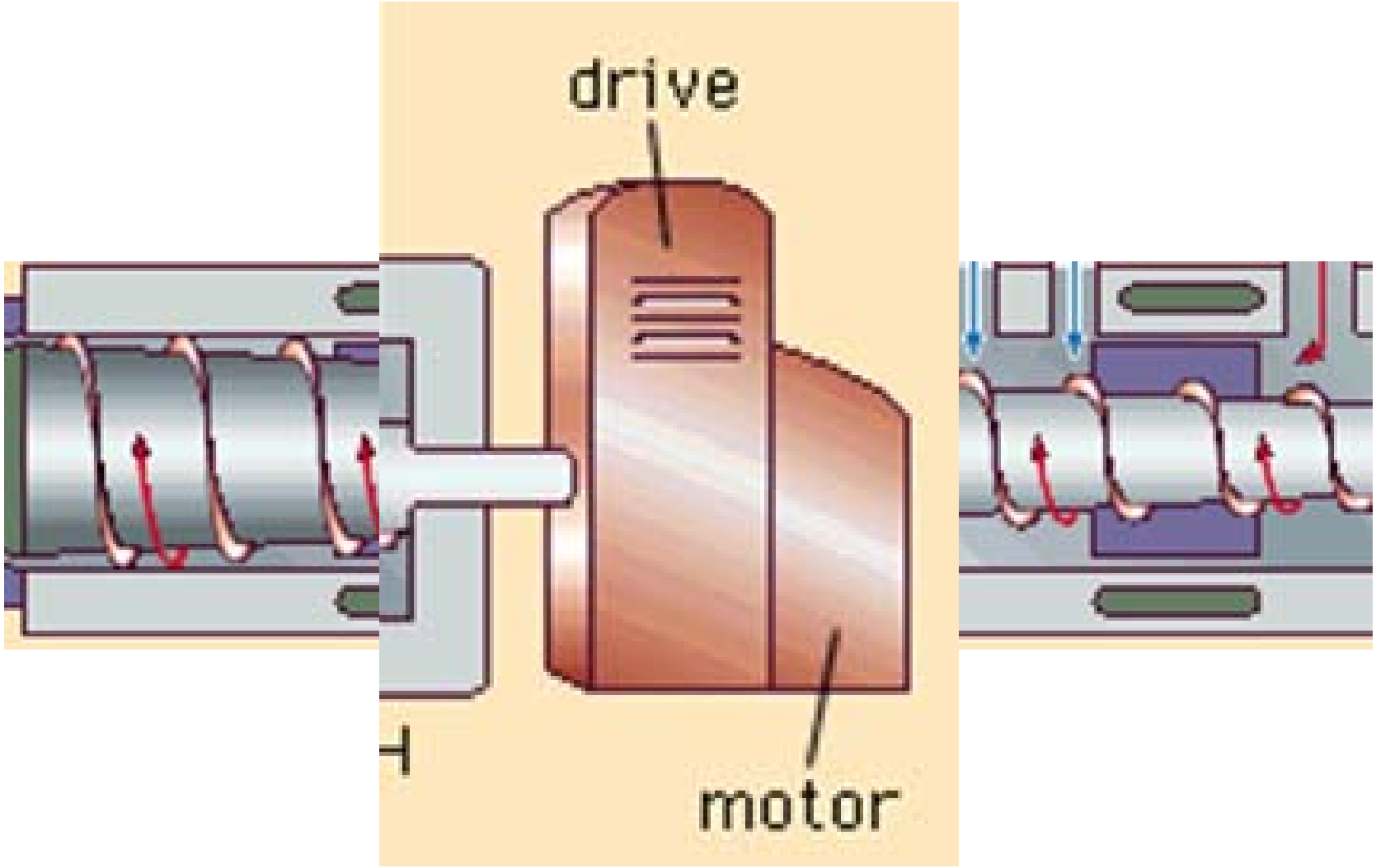
Example Plastic Extrusion Machine



Pressurizing Screw



Motor Drive



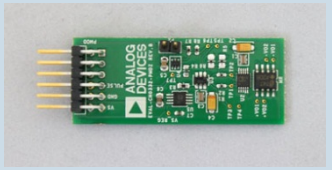
Adding more feedback (Current)

Sensing Type	Performance / Specs	Part Number
Current Sensing	• +/- 32 V input over voltage protection • High side sensing rejects ground noise • Low power, single 5 V supply	CN0241 

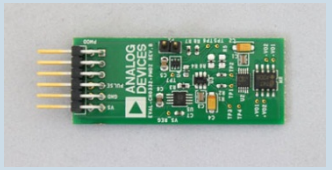
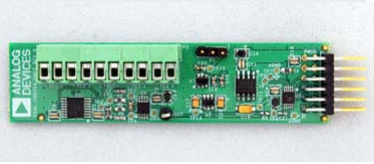
Adding more feedback (Vibration)

Sensing Type	Performance / Specs	Part Number
Current Sensing	• +/- 32 V input over voltage protection • High side sensing rejects ground noise • Low power, single 5 V supply	CN0241 
Vibration Sensing	• High-g MEMS-based vibration analyzer • Flat frequency response to 22kHz • 70g, 250g, and 500g range versions	CN0303 

Adding more feedback (Rotation)

Sensing Type	Performance / Specs	Part Number
Current Sensing	• +/- 32 V input over voltage protection • High side sensing rejects ground noise • Low power, single 5 V supply	CN0241 
Vibration Sensing	• High-g MEMS-based vibration analyzer • Flat frequency response to 22kHz • 70g, 250g, and 500g range versions	CN0303 
Speed/Velocity Sensing	• Robust, non-contact Magneto-resistive sensing resists typical mechanical wear • Measures up to 1MHz rotational speed • Greater SNR than a Hall effect sensor	CN0332 

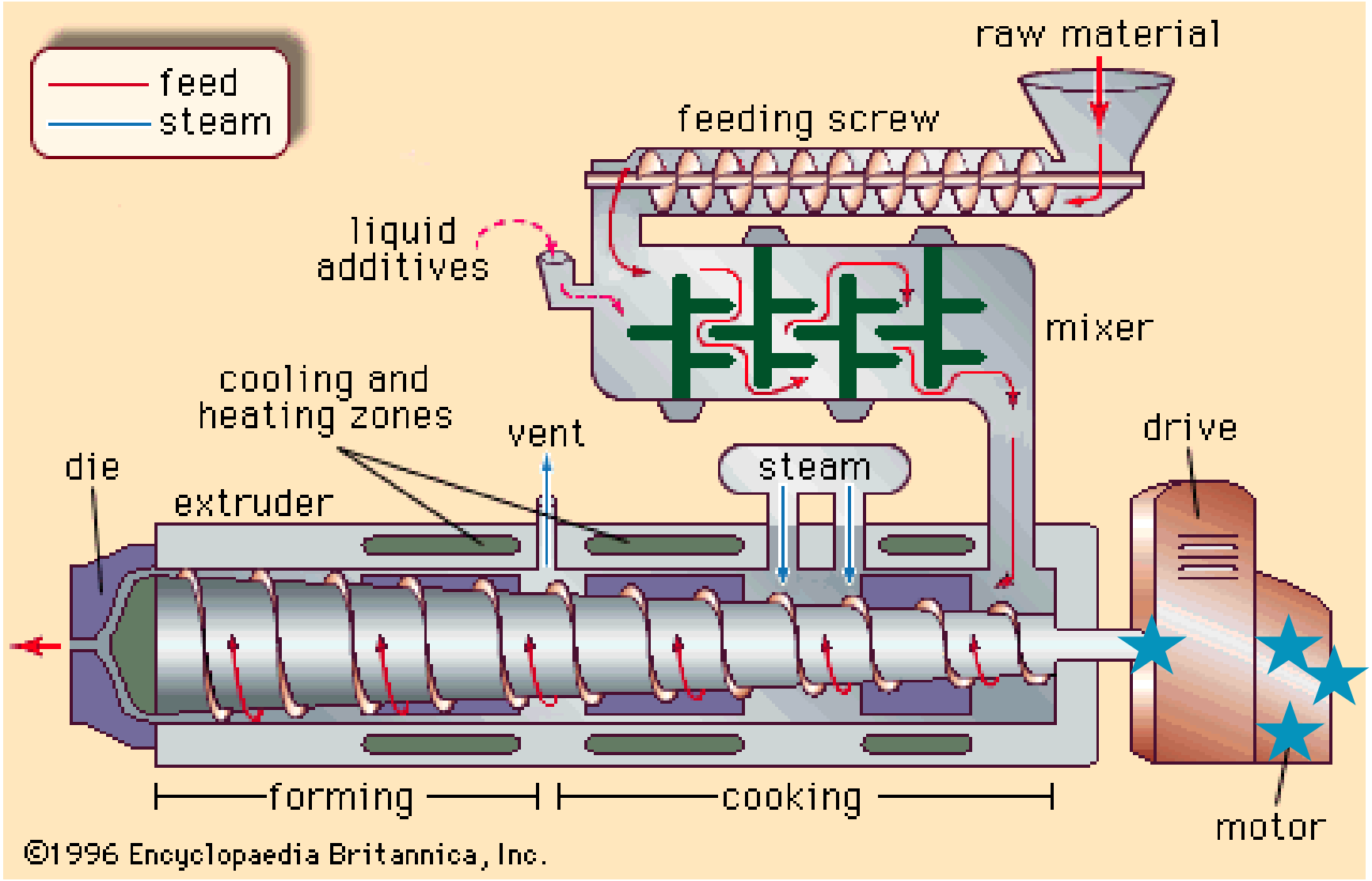
Adding more feedback (Temperature)

Sensing Type	Performance / Specs	Part Number
Current Sensing	• +/- 32 V input over voltage protection • High side sensing rejects ground noise • Low power, single 5 V supply	CN0241 
Vibration Sensing	• High-g MEMS-based vibration analyzer • Flat frequency response to 22kHz • 70g, 250g, and 500g range versions	CN0303 
Speed/Velocity Sensing	• Robust, non-contact Magneto-resistive sensing resists typical mechanical wear • Measures up to 1MHz rotational speed • Greater SNR than a Hall effect sensor	CN0332 
Temperature Sensing	• 4-channel thermocouple block • Cold junction compensation using thermocouple amplifier • Single supply rail, measure -200 to 800 Deg C	CN0354 

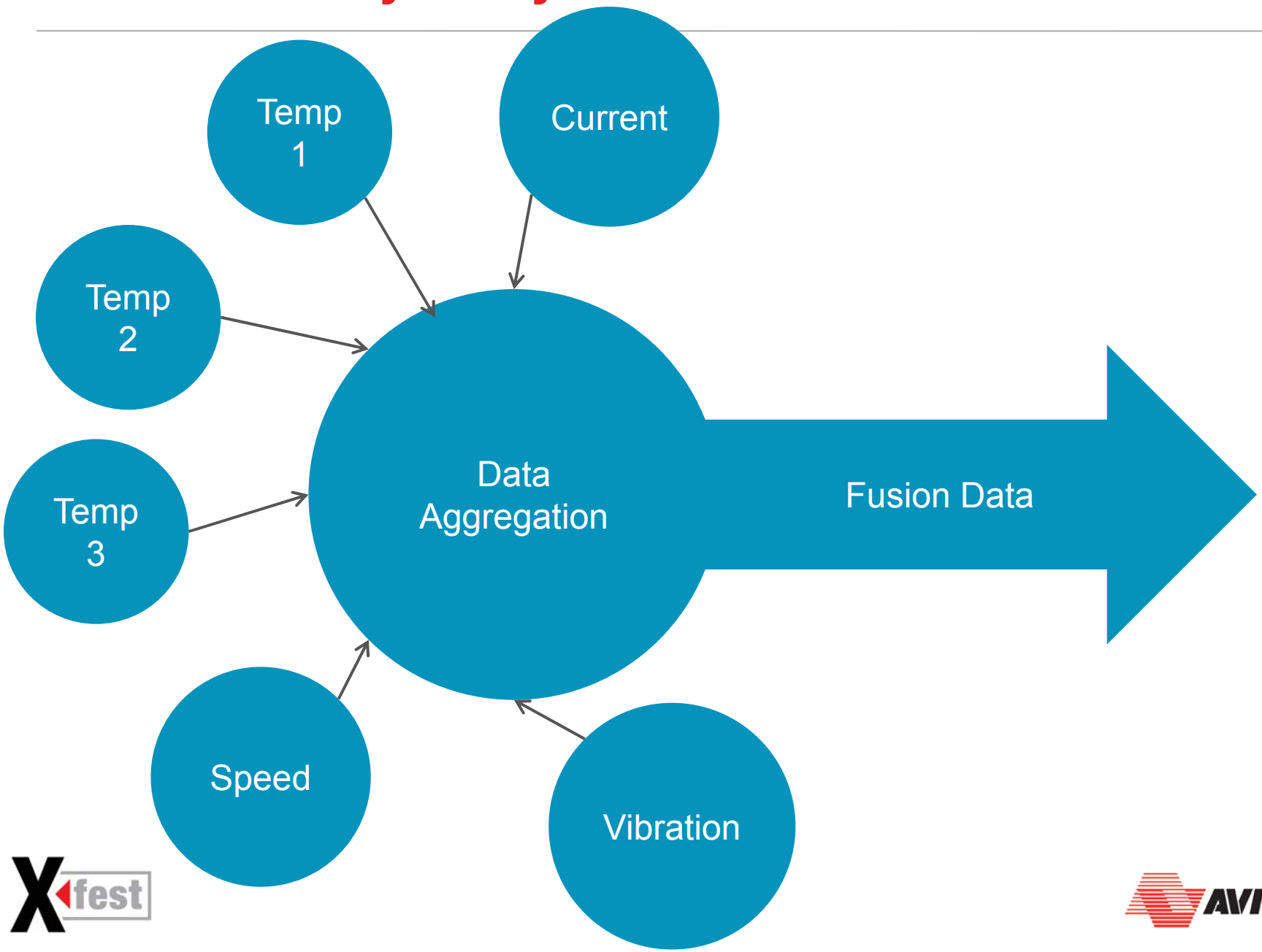
Even more!

Sensing Type	Title/Description
Current	CN0188: Low Cost, Level Shifted Low Side Current Monitor for Negative High Voltage Rails CN0218: 500 V Common-Mode Voltage Current Monitor CN0240: Bidirectional Isolated High-Side Current Sense with 270 V Common-Mode Rejection
Motion	CN0189: Tilt Measurement Using a Dual Axis Accelerometer CN0350: 12-Bit, 1 MSPS, Single-Supply, Two-Chip Data Acquisition System for Piezoelectric Sensors
Magneto-Resistive	CN0323: Magneto-resistive Angle Measurement CN0341: Magneto-resistive Linear Position Measurement
Temperature	CN0172: 3-Channel Thermocouple Temp Measurement Sys w/ 0.25 ° C Accuracy CN0221: USB Thermocouple Temp Measurement Sys Using ARM Cortex - M3 CN0271: Thermocouple Temp Measurement System with Amplifier - Based Cold Junction Compensation CN0319: 14-Bit, 4-20 mA, Loop Powered, Thermocouple Temperature Measurement System Using ARM Cortex-M3 CN0337: 12-Bit, 300 kSPS, Single-Supply, Fully Isolated RTD Temperature Measurement System with 3-Wire Compensation

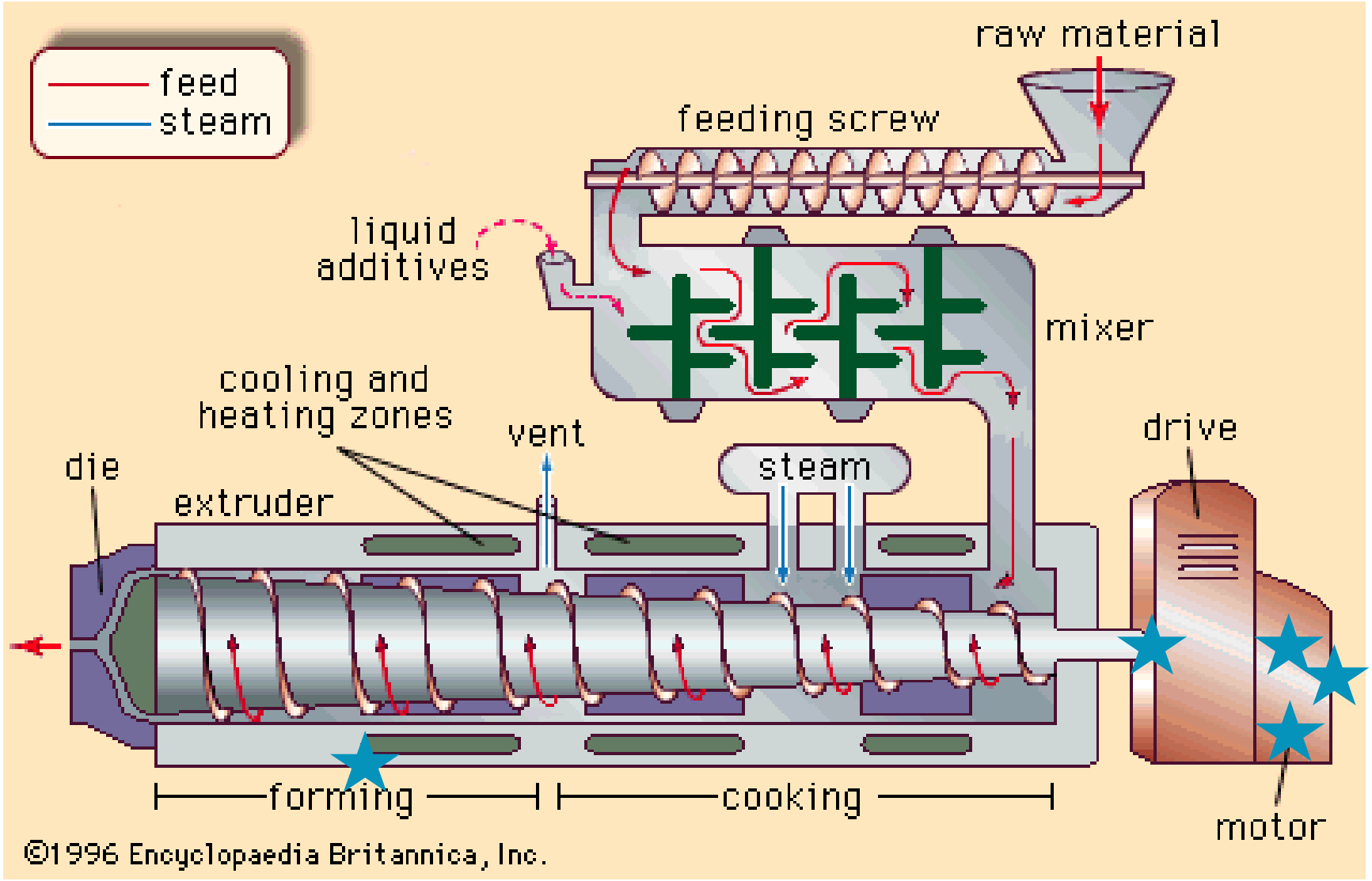
The Take Away



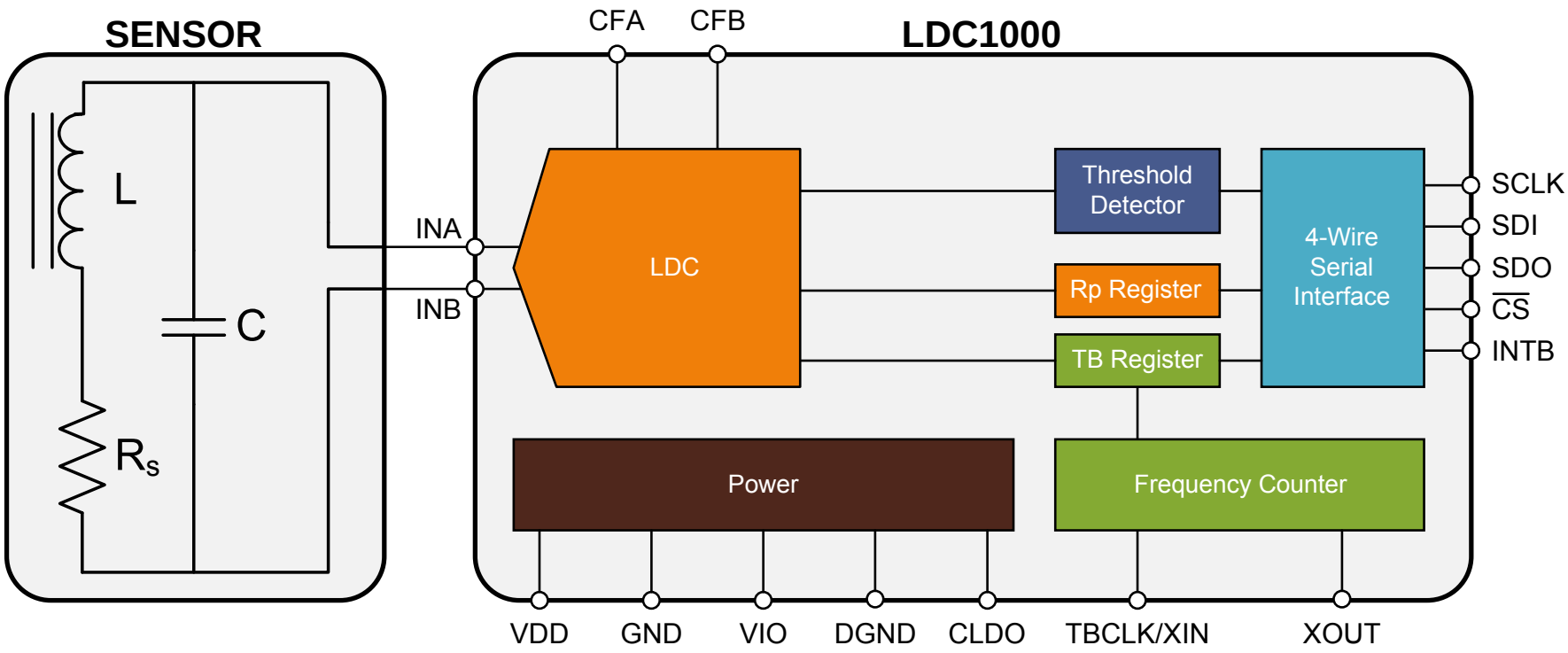
The Take Away…Buy Vs. Make



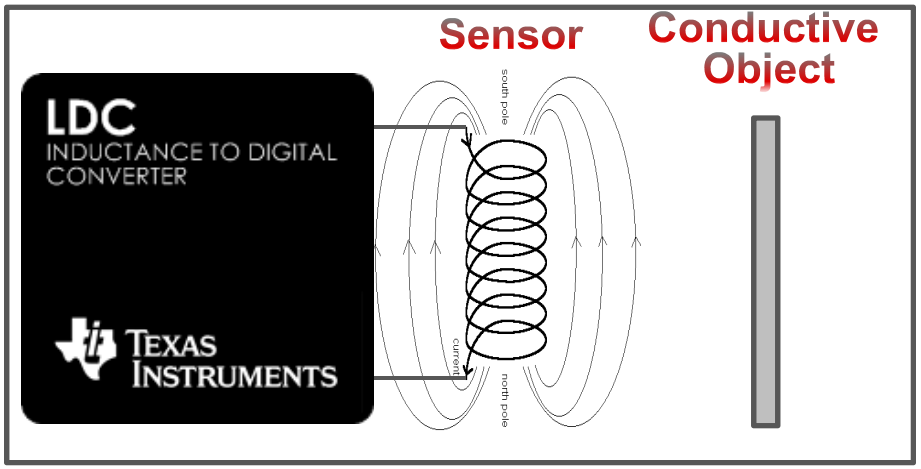
What more?


feed
steam
raw material
feeding screw
liquid additives
mixer
cooling and heating zones
vent
steam
drive
die
extruder
forming
cooking
motor
©1996 Encyclopaedia Britannica, Inc.

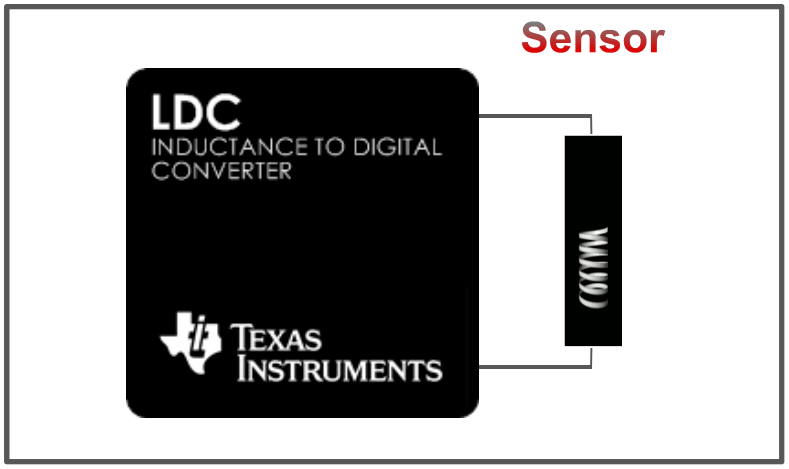
Adding more feedback (Inductive)



Adding more feedback (Inductive)

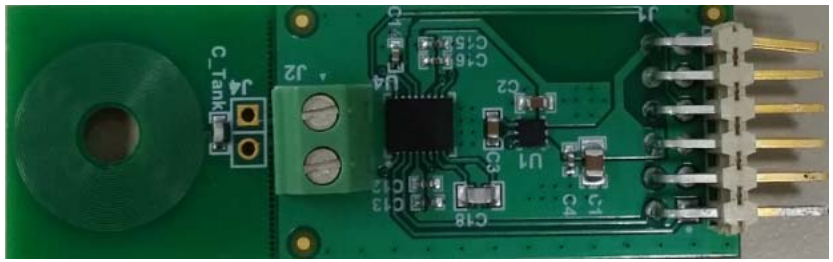


LDC measures distance to a conductive target

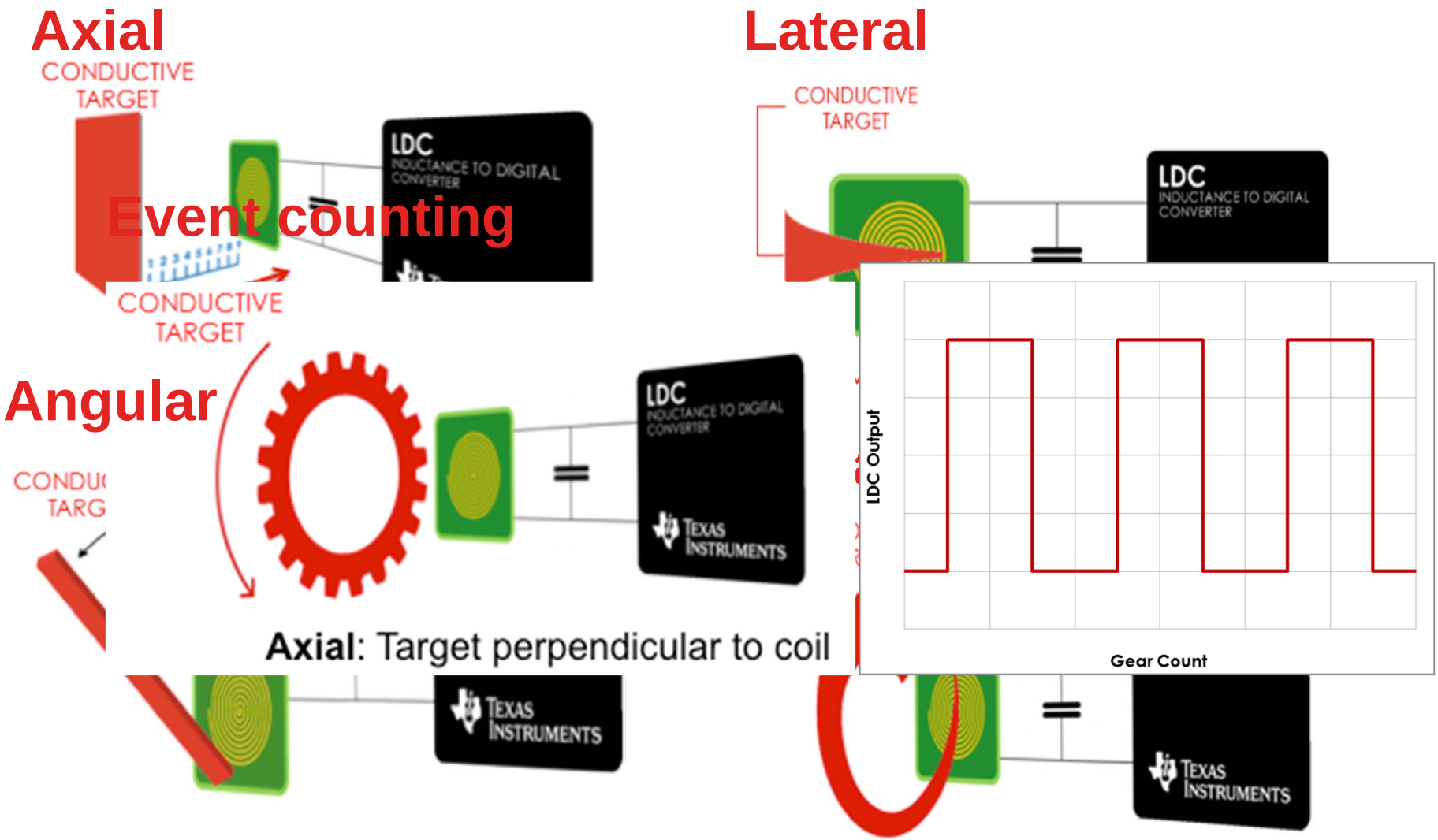


LDC measures compression of a coil

- USB and PMOD versions

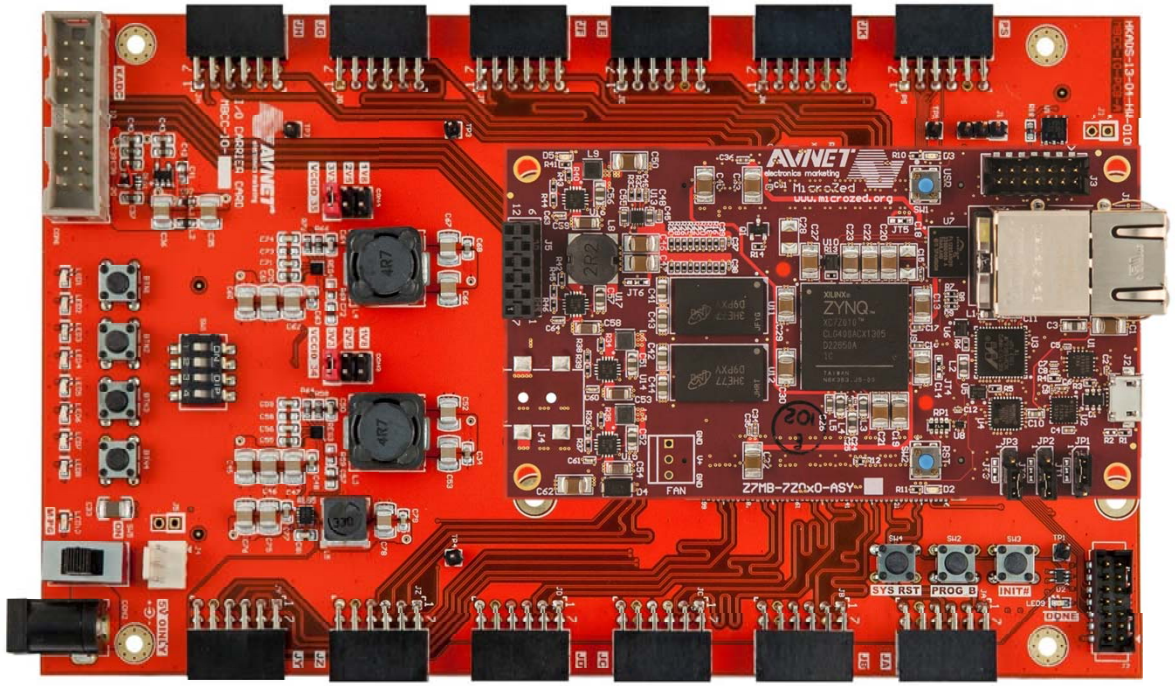


Adding more feedback (Inductive)



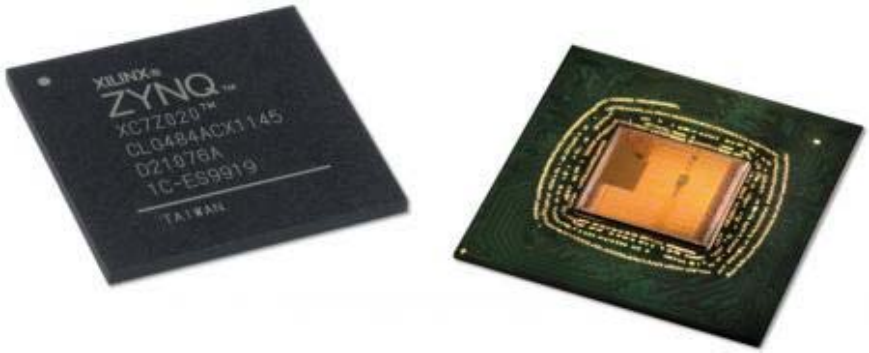
Add more processing power

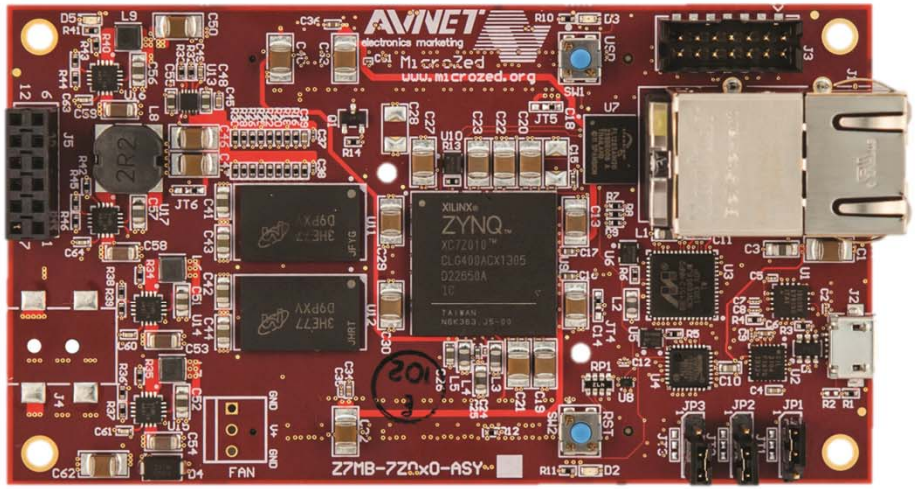
- More efficient processing, more complex algorithms
- Not just more, but faster!
  - True parallel operations



Zynq…best fit!

- More efficient processing, more complex algorithms
- Not just more, but faster!
  - True parallel operations
  - Dual Arm Core up to 1GHz
  - Programmable Logic





Leveraging the Programmable Logic

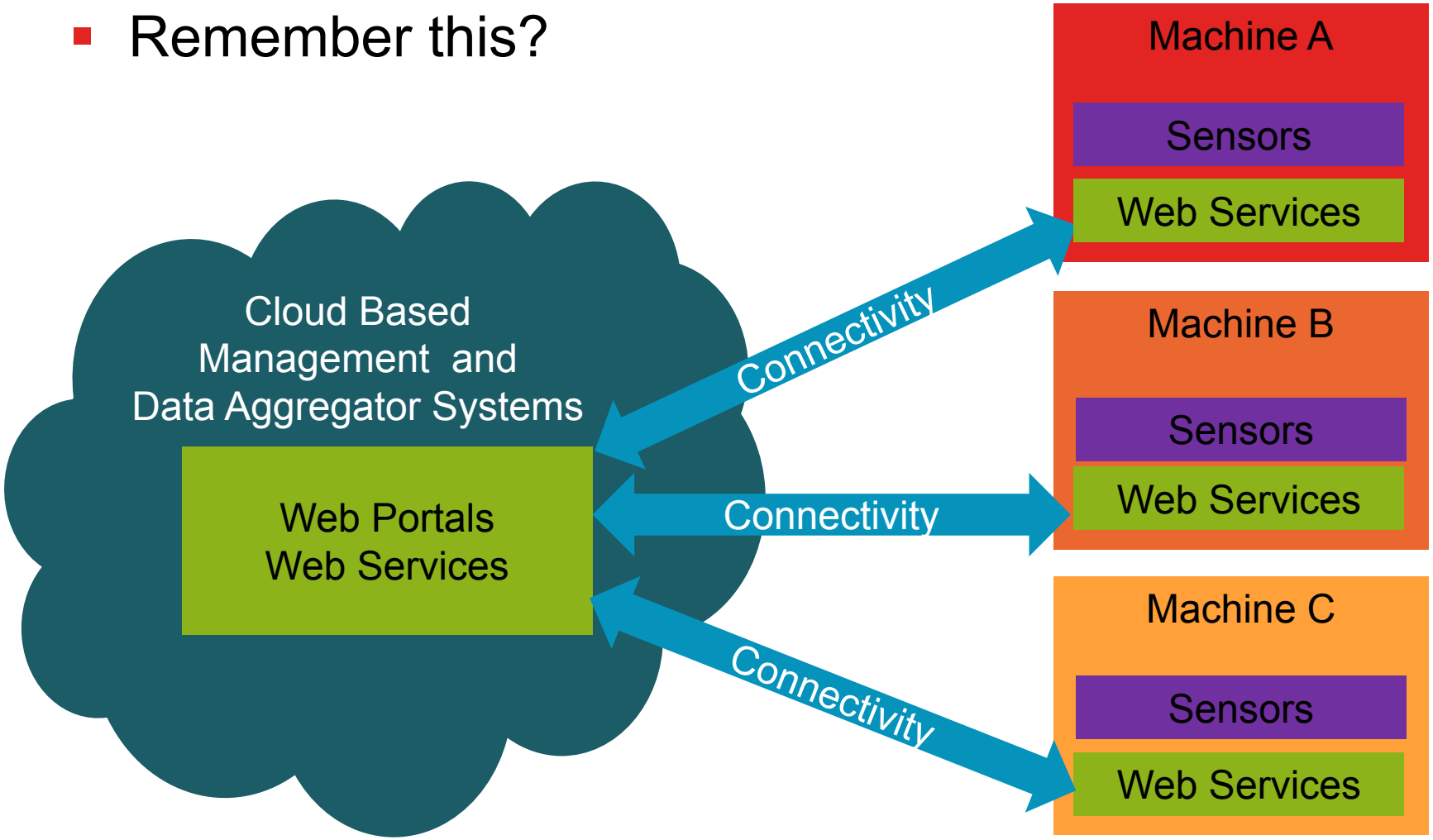
- SDR Waveform Comparison

  - HLS (no optimizations)
    - 400Mhz Clock
    - 1032 Clock Cycle Latency
    - ~2580ns cycle time

  - HLS (optimized)
    - 340Mhz Clock
    - 8 Clock Cycle Latency
    - ~23.5ns cycle time
      despite lower clock rate

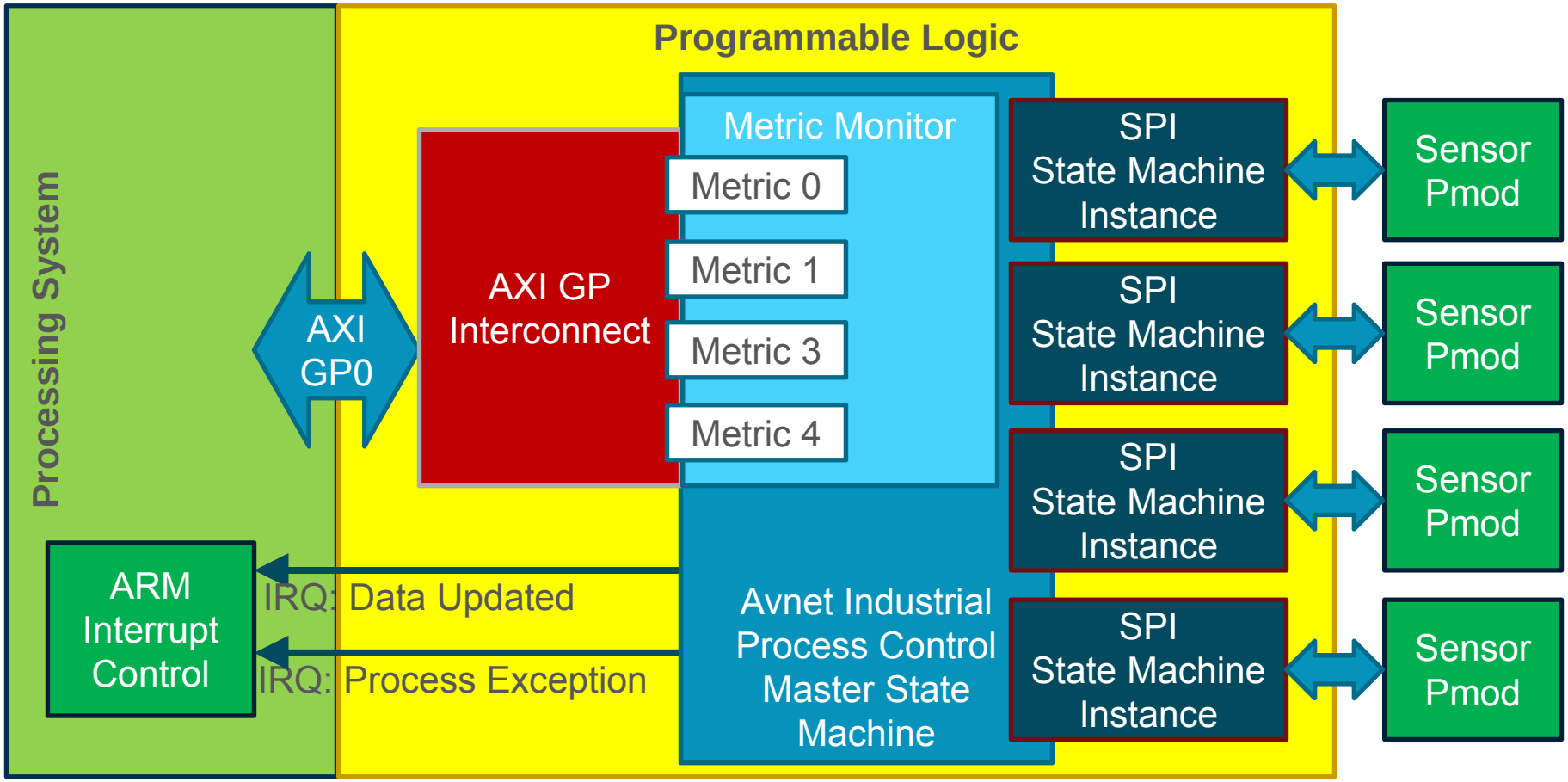
Add Ability for Reporting

- Remember this?



Add Ability for Reporting

- Remember data flows RIGHT TO LEFT ←



Nyquist Strikes again!

- Why 800+Hz?

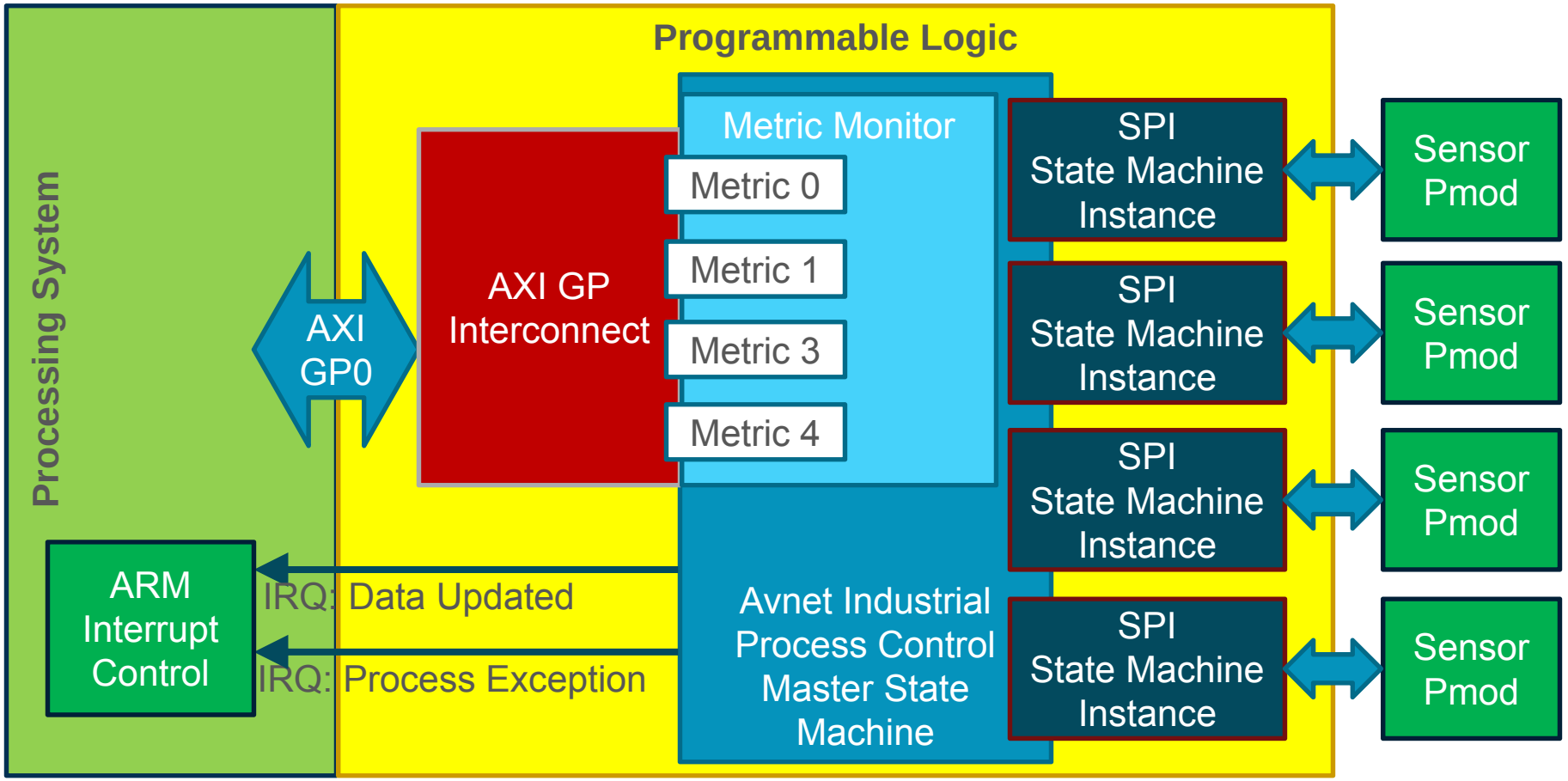
- Typical PEX extrusion process runs at 1000 feet per minute; correcting every 0.5in

  $1000\frac{ft}{min}/60\frac{sec}{min}*12\frac{in}{ft} = 200\frac{in}{sec}$

  $200\frac{in}{sec} / \frac{1}{2}“ \ *2$ (Nyquist) =

- ***$800\frac{samples}{second}$ MINIMUM***

Alerting the PS for Service



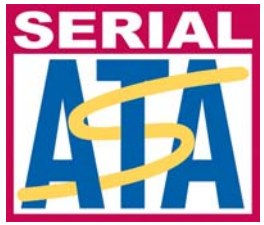
Processing the data in the smarter device

Processing the data in the smarter device

- Need to interface to a wide variety of things (flexible and wide I/O)
- Need to process and analyze the data – potentially with either the PS or a PL accelerator
- Need to digest raw information into meaningful metrics for transmission

Interface to a wide variety of things

- Capturing the data
  - USB, UART, SPI, I2C, Parallel (ADC/DAC), PCI-E, MIPI, JESD204B, CAN, SATA, PCI Express, SDIO, SerialRapidIO and more!
  - Supported through Hard IP, IP download from Xilinx IP library or even custom design!

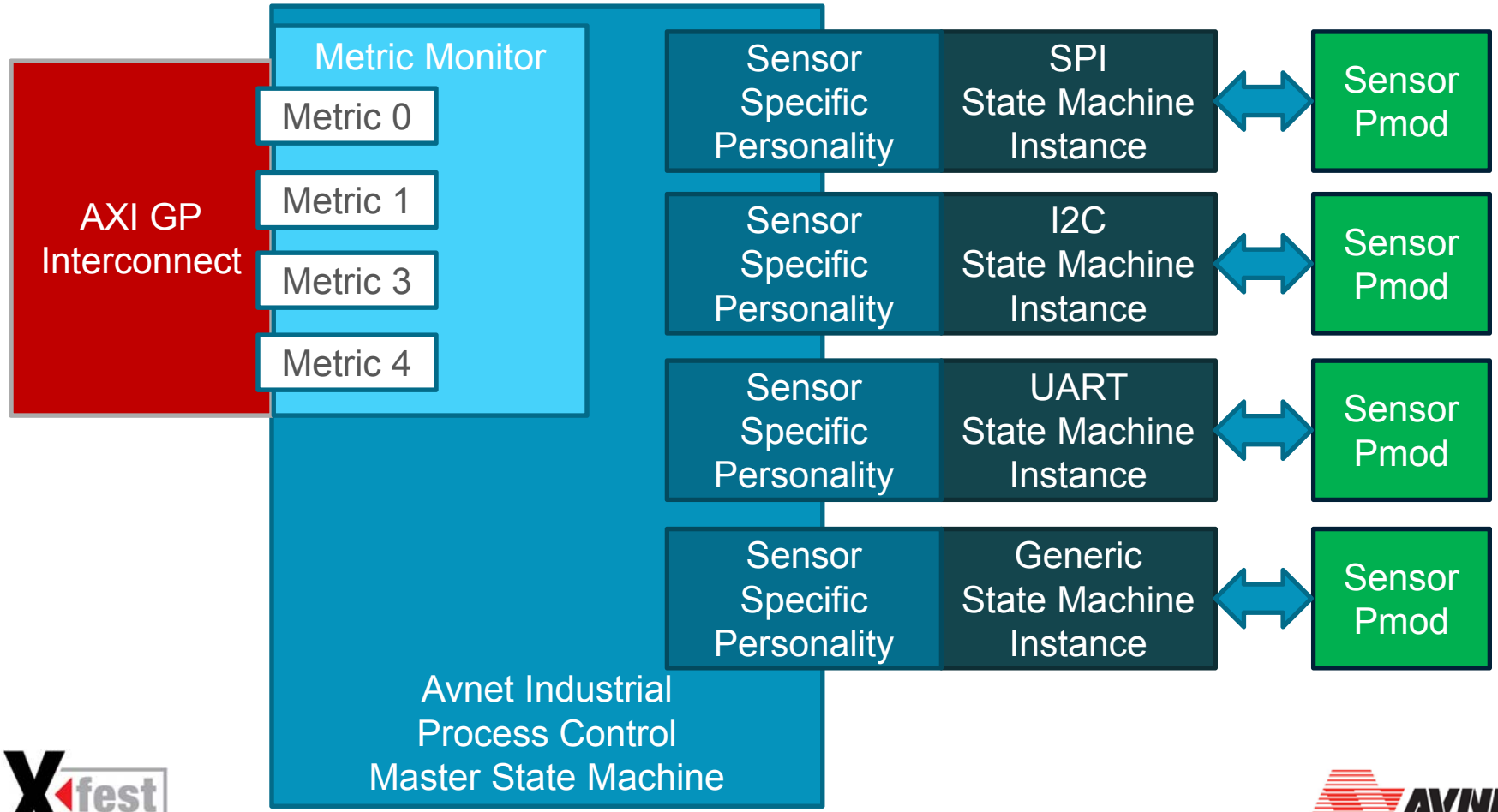


Process and analyze the data

- Process and analyze the data – potentially with either the PS or a PL accelerator

Digesting raw information

- Digesting raw information into meaningful metrics for transmission



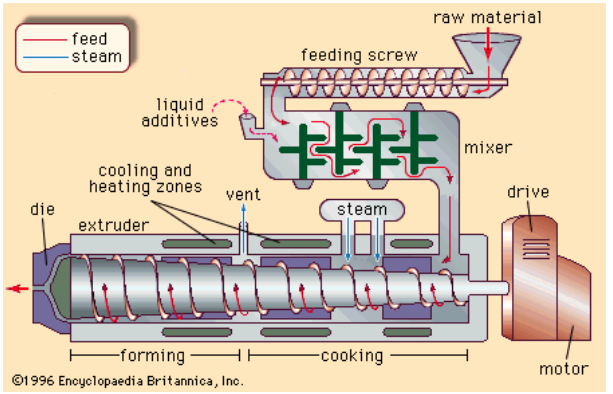
Connecting to the cloud

Connecting Zynq to the cloud

- Many Industrial Ethernet Standards are enabled by Zynq (most are MAC level controls, REQ. PL)
- Easier to implement IP stacks due to Zynq enabling Linux
- Wireless technology
  - Bluetooth (BLE)
  - 802.15.4 (Zigbee / 6LowPAN)
  - Custom
  - WI-FI

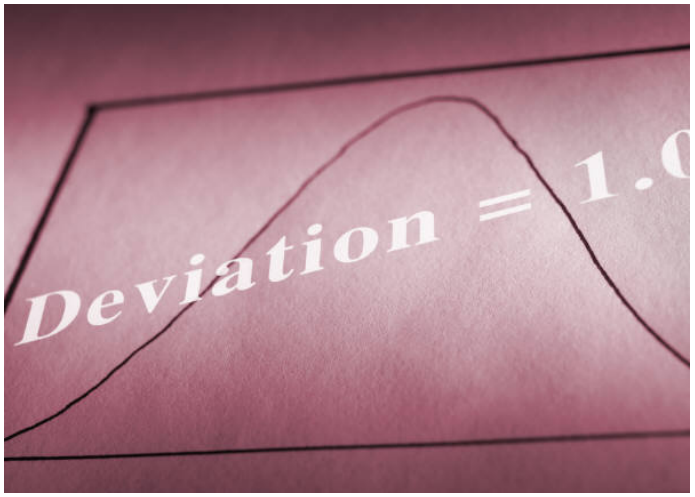
Why do this? – Feeding the Cloud

- Why do this?
  - If the system is so autonomous, why?
- Consider our data set
  - Make 1 widget, no real metrics
  - Make 1,000+ widgets, we can start to formulate patterns from the data
- Provides ability to start data mining



Why do this? – Feeding the Cloud

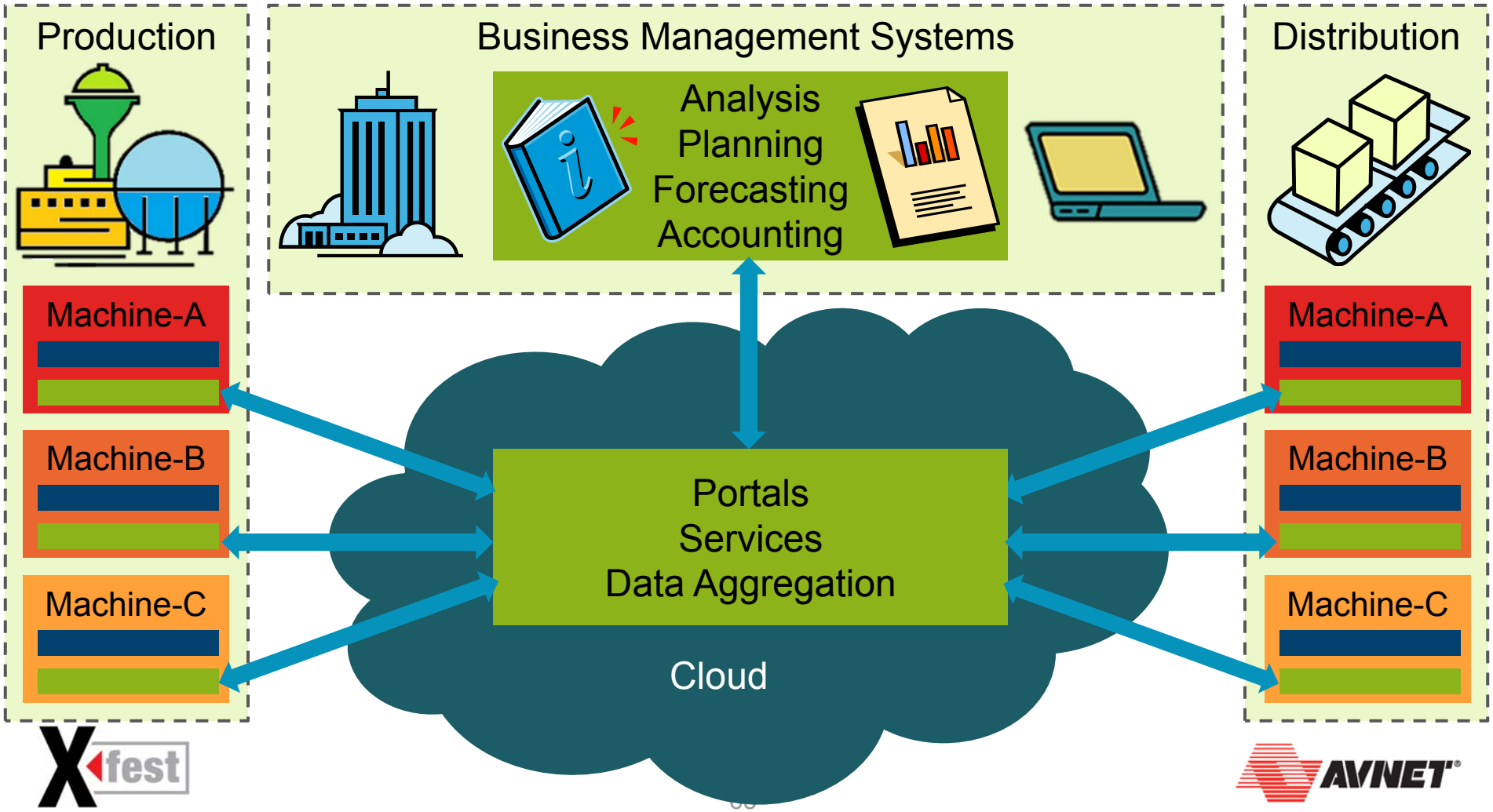
- Supplier's media typically follows a bell curve
- Poor quality media ends up at upper or lower ends of deviations
  - Machine auto correct temperature / pressure / etc. based on media being used
  - PS Need only request this information from the cloud



- Conclusion?
  - Lower cost might cost more in hidden manufacturing costs
  - Now we are tracking this!

Smarter Systems for Smarter Business

- Analytical control across entire business operations



Why do this? – Using the cloud

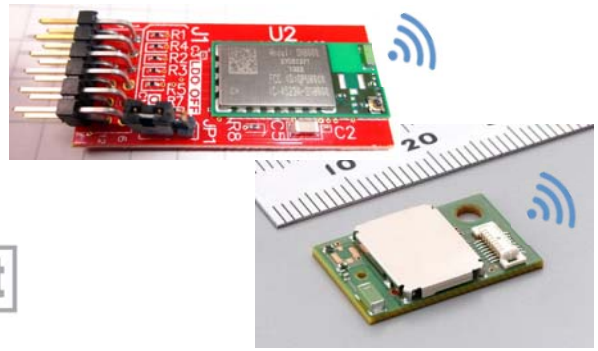
- Questions to consider for your application:
  - What metrics are useful?
  - How do you get them?
  - How do useful metrics keep you competitive?
  - Where do you need to get to?

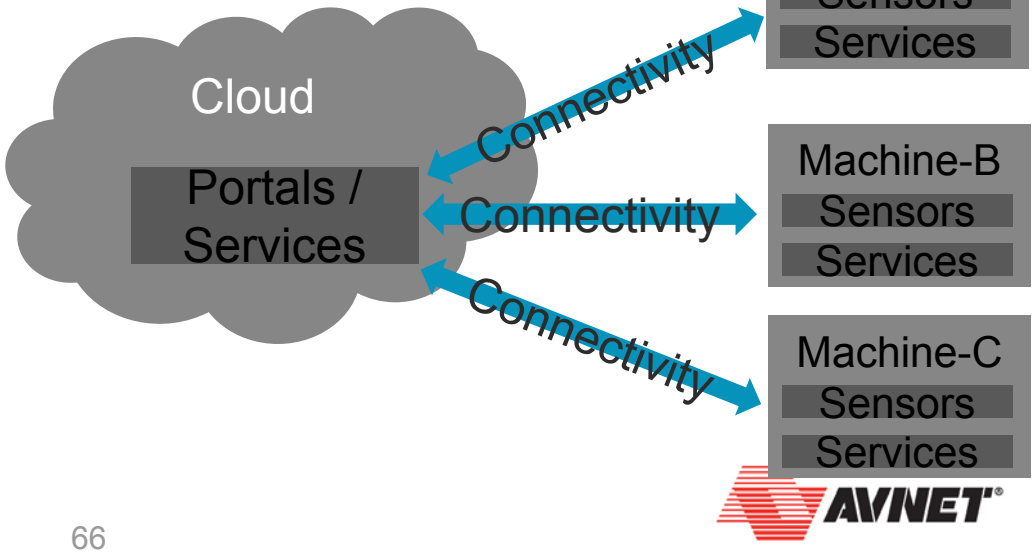
Where to find more information

Adding Wireless Connectivity to Zynq Systems

- Linux-based Zynq platforms facilitate LAN and WLAN Network Connectivity with sophisticated data transport and security options
- Flexibility of SoC FPGA based solutions allows local Sensor-Hub data processing and connectivity to be efficiently added
- Wireless connectivity gets comprehensive coverage at X-Fest at the following course:

"Adding Wireless Connectivity to Zynq Systems"

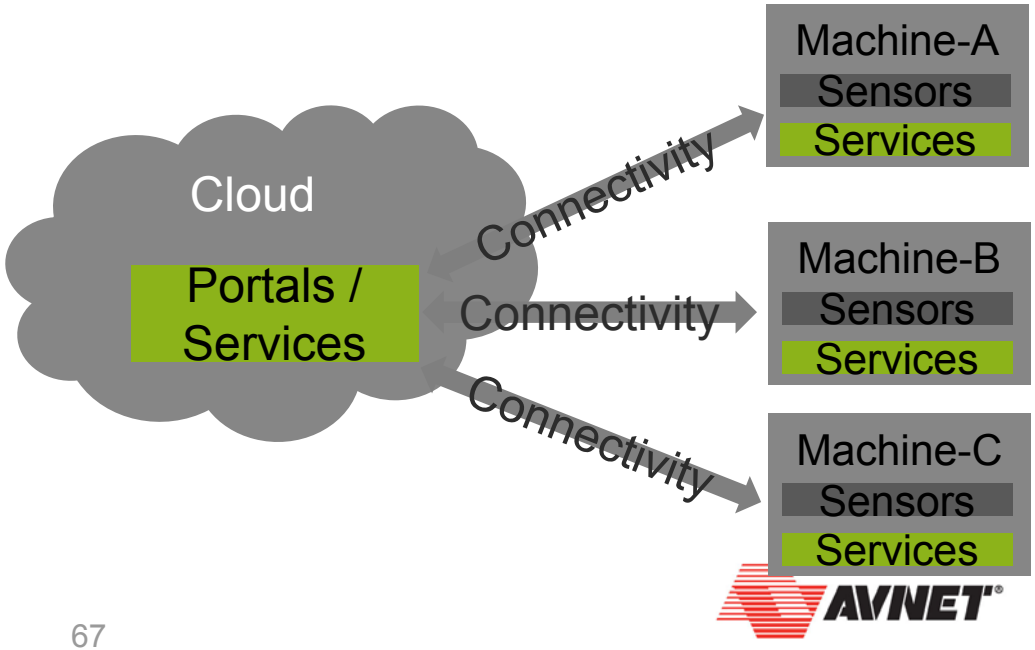




Building Blocks for Enhancing User Interfaces

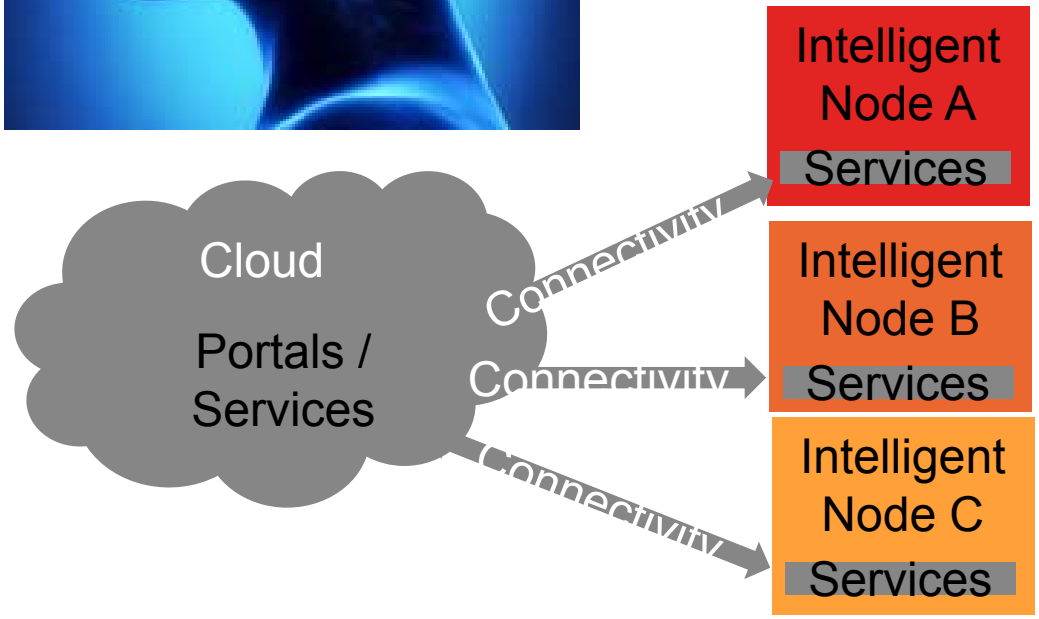
- Zynq SOM based solutions provide flexible I/O needed to tie multiple user interface components together quickly

- User interface and web based services covered at X-Fest in this course later today



Adding Smarter Vision to your Product with Zynq

- Today
  - Image Sensor + Processing
  - Intent
    - Understand scene
    - Video analytics
  - Challenges
    - high pixel rate video and image processing
    - complex analytics operations



Exclusive Post X-fest Coverage

For Attendees Only!!!

www.xfest2014.com

- PDFs of all presentations
- Course forums


Thank You
Asante
Shukria
Dhanyavadagalu
Vinaka
köszönöm
Kiitos
Maake
Manana
Dankon
Kam Sah Hammida
Matondo
Terima Kasih
Taiku
Tack
Dank Je
Dankscheen
спасибо
Mauruuru
Biyan
Blagodaram
Ngiyabonga
Dziekuje
Chokrane
Diolch i Chi
Grazie
Juspaxar
Arigato
Mochchakkeram
Gracias
Khap
Tingki
Paldies
நன்றி
धन्यवाद
cảm ơn bạn
Gratias Tibi
Ua Tsaug Rau Koj
Bedankt
Dakujem
Grazas
Kia Ora
Kop Khun
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Nirringrazzjak
Di Ou Mèsi
ありがとう
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Welalin
Djiere Dieuf
Matur
谢
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Misaotra
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Merci
Go Raibh Maith Agat
Eskerrik Asko
Salamat
ขอขอบคุณคุณ
Najis Tuke
хвала