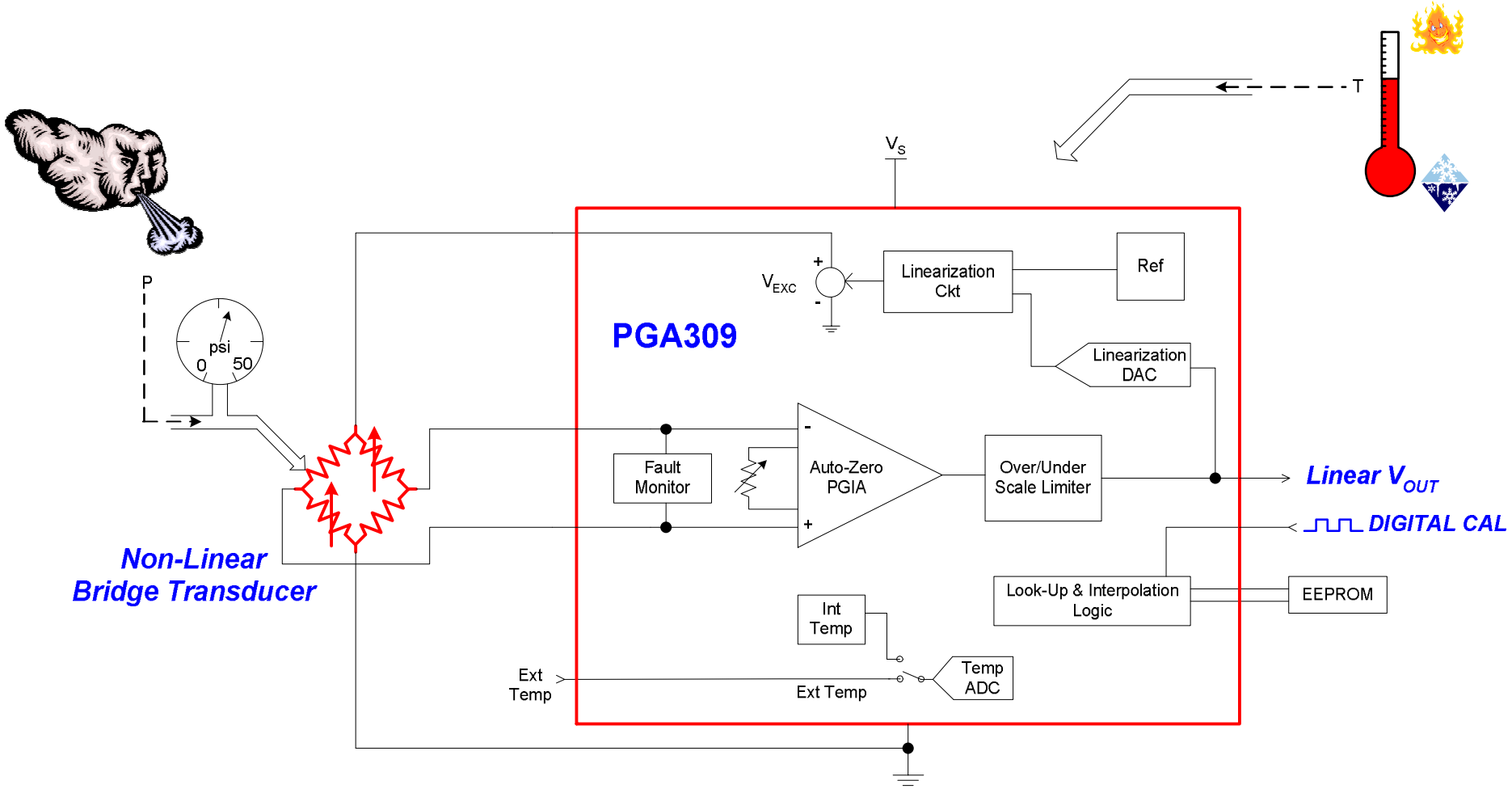
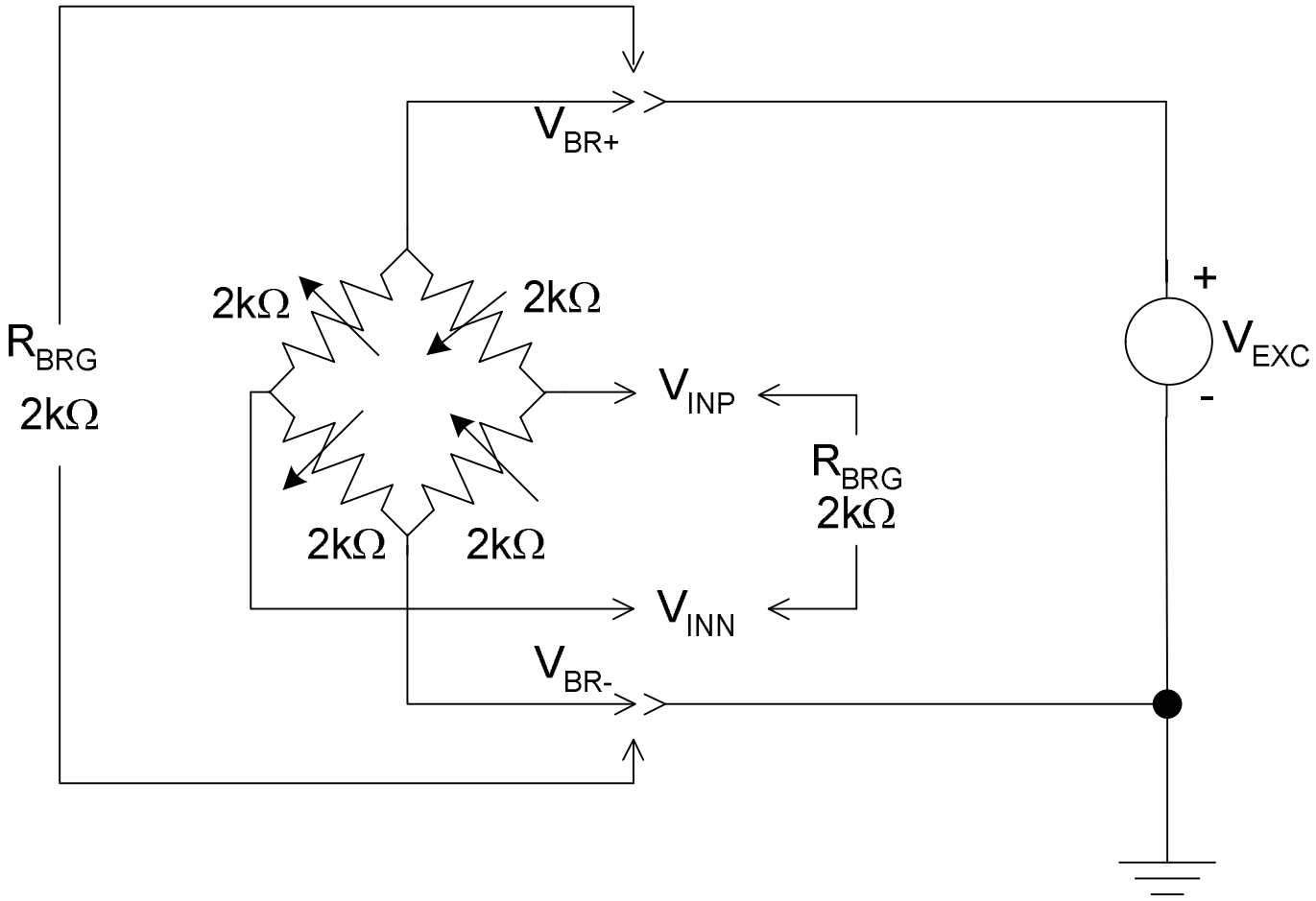
PGA309 – Programmable Sensor Signal Conditioner

"Bringing Linearity to a Non-Linear Pressure Sensor World"



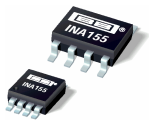
Typical “Wheatstone Bridge” Pressure Sensor

Bridge Resistance is Symmetrical

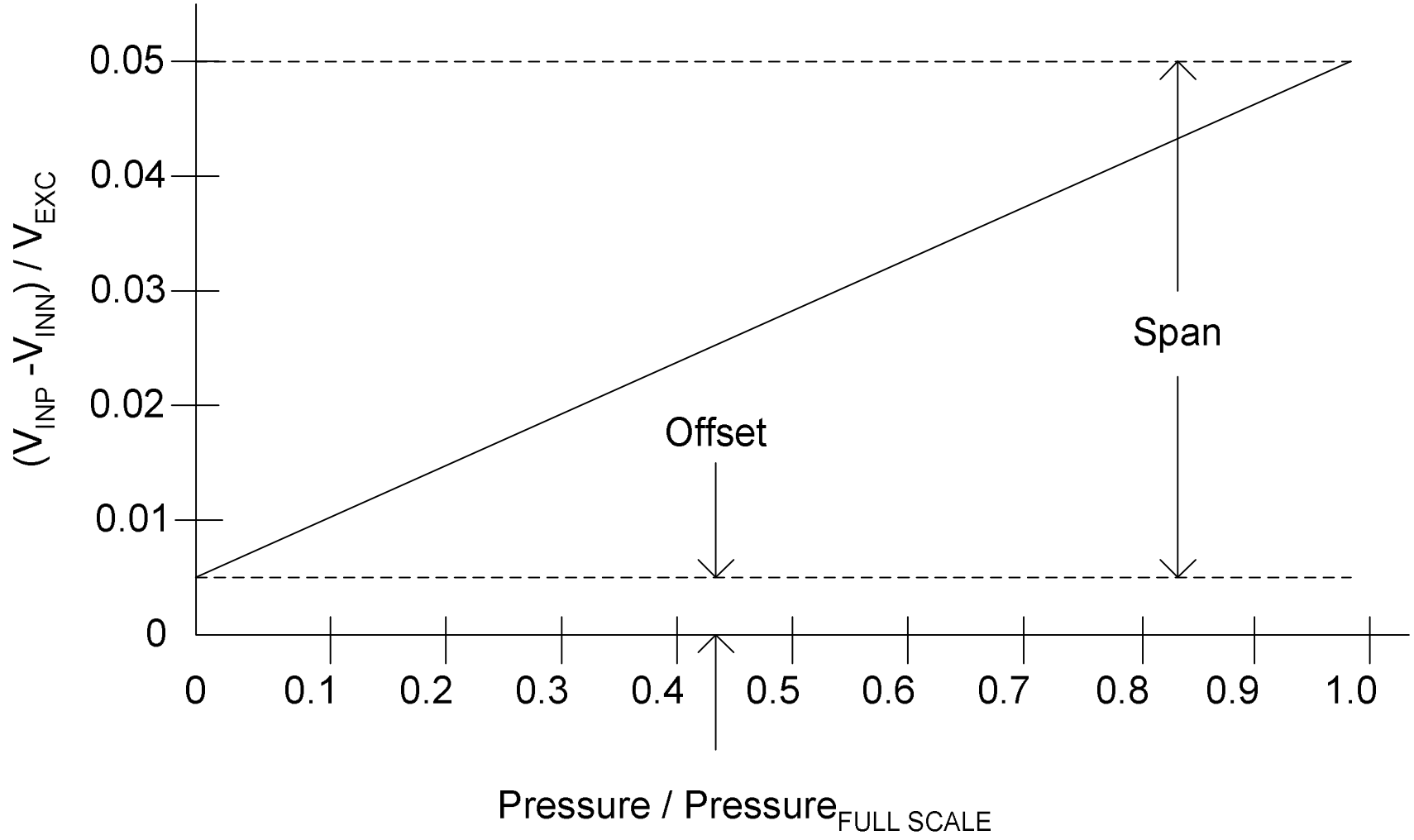


Pressure Sensor Terminology

- Span
  (Scale factor for V_{INP}-V_{INN} @ Full-Scale Pressure relative to V_{EXC})
  - FSO (Full Scale Output)
  - FSS (Full Scale Sensitivity)
  - “Gain”
  - Sensitivity
    - i.e. 2mV/V
      (implies V_{INP}-V_{INN} = 10mV @ FS Pressure with V_{EXC}=+5V)
- Offset
  (V_{INP}-V_{INN} @ Zero Pressure)
  - Zero
    - i.e. 10mV

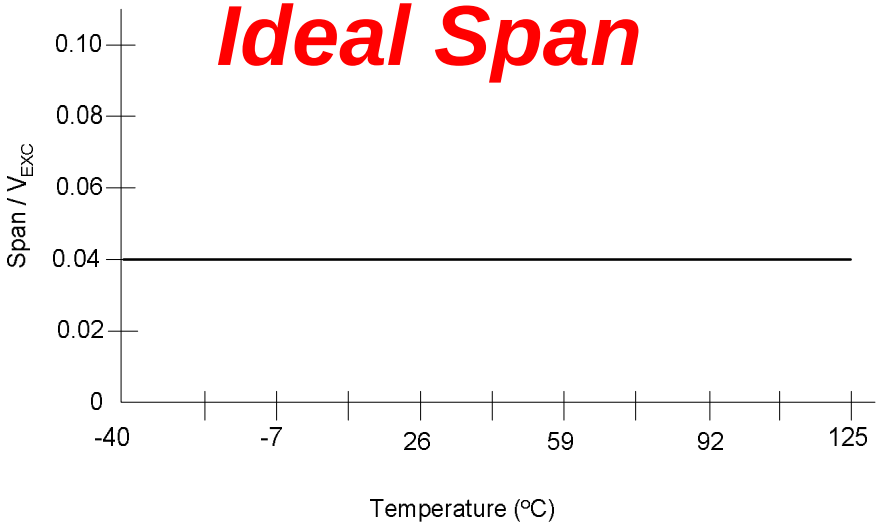


Definition of Offset & Span

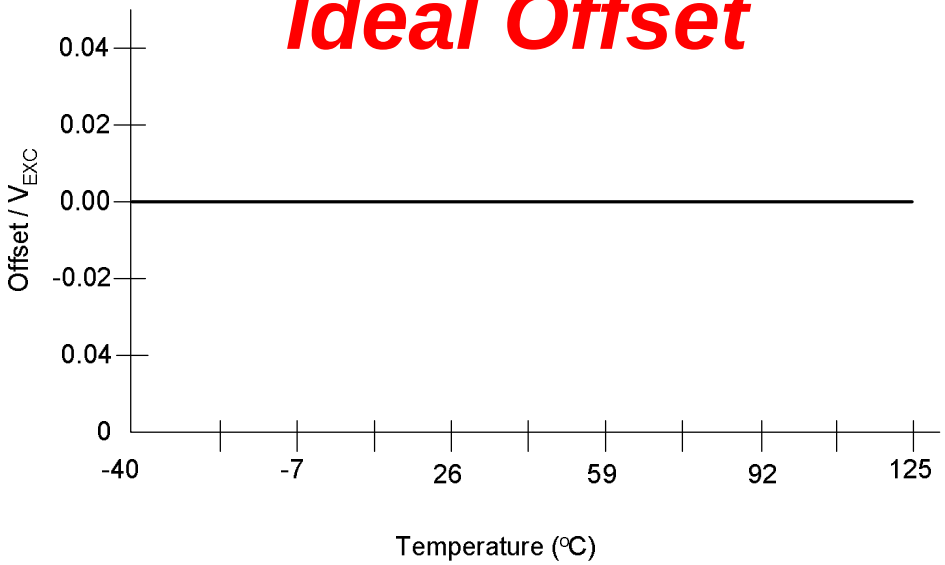


Ideal Span & Offset

Ideal Span



Ideal Offset



Real World Sensors

- Span
  - Variations @ 25°C
  - Linear changes with Temperature
  - NonLinear changes with Temperature
- Offset
  - Variations @ 25°C
  - Linear changes with Temperature
  - NonLinear changes with Temperature
- Bandwidth
  - ≤4kHz for most pressure sensor applications

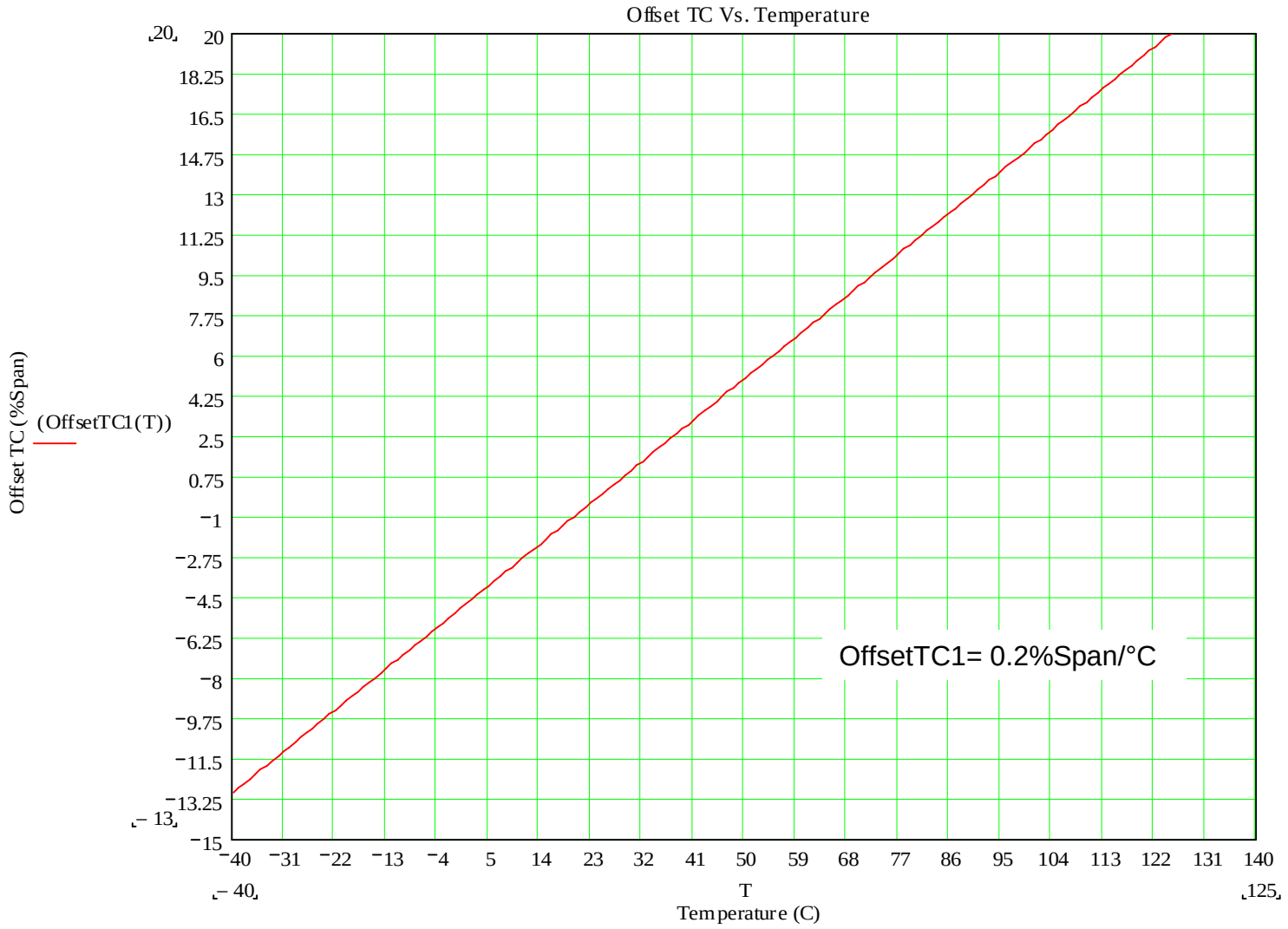
Typical Pressure Sensor NonLinearities

- **Initial Offset**: -2%< Offset <+2% (of V_{EXC})
- **OffsetTC1**: -0.1%< OffsetTC1 <+0.3% (of Span/^{o}C)
  - (Linear Offset Temperature Coefficient)
- **OffsetTC2**: -0.5%< OffsetTC2 <+0.5% (of Span)
  - (NonLinear, Second-Order, Offset Temperature Coefficient)

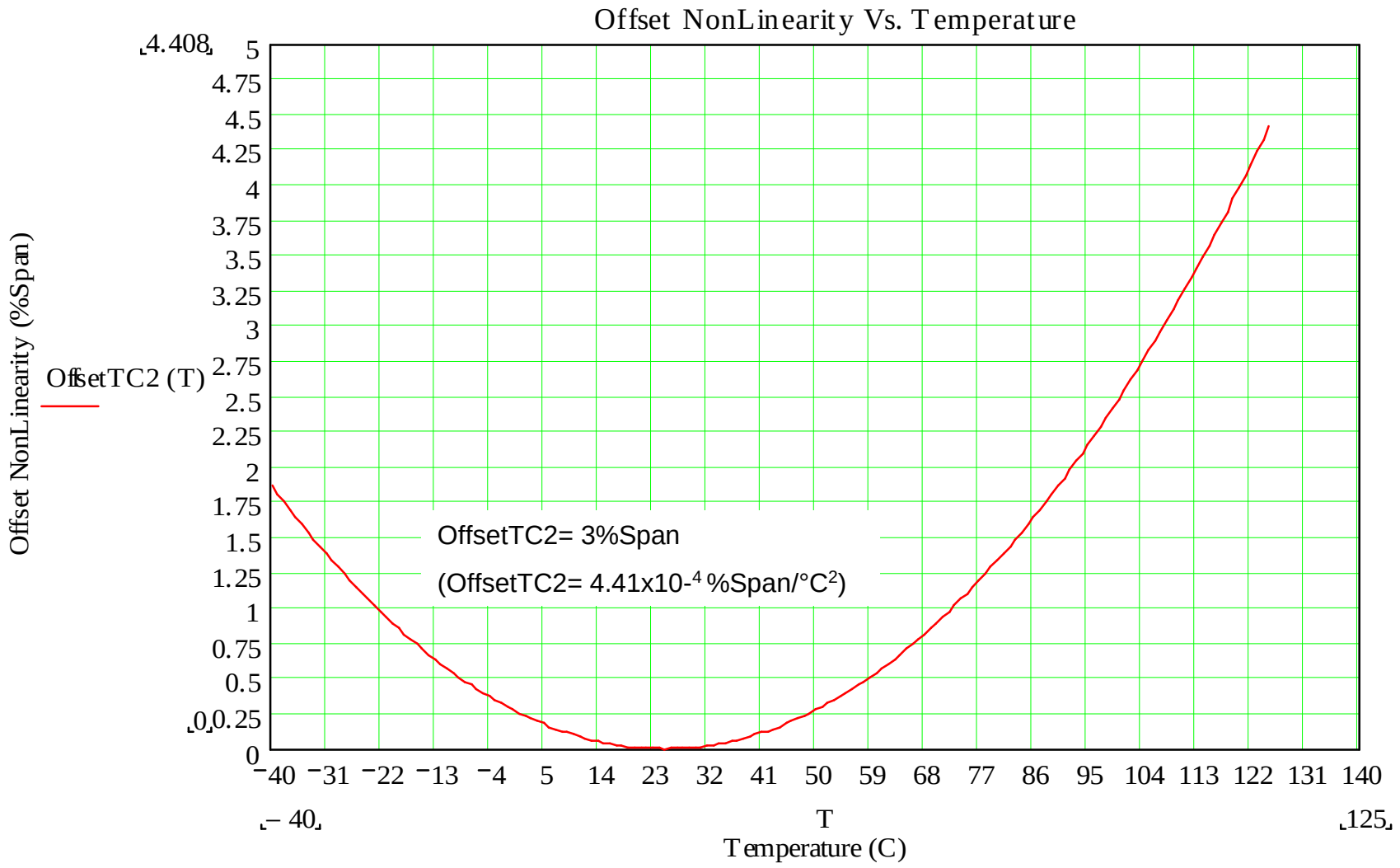
- **Initial Span**: -0.4%< Span <+16% (of V_{EXC})
- **SpanTC1**: -0.3%< SpanTC1 <+0.3% (of Span/^{o}C)
  - (Linear Span Temperature Coefficient)
- **SpanTC2**: -2%< SpanTC2 <+3% (of Span)
  - (NonLinear, Second-Order, Span Temperature Coefficient)

- ***Many Sensors also have higher order NonLinearities***

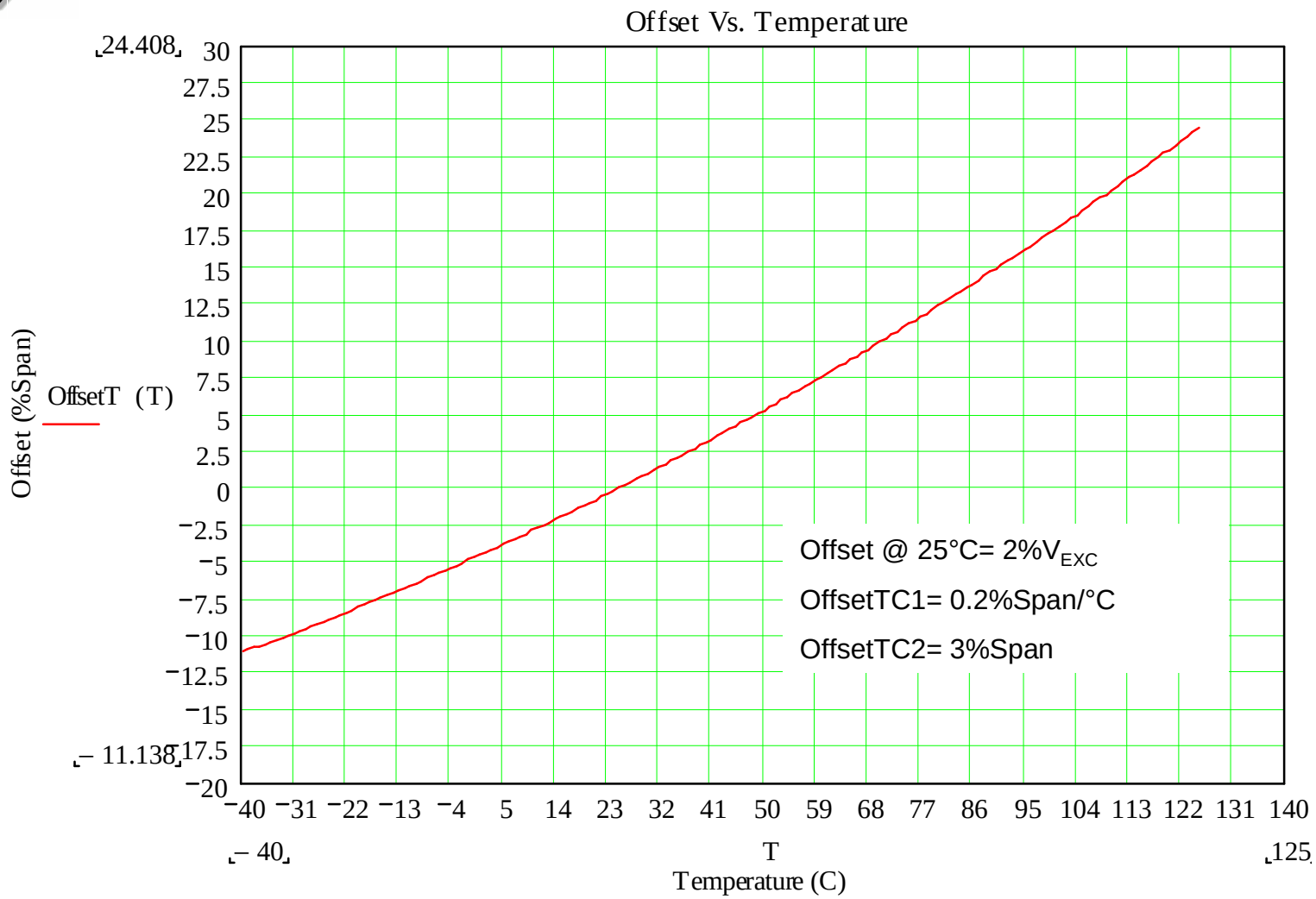
Typical OffsetTC1



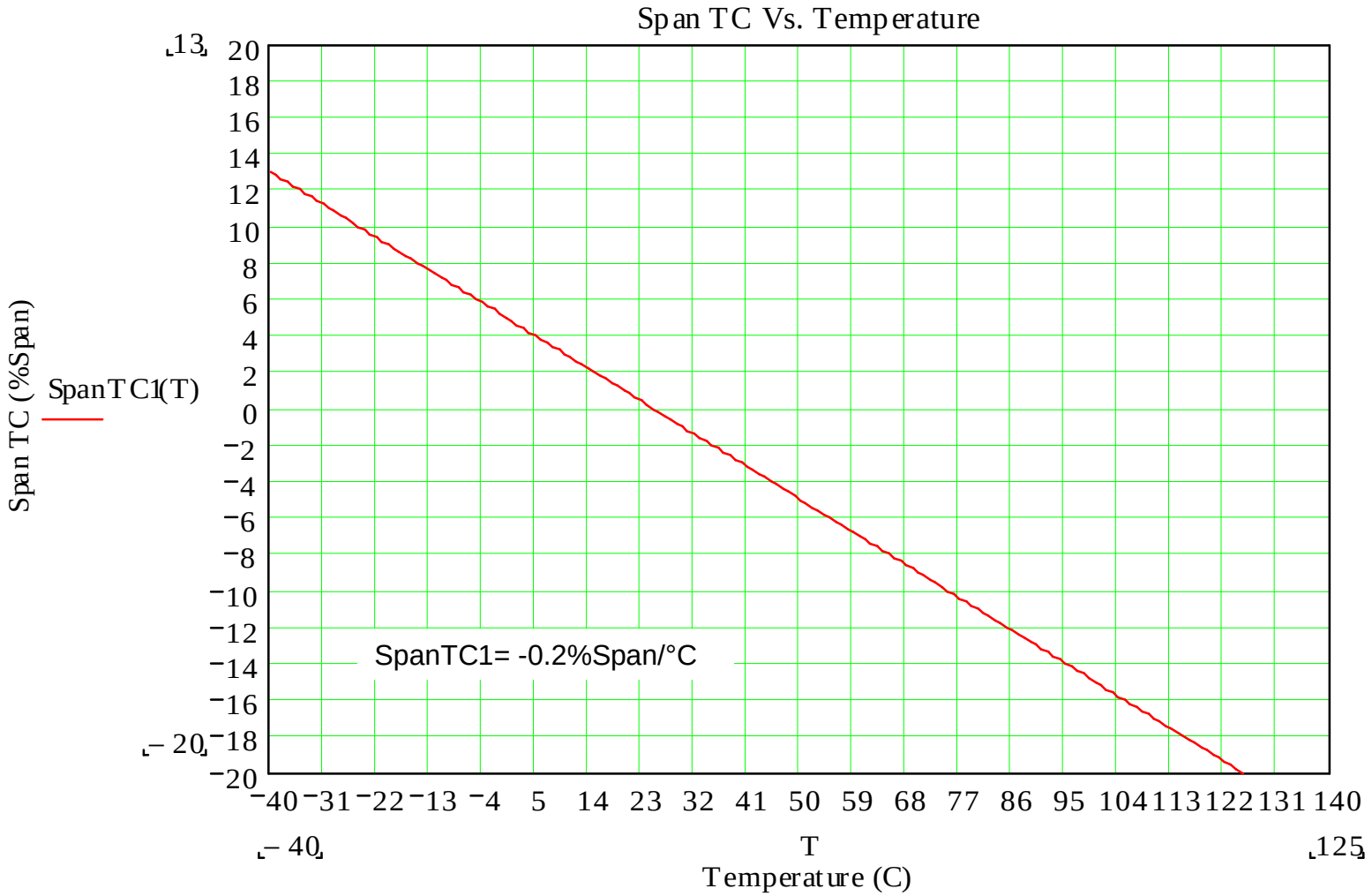
Typical OffsetTC2



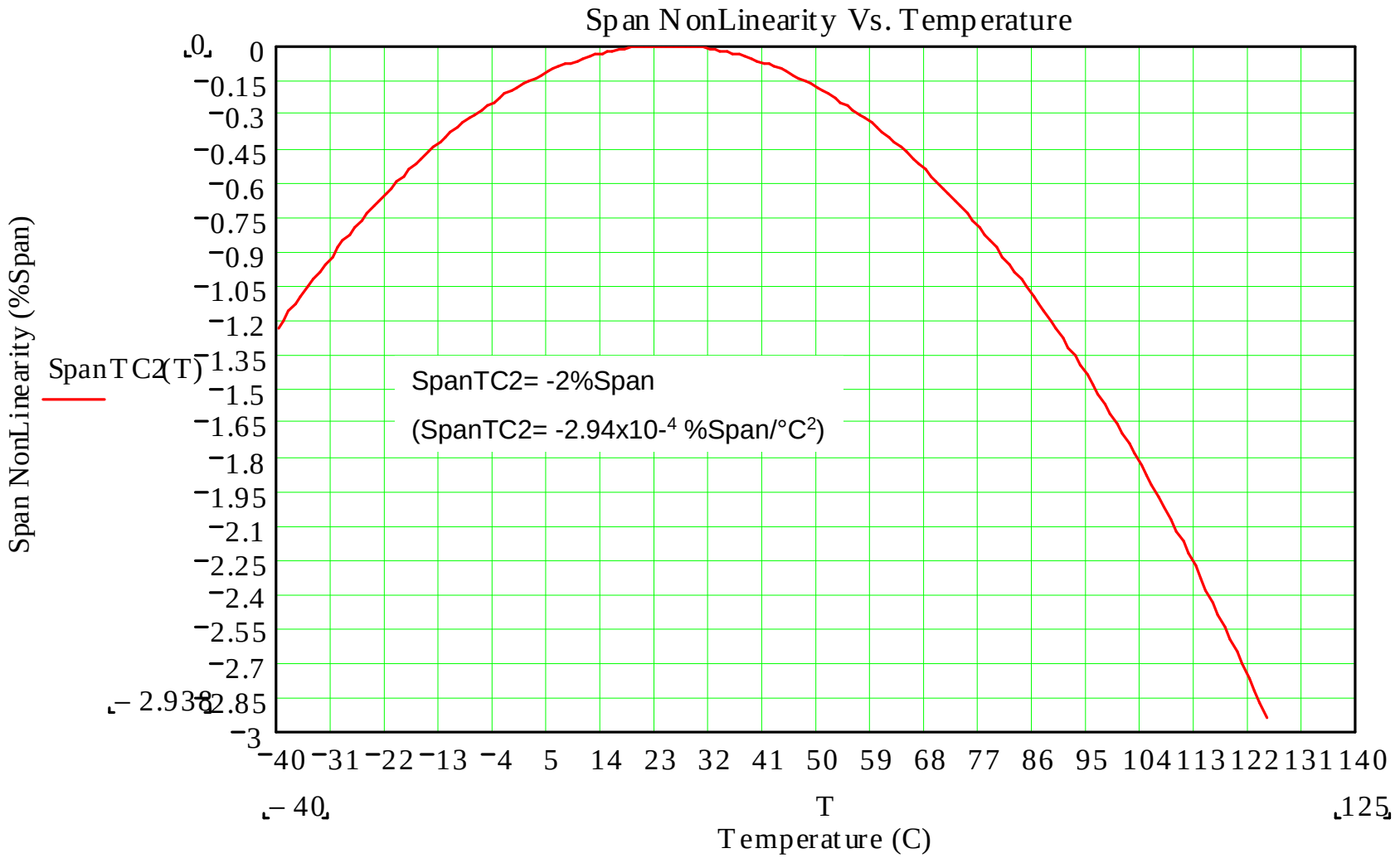
Typical Total Offset vs Temp



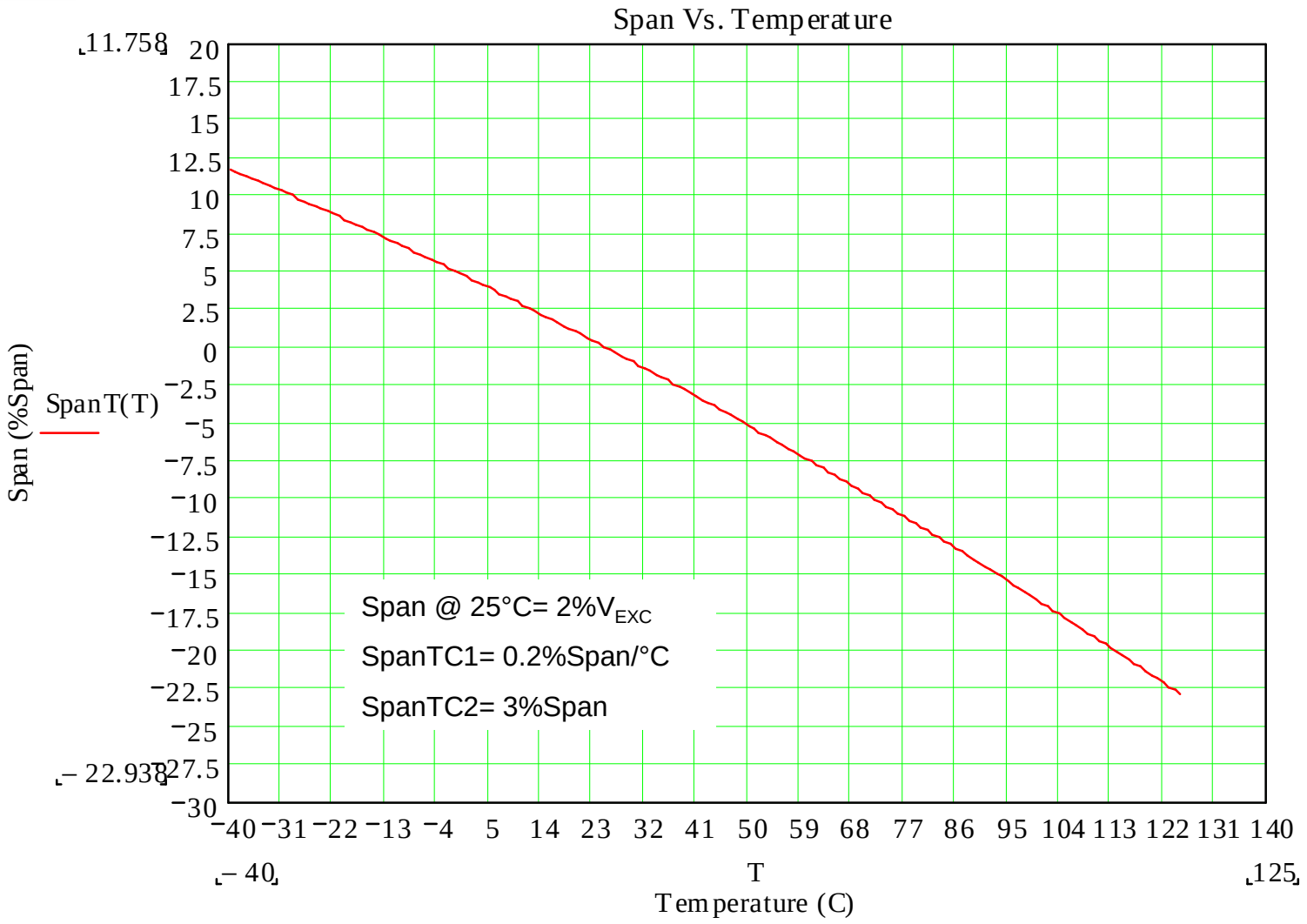
Typical SpanTC1



Typical SpanTC2



Typical Total Span vs Temperature

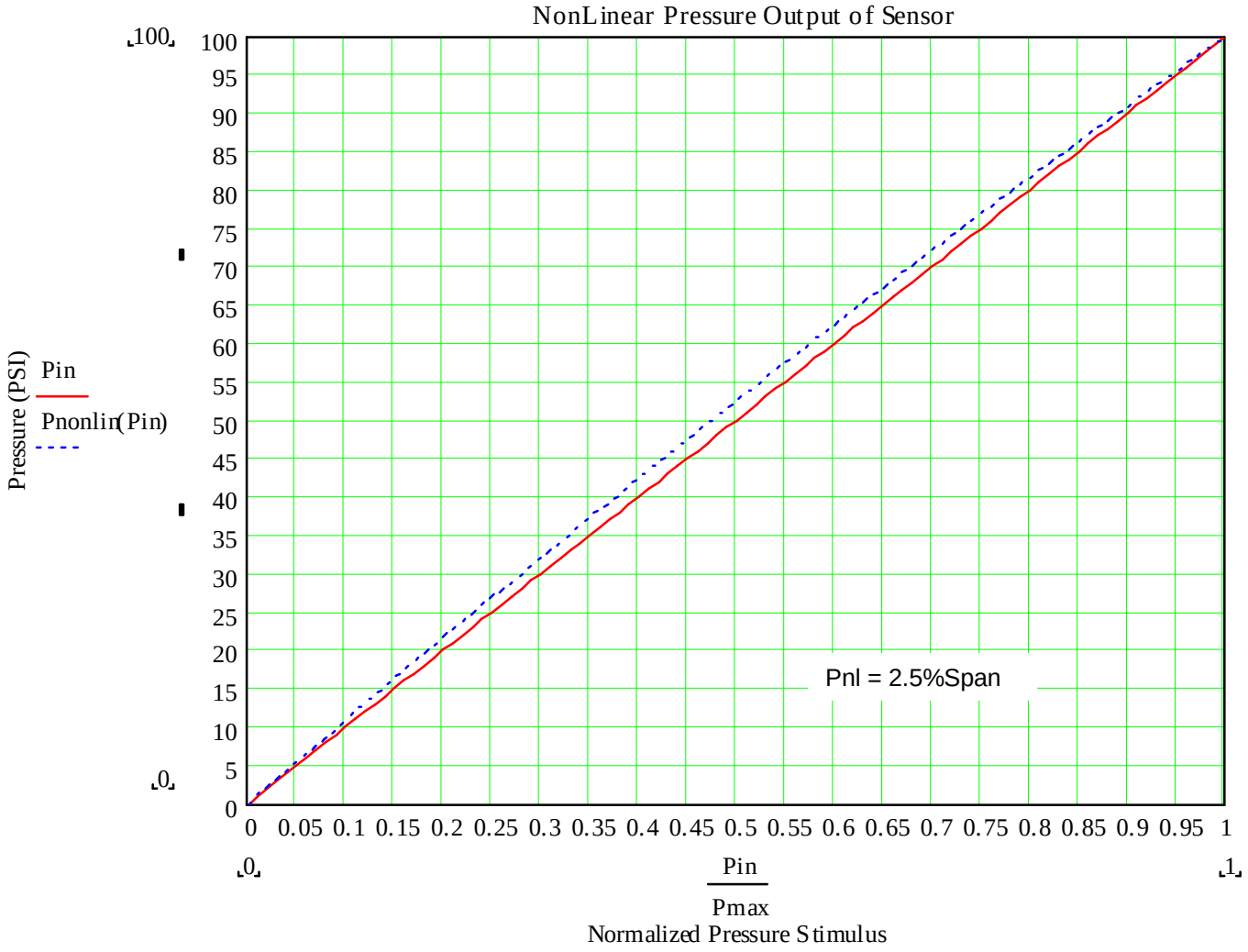


Pressure NonLinearity

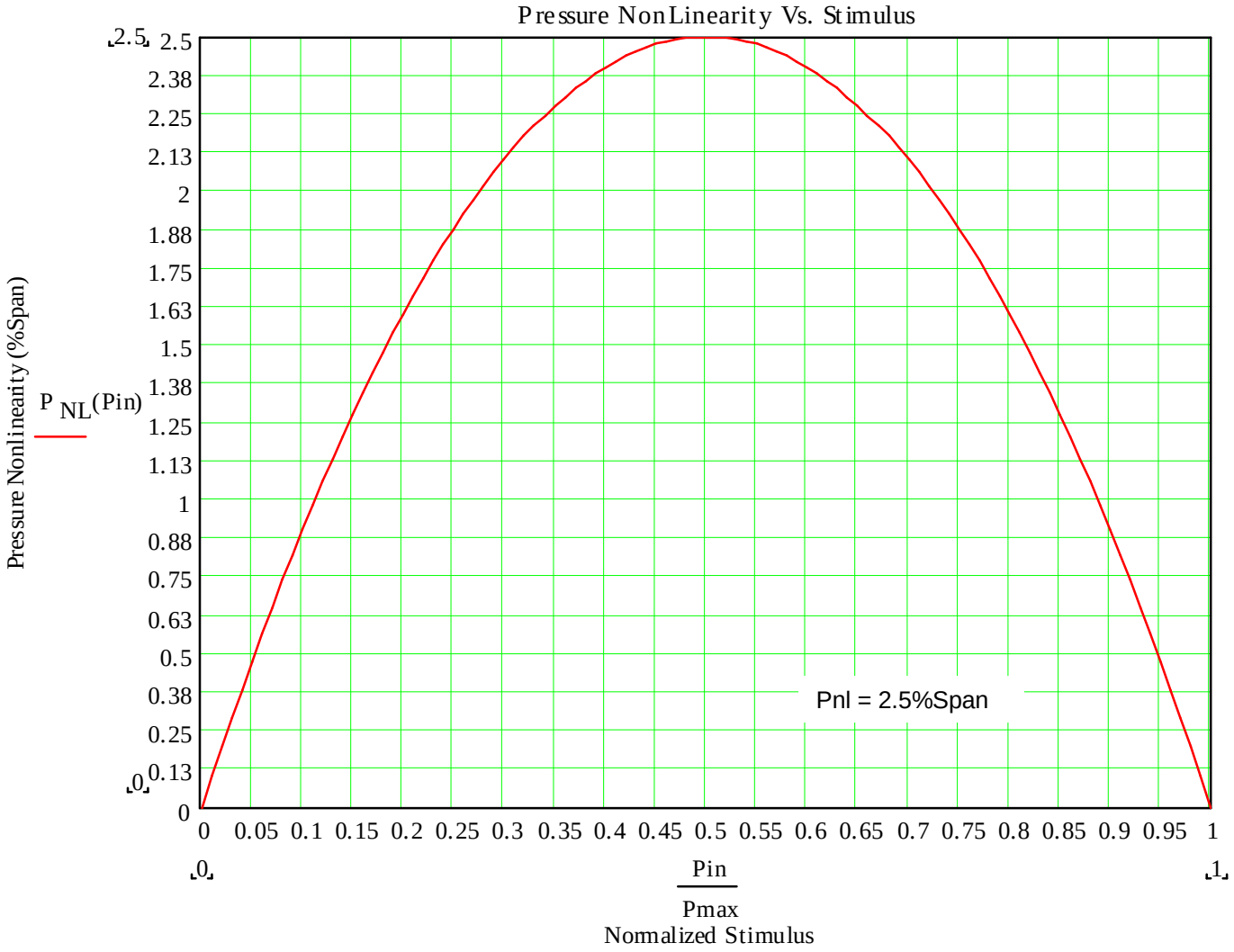
- Many Bridge Sensors also have NonLinear Outputs with applied Pressure
- Typical Pnl (Pressure NonLinearity)

  -2.5%< Pnl <+2.5% (of Span)

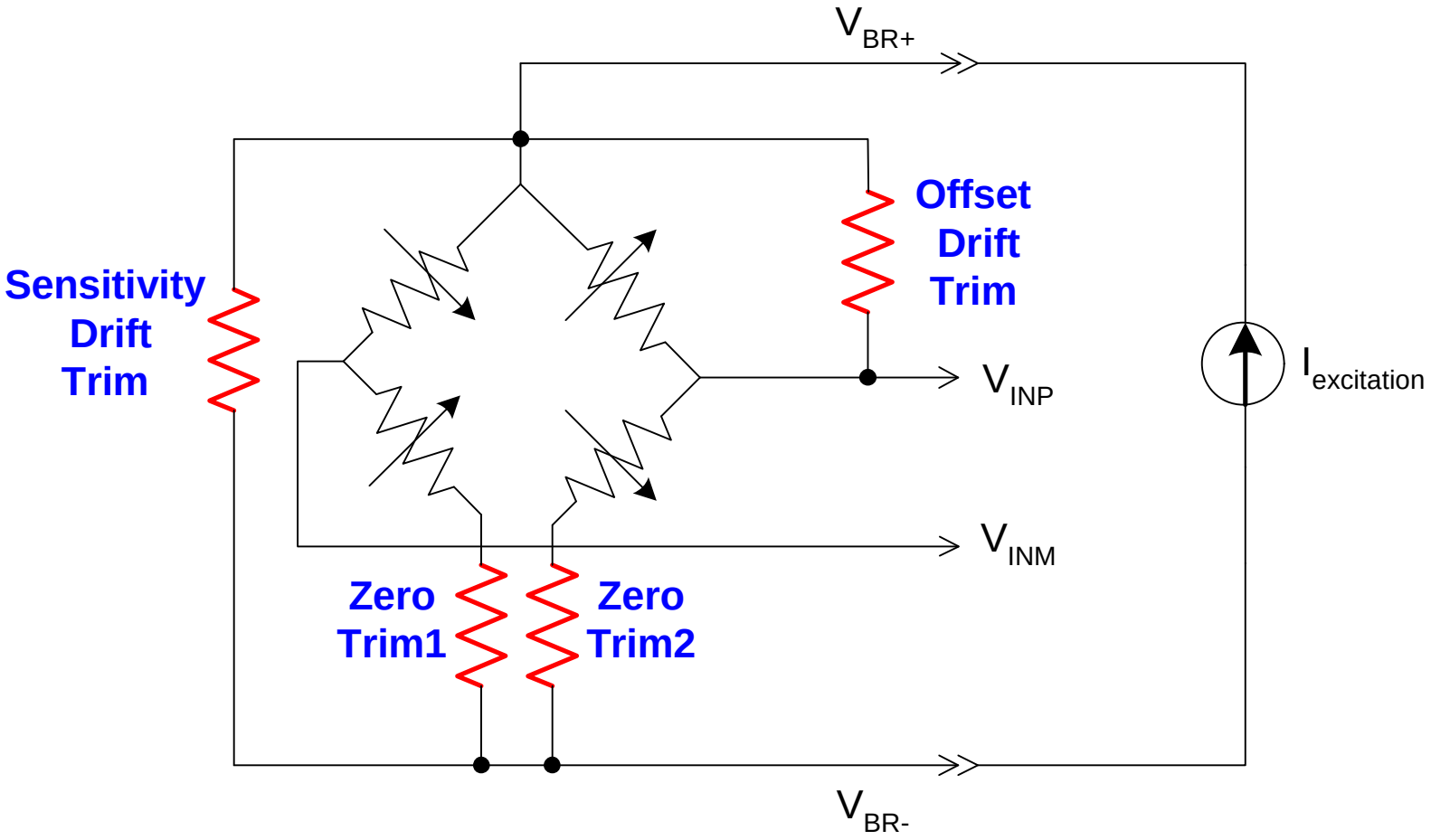
Pnl (Pressure NonLinearity) Example



Pnl (Pressure NonLinearity) Example



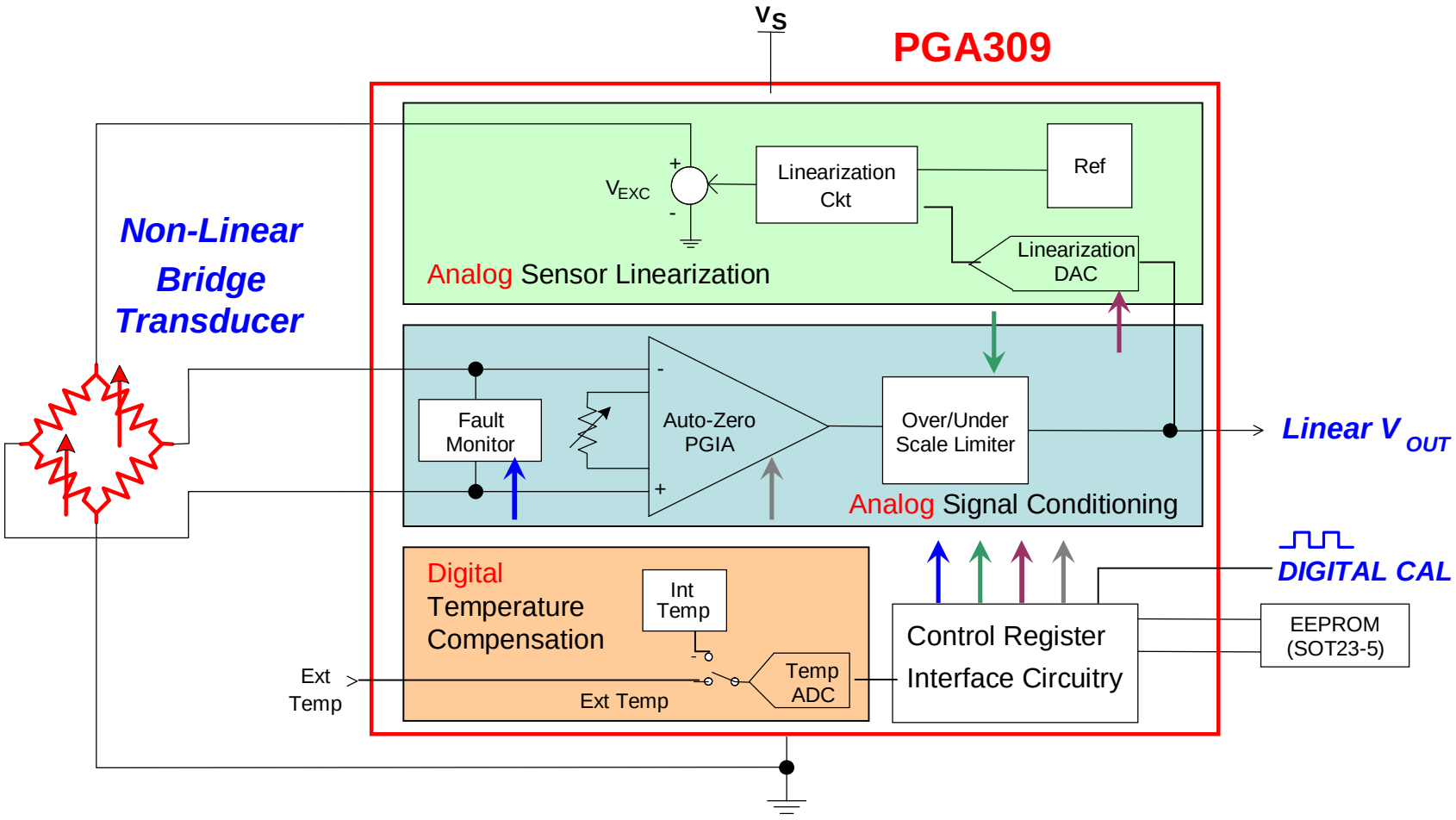
Traditional Trim for NonLinearities



Traditional Trim for NonLinearities

- Requires special pre-package fixtures
- Requires special laser or manual resistor trims
- Trims are interactive with each other
- Multiple test/trim/test/trim passes required
- Finite number of trims and range
- No 1-step easy trim for electronics & sensor

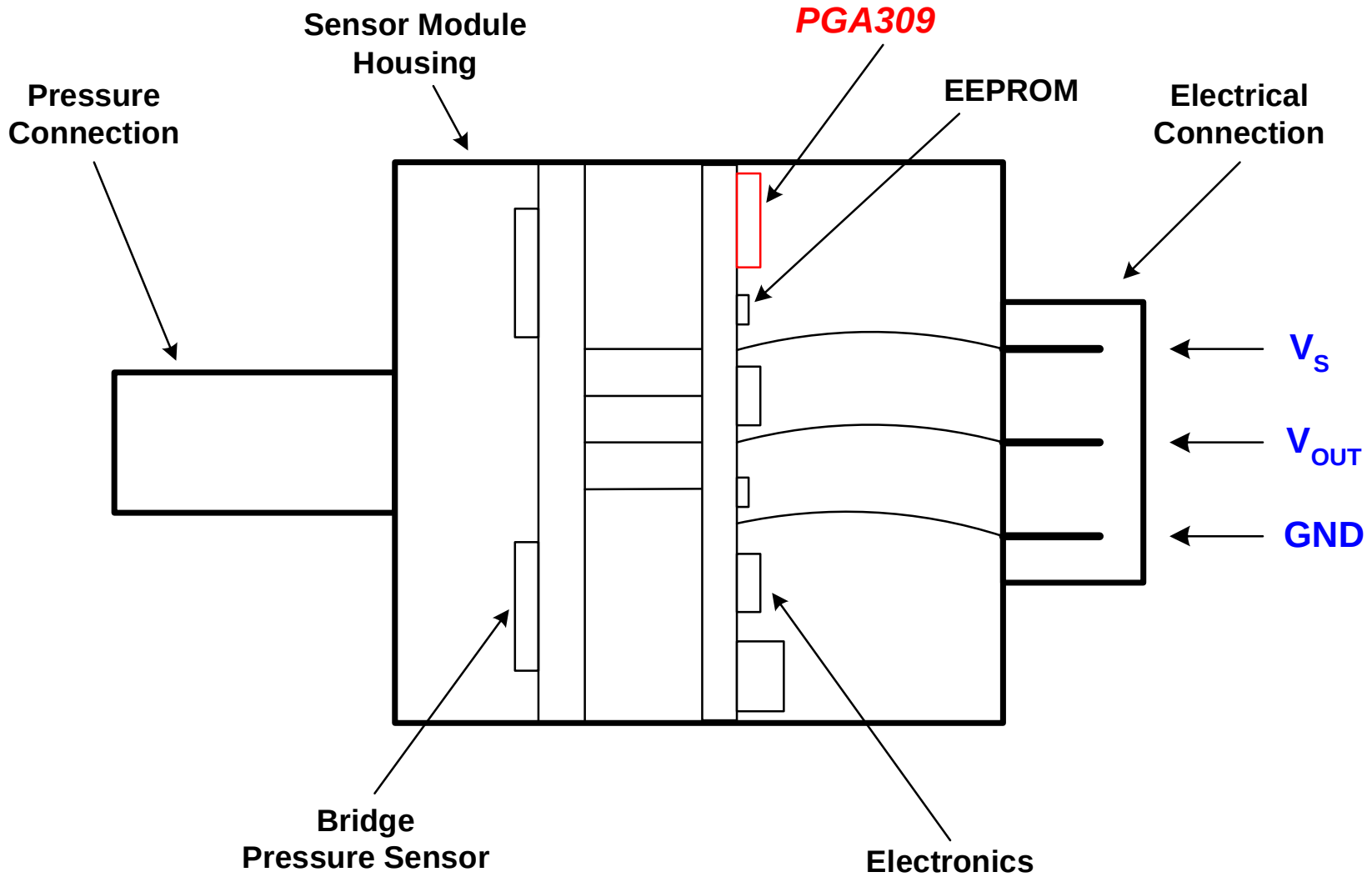
Modern Digital Trim for NonLinearities



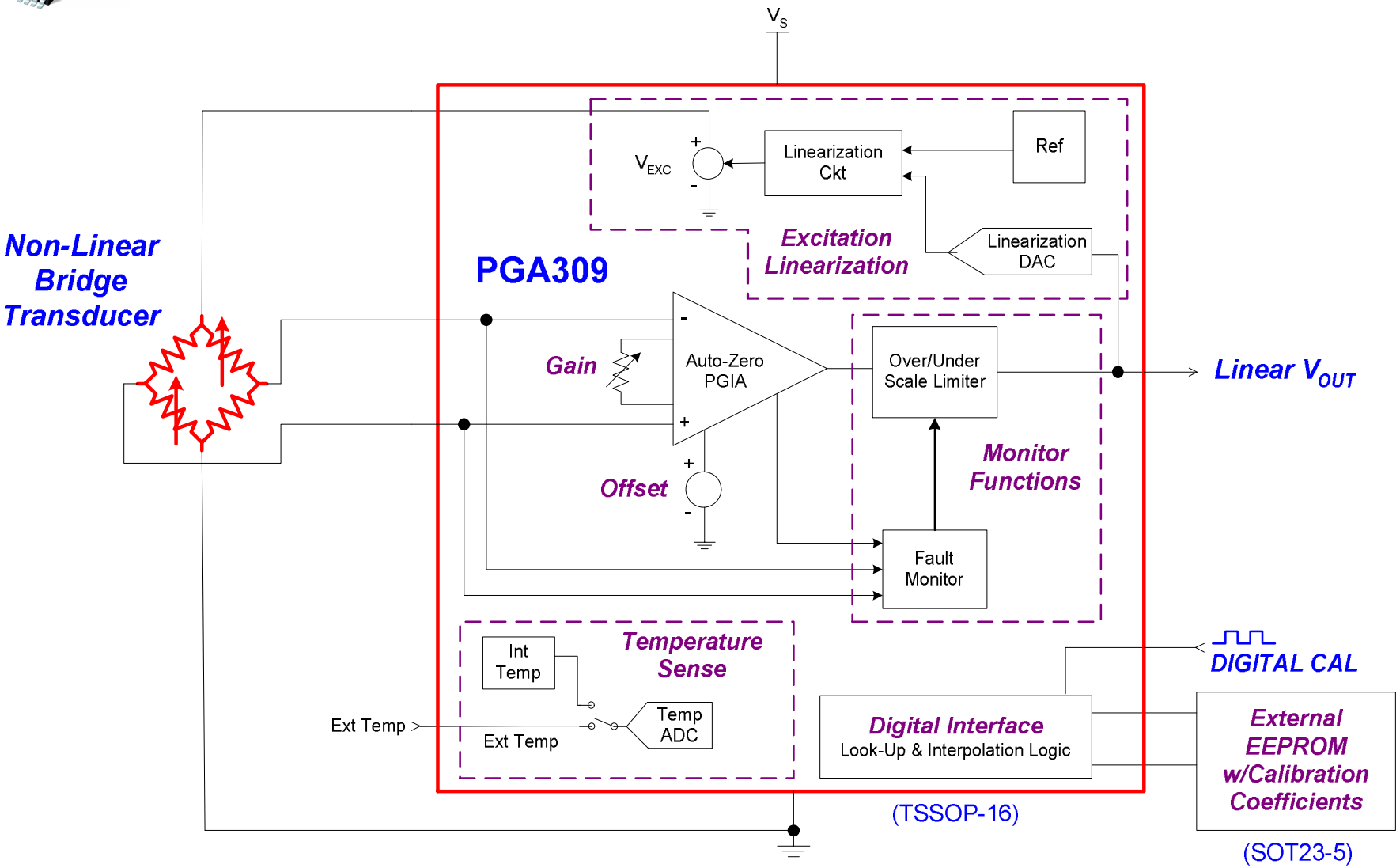
Modern Digital Trim for NonLinearities

- **Allows for final post-package trim**
- **Simple digital trim with computer calculated calibration coefficients.**
- **Almost infinite number of trims with finer resolution and wider range**
- **Less interaction between trims**
- **1-step easy trim for electronics & sensor**

Typical 3-Terminal Sensor Module Application



PGA309 *Overview*



PGA309 *Inside Tour*

- **Gain Blocks**
  - Front End PGA
  - Output Amplifier & Fine Gain Adjust
  - Combined Gain Settings
- **Offset**
  - Coarse Offset Adjust
  - Fine Offset Adjust
  - Reference: Internal/External
- **Monitor Functions**
  - Fault Monitor: Internal/External Comparators
  - Scale Limits: Over-Scale/Under-Scale
- **Temperature Sense**
  - Internal/External
- **Excitation Linearization**
- **Dynamic Digital Temperature Compensation**
- **Digital Interface Options for Calibration**
  - Two-Wire
  - Single-Wire

PGA309 *Inside Tour*

Will Use Definition by Example:

Bridge Sensor:

0psi < Pin < 100psi

FSO = 2mV/V

Pnl = +2.5% FSR

Calibrated PGA309 + Sensor

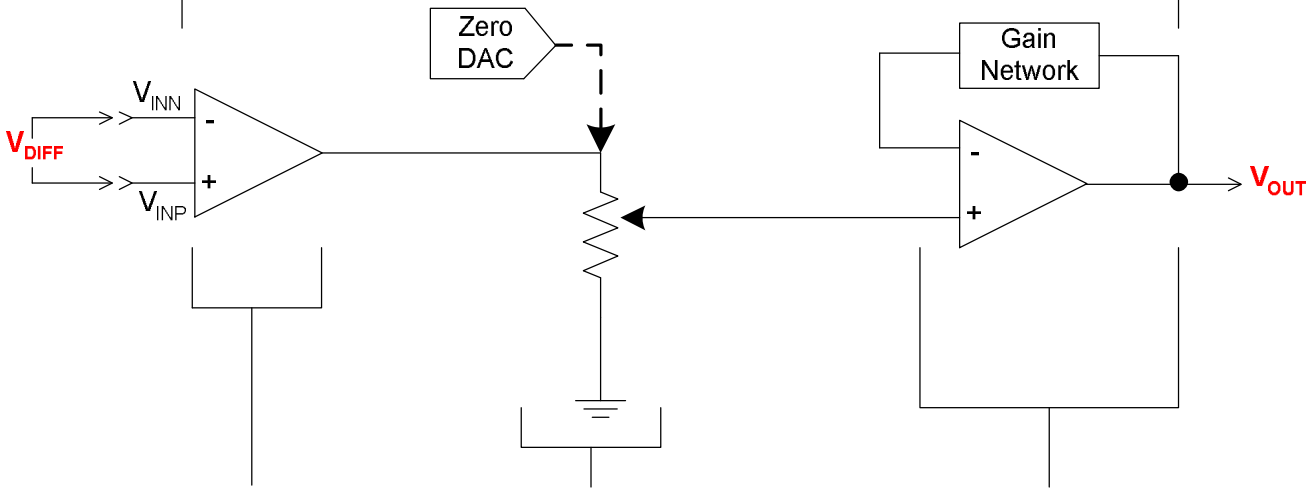
Pin = 0psi, VOUT = 0.5V

Pin = 100psi, VOUT = 4.5V

PGA309 *Gain Blocks*

PGA309 Differential Gain Range
X2.6666 to X1152

Bandwidth: (700kHz) (60kHz)



Front End PGA

X4
X8
X16
X23.27
X32
X42.67
X64
X128

Fine Gain Adjust

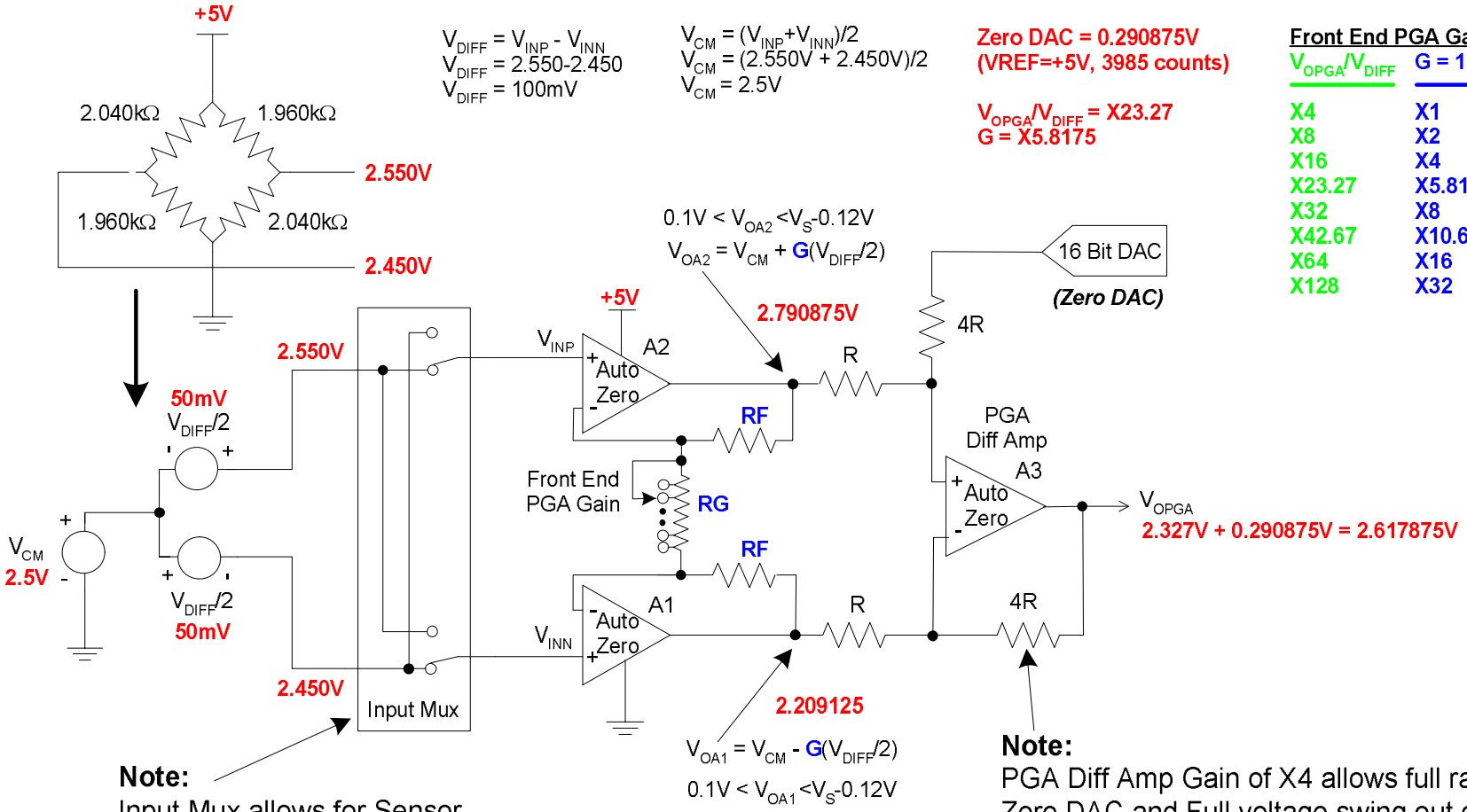
X0.3333
to
X1

16-Bit Resolution

Output Amplifier

X2
X2.4
X3
X3.6
X4.5
X6
X9

PGA309 Front End PGA



$V_{DIFF} = V_{INP} - V_{INN}$
$V_{DIFF} = 2.550\text{-}2.450$
$V_{DIFF} = 100mV$

$V_{CM} = (V_{INP}+V_{INN})/2$
$V_{CM} = (2.550V + 2.450V)/2$
$V_{CM} = 2.5V$

Zero DAC = 0.290875V
(VREF=+5V, 3985 counts)

V_{OPGA}/V_{DIFF} = X23.27
G = X5.8175

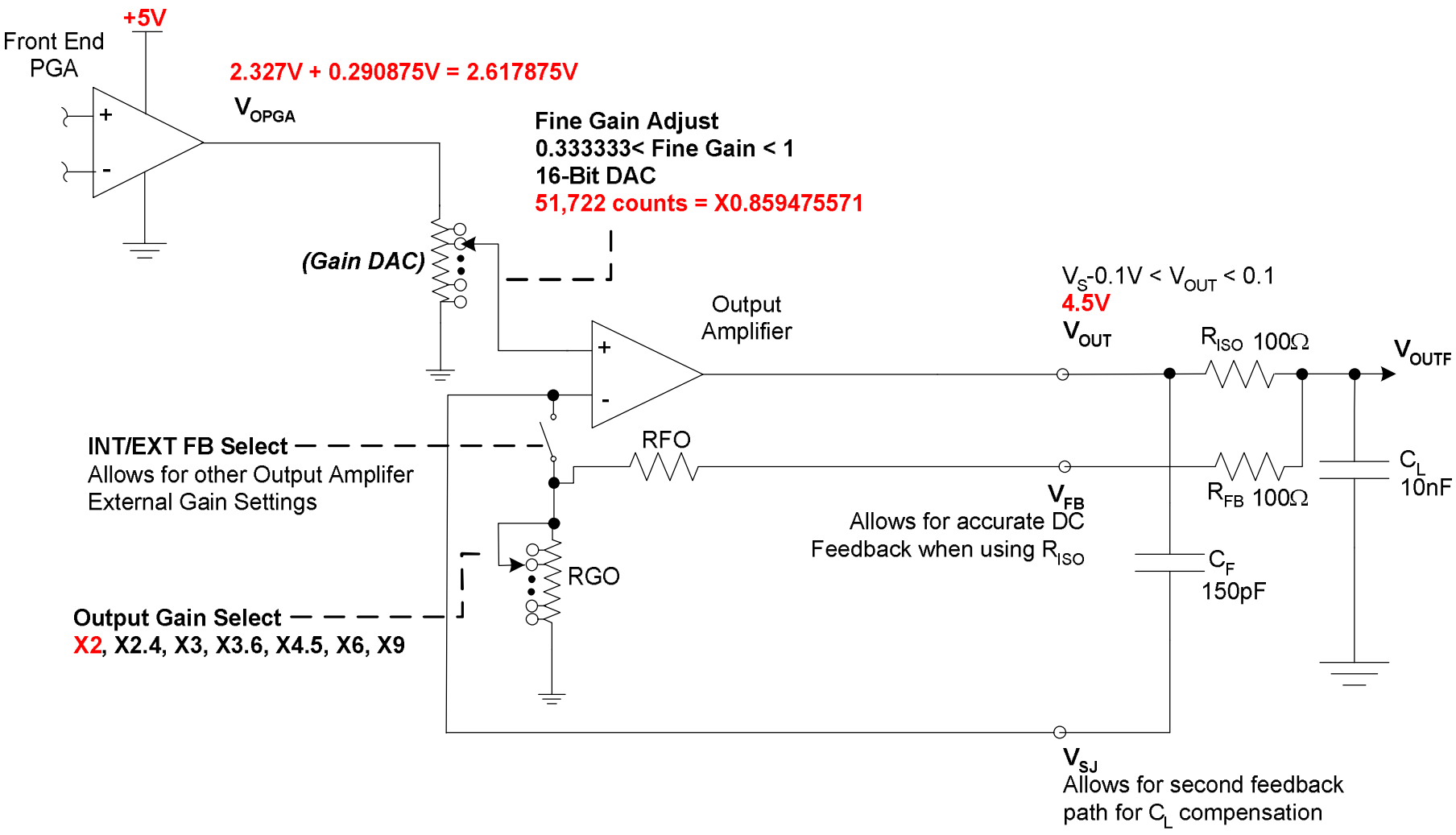
Front End PGA Gains

V_{OPGA}/V_{DIFF}	G = 1+2 RF/RG
X4	X1
X8	X2
X16	X4
X23.27	X5.8175
X32	X8
X42.67	X10.6675
X64	X16
X128	X32

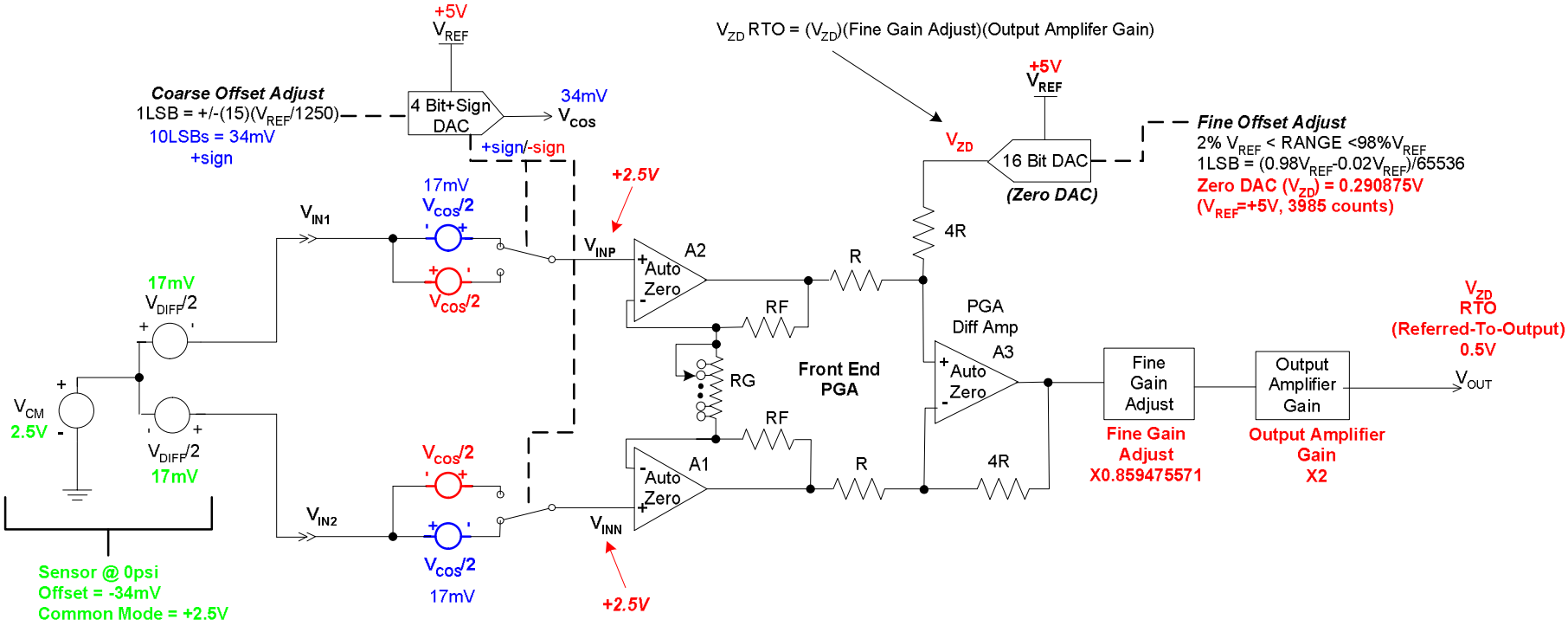
Note:
Input Mux allows for Sensor Output polarity reversal.

Note:
PGA Diff Amp Gain of X4 allows full range out of Zero DAC and Full voltage swing out of A1 and A2 without Common Mode violation on A3 input.

PGA309 Output Amplifier & Fine Gain Adjust

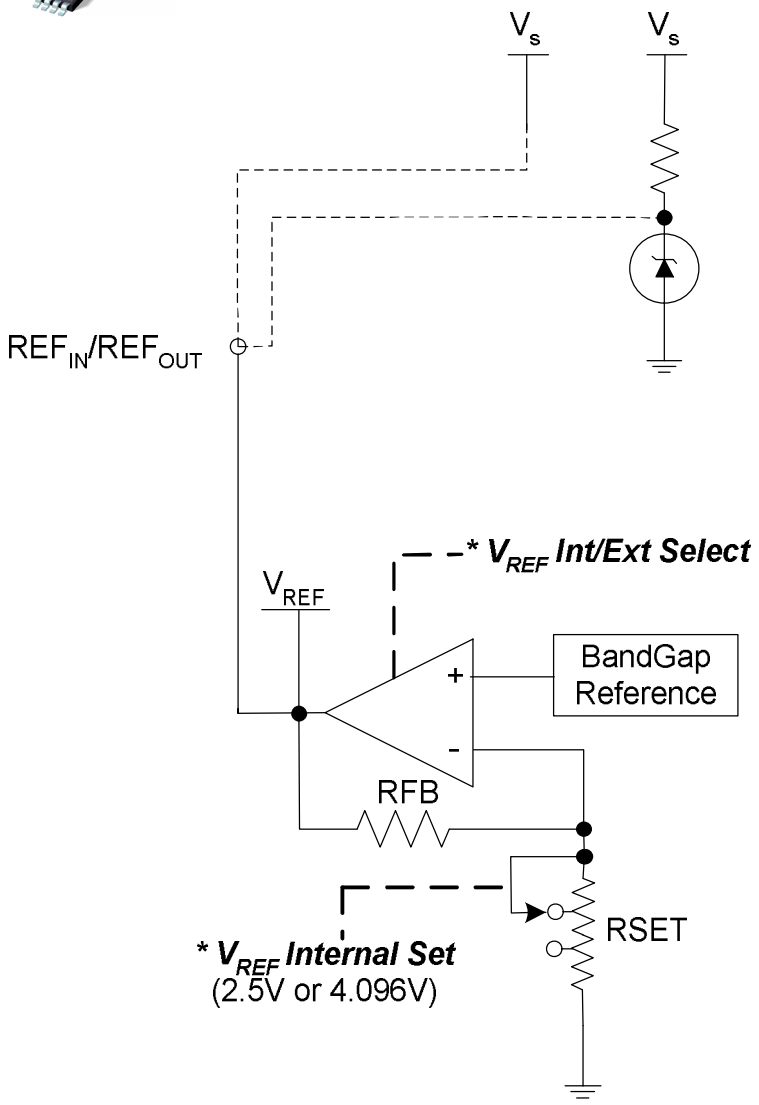


PGA309 *Offset*



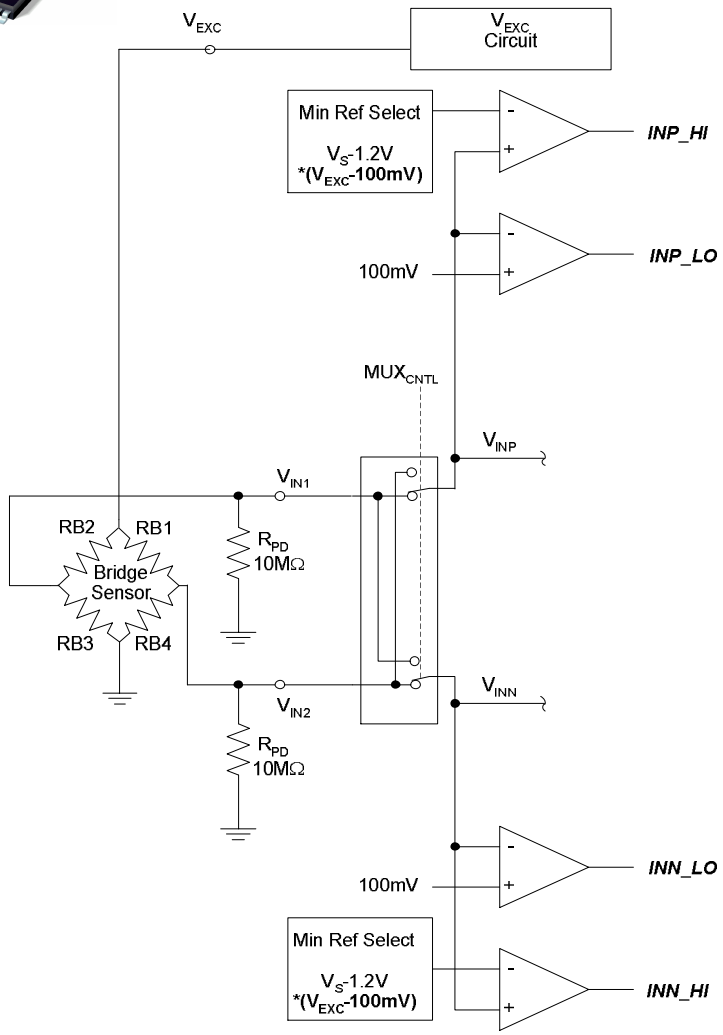
- **Coarse Offset**
  - Positive or Negative
  - Applied before Front End PGA Gain
- **Fine Offset**
  - 16-Bit, Range: 2%V_{REF} to 98%V_{REF} *(For V_{REF}=5V)*
  - For RTO: Amplified by Fine Gain Adjust & Output Amplifier Gain

PGA309 Reference



- **Internal Reference**
  - Ø +2.5V
  - Ø +4.096V
  - Ø 2.4%Initial Accuracy
  - Ø +10ppm/°C Drift
- **External Reference**
  - Ø +1.25V to V_S
  - Ø Power-on to External Ref

Fault Monitor – External Comparators

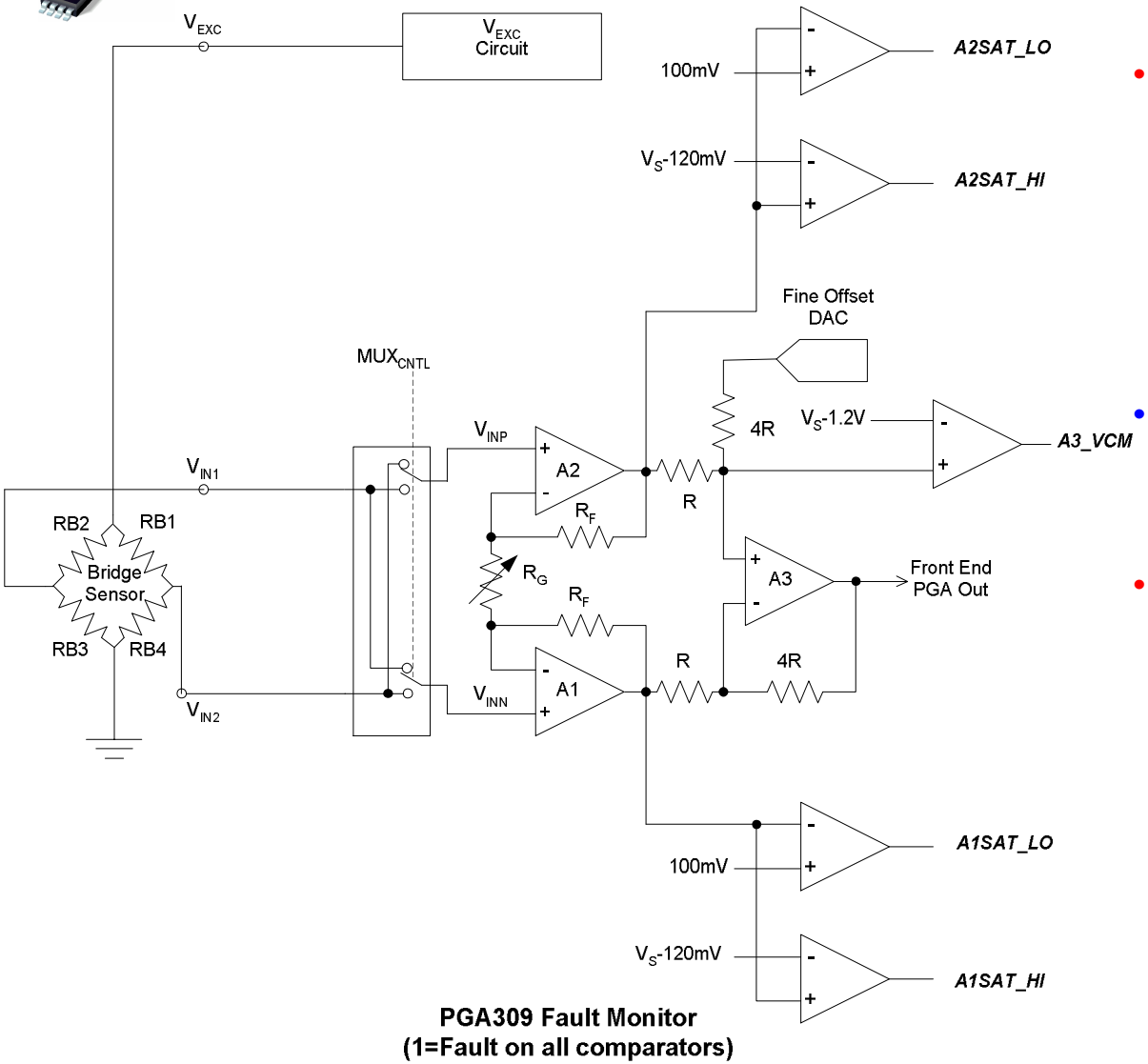


Note:
1=Fault on all comparators
*** If V_{EXC} is Enabled**

Case	INN_HI (ALM3)	INN_LO (ALM2)	INP_HI (ALM1)	INP_LO (ALM0)
Normal	0	0	0	0
RB1 open	0	0	0	1
RB2 open	0	1	0	0
RB3 open	1	0	0	0
RB4 open	0	0	1	0
RB1 short	0	0	1	0
RB2 short	1	0	0	0
RB3 short	0	1	0	0
RB4 short	0	0	0	1
open sensor gnd	1	0	1	0
open sensor V_{EXC}	0	1	0	1
V_{EXC} short gnd	1*	1	1*	1
V_{IN1} (V_{INP}) open	0	0	0	1
V_{IN2} (V_{INN}) open	0	1	0	0
V_{IN1} (V_{INP}) short gnd	0	0	0	1
V_{IN2} (V_{INN}) short gnd	0	1	0	0
V_{IN1} (V_{INP}) short V_{EXC}	0	0	1	0
V_{IN2} (V_{INN}) short V_{EXC}	1	0	0	0
V_{IN1} (V_{INP}), V_{IN2} (V_{INN}) open	0	1	0	1
V_{IN1} (V_{INP}), V_{IN2} (V_{INN}) short gnd	0	1	0	1
V_{IN1} (V_{INP}), V_{IN2} (V_{INN}) short V_{EXC}	1	0	1	0
* Typically a logic 1 but not guaranteed by design and nature of fault				

Minimum Select Circuit for Inx_HI Comparators:
When V_{EXC} enabled the lower of V_{EXC}-100mV and V_{SA}-1.2V is used as comparator reference. Ensures fault monitor when V_{EXC} increases due to linearization circuit and bridge has faults which violate positive V_{CM} of front end PGA.

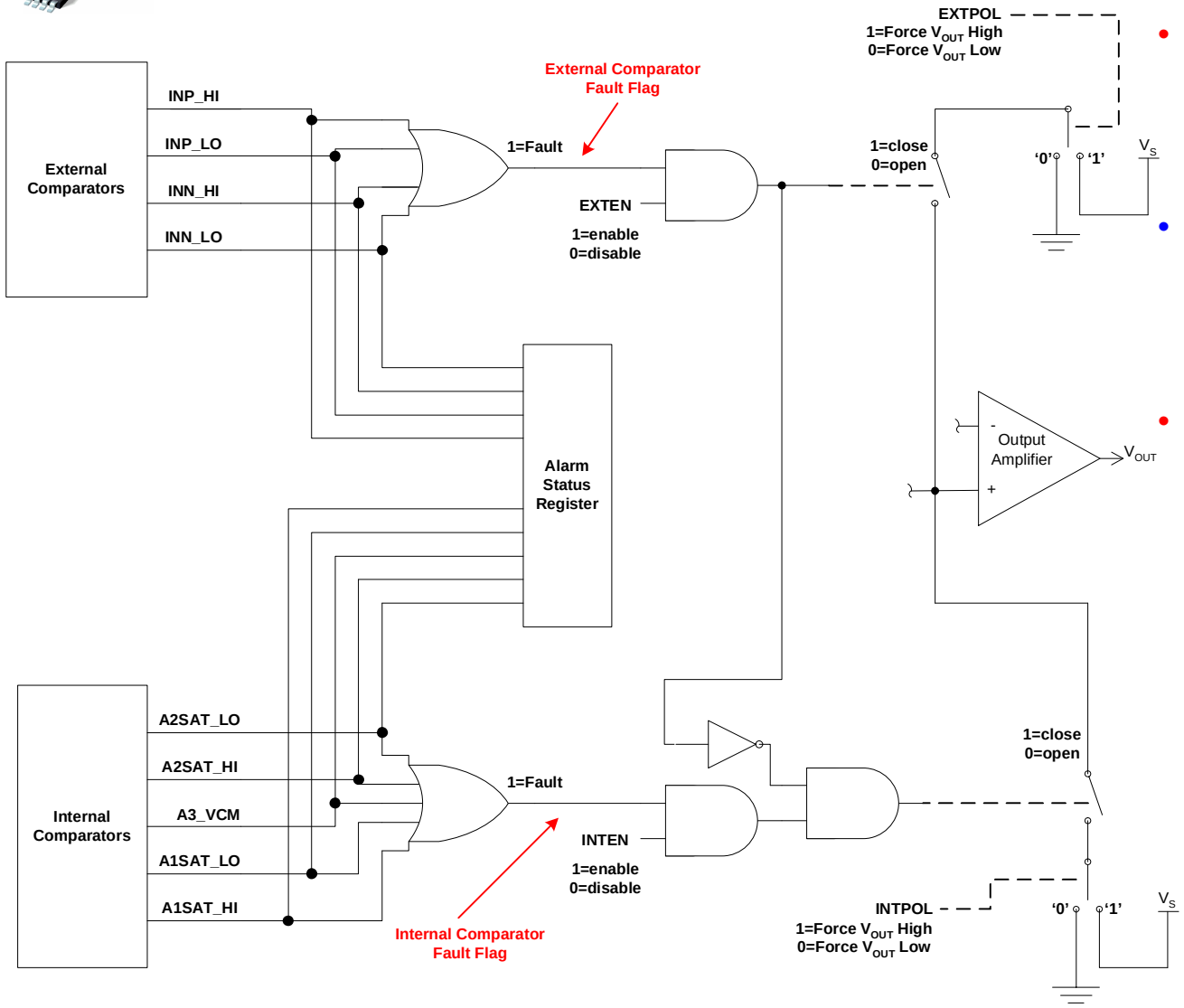
Fault Monitor – Internal Comparators



PGA309 Fault Monitor
(1=Fault on all comparators)

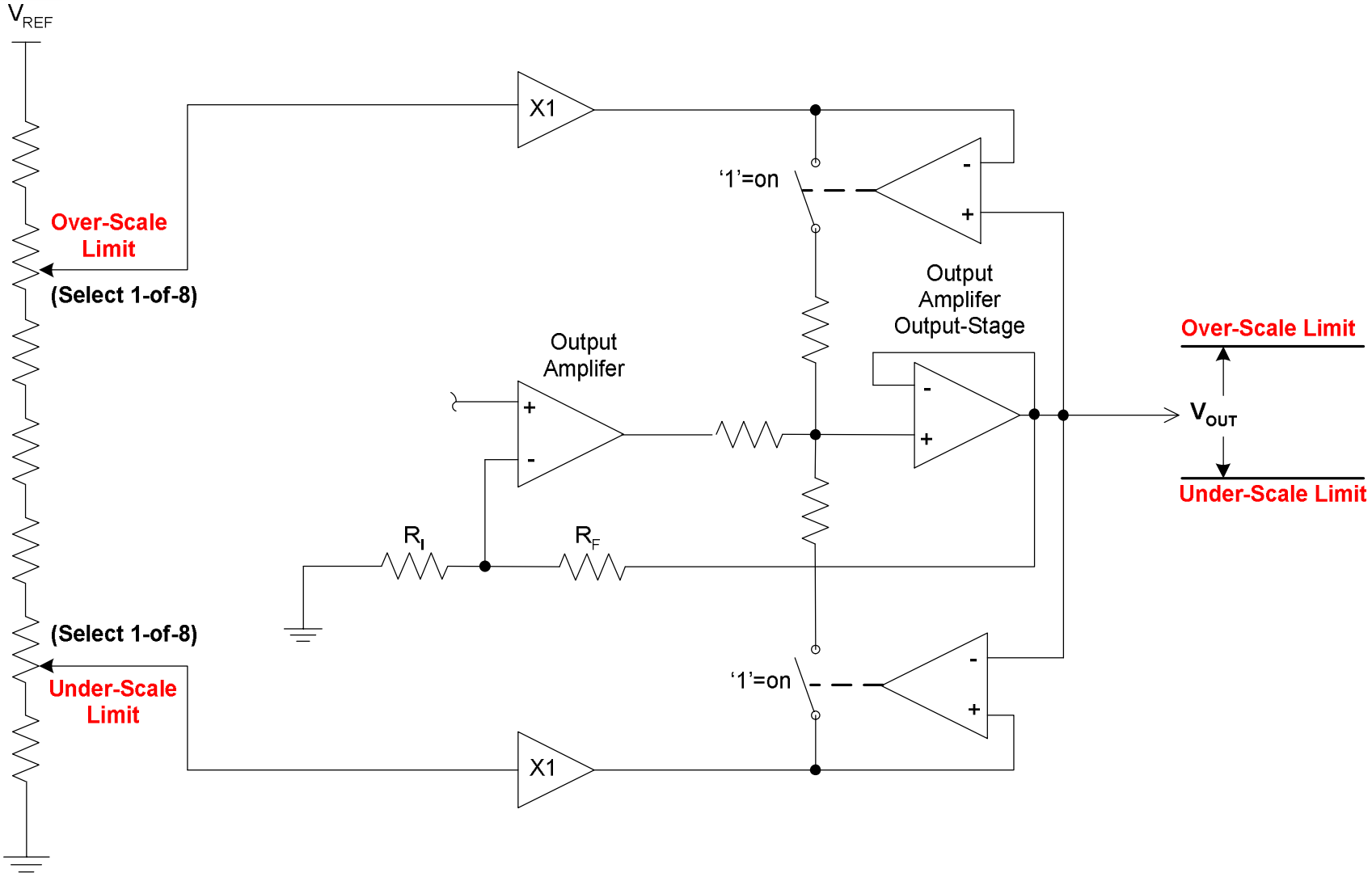
- **Front End PGA Linear Range Monitor**
  - A2 Positive Saturation
  - A2 Negative Saturation
  - A1 Positive Saturation
  - A1 Negative Saturation
  - A3 Common Mode
- **Mostly Used During Calibration**
  - ***V_{OUT} can be valid but Internal Nodes invalid!***
- **Faults Indicate**
  - Improper Gain Settings
  - Wrong coarse offset polarity/value
  - Incorrect Fine Offset DAC setting

Fault Monitor – Comparator Flags



- **Internal Comparator Fault Flag**
  - Enable/Disable
  - Polarity to Force V_{OUT}
- **External Comparator Fault Flag**
  - Enable/Disable
  - Polarity to Force V_{OUT}
- **External Comparator Fault Flag**
  - Supersedes Internal Fault Flag when fault detected

Over/Under Scale Limit



A/D Range "Budget"

100% of V_{REF} A/D
98.4% of V_{REF} A/D
A/D Upper "Headroom"

97.4% V_{REF} A/D - Fault Flag Trip Point

96.4% V_{REF} A/D - Over-Scale Limit (max)

92.6% V_{REF} A/D - Over-Scale Limit (typ)

88.9% V_{REF} A/D - Over-Scale Limit (min)

87.8% V_{REF} - A/D Over-Scale Trip Point

86.8% of V_{REF} A/D

Real World Useable A/D Range

PGA309 Linear Output Range

8% of V_{REF} A/D

7% V_{REF} A/D - Under-Scale Trip Point

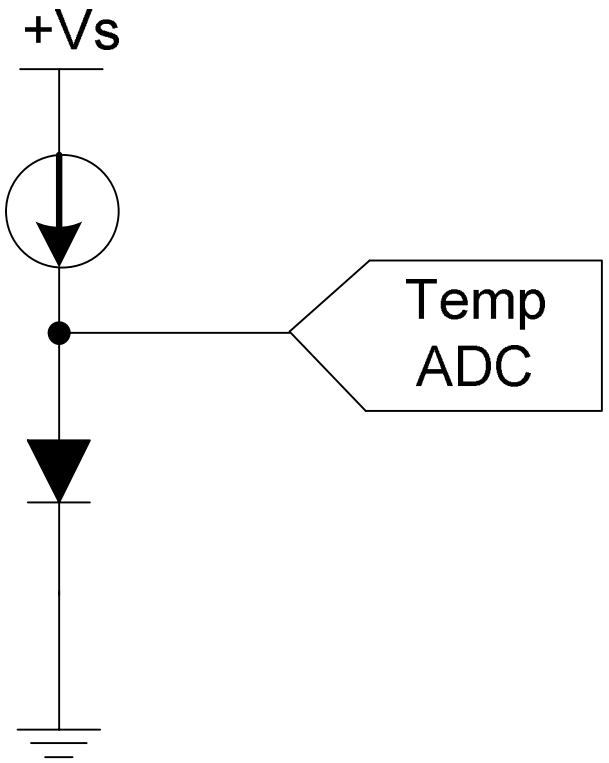
6.1% V_{REF} A/D - Under-Scale Limit (max)

4.7% V_{REF} A/D - Under-Scale Limit (typ)

3.3% V_{REF} A/D - Under-Scale Limit (min)

2% of V_{REF} A/D
0% of V_{REF} A/D
A/D Lower "Headroom"

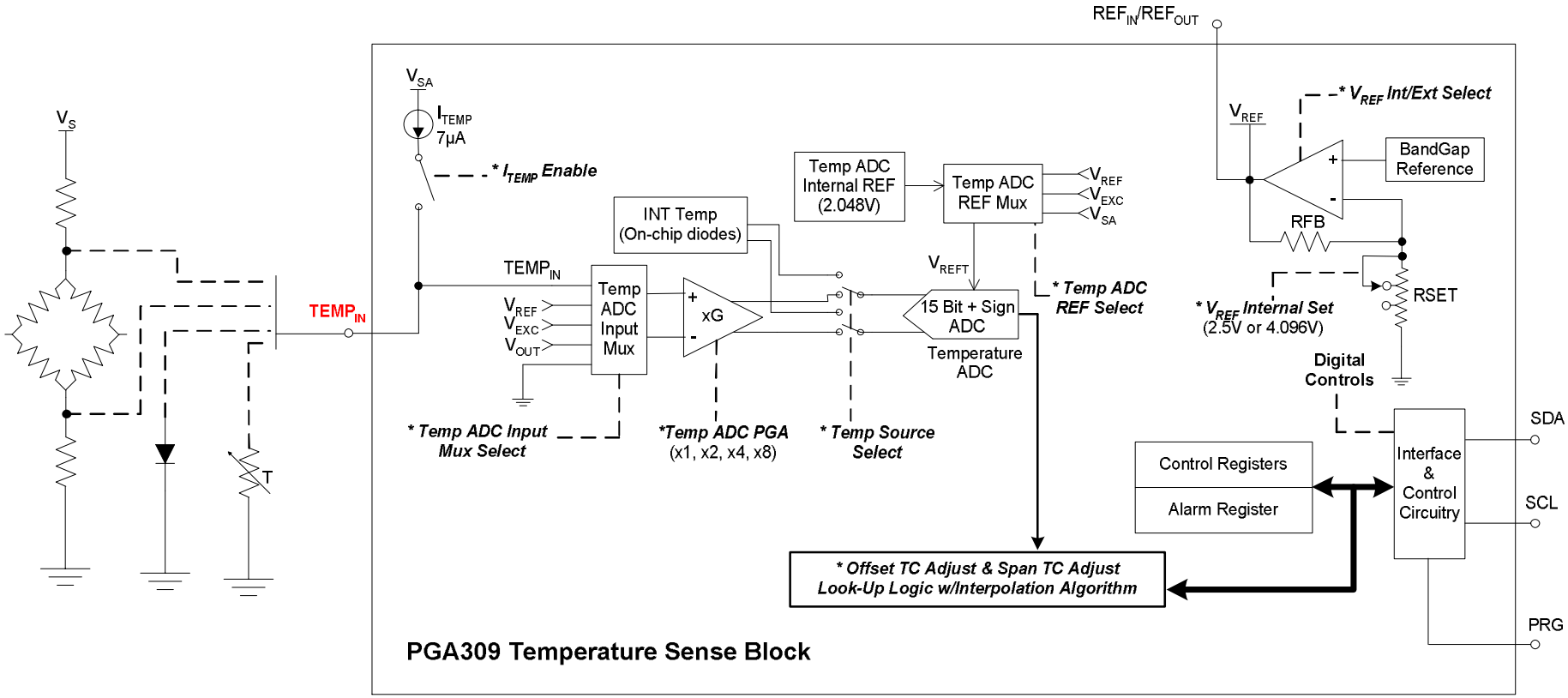
Internal *Temperature Sensor*



- Similar to TMP100
- +/-2°C initial Accuracy
- +/-0.0625°C typical resolution
- 12 Bit + Sign data
- -128°C to +128°C Range

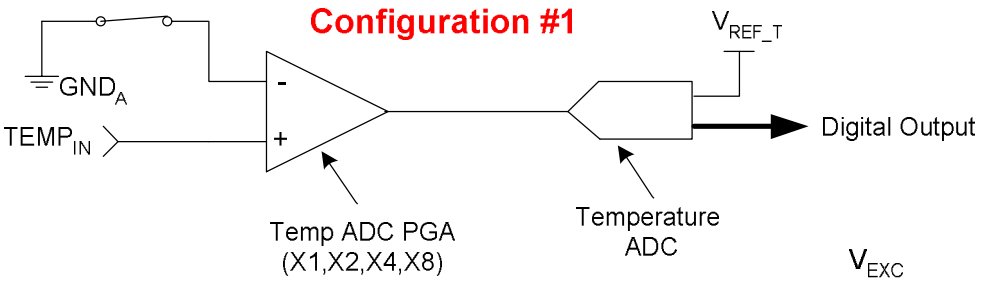
Temperature errors calibrated out when PGA309 + Sensor calibration is performed

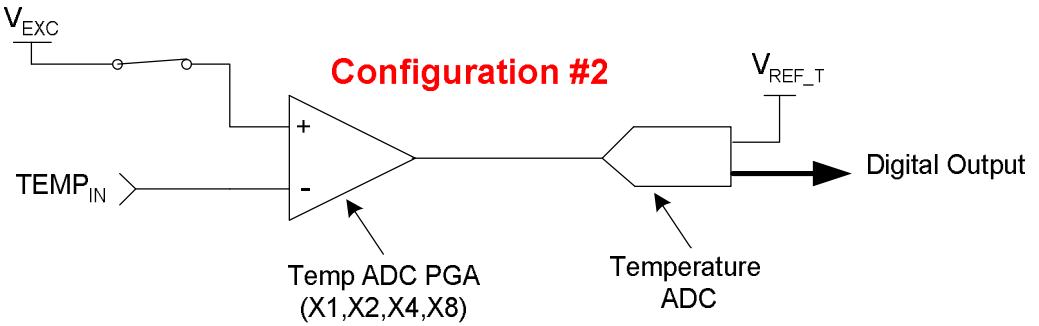
External Temperature Sense

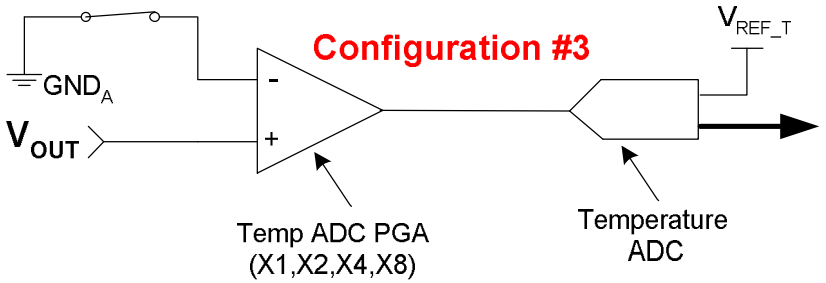


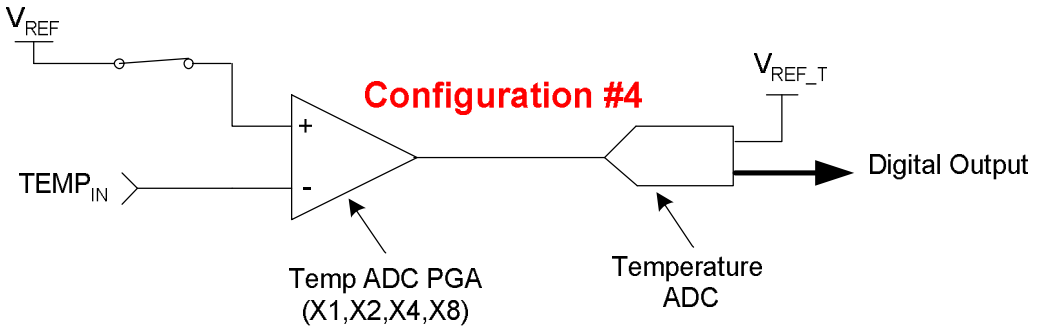
Temp ADC Resolution: 11Bit+Sign to 15Bit+sign

External Temp Sense - Configuration

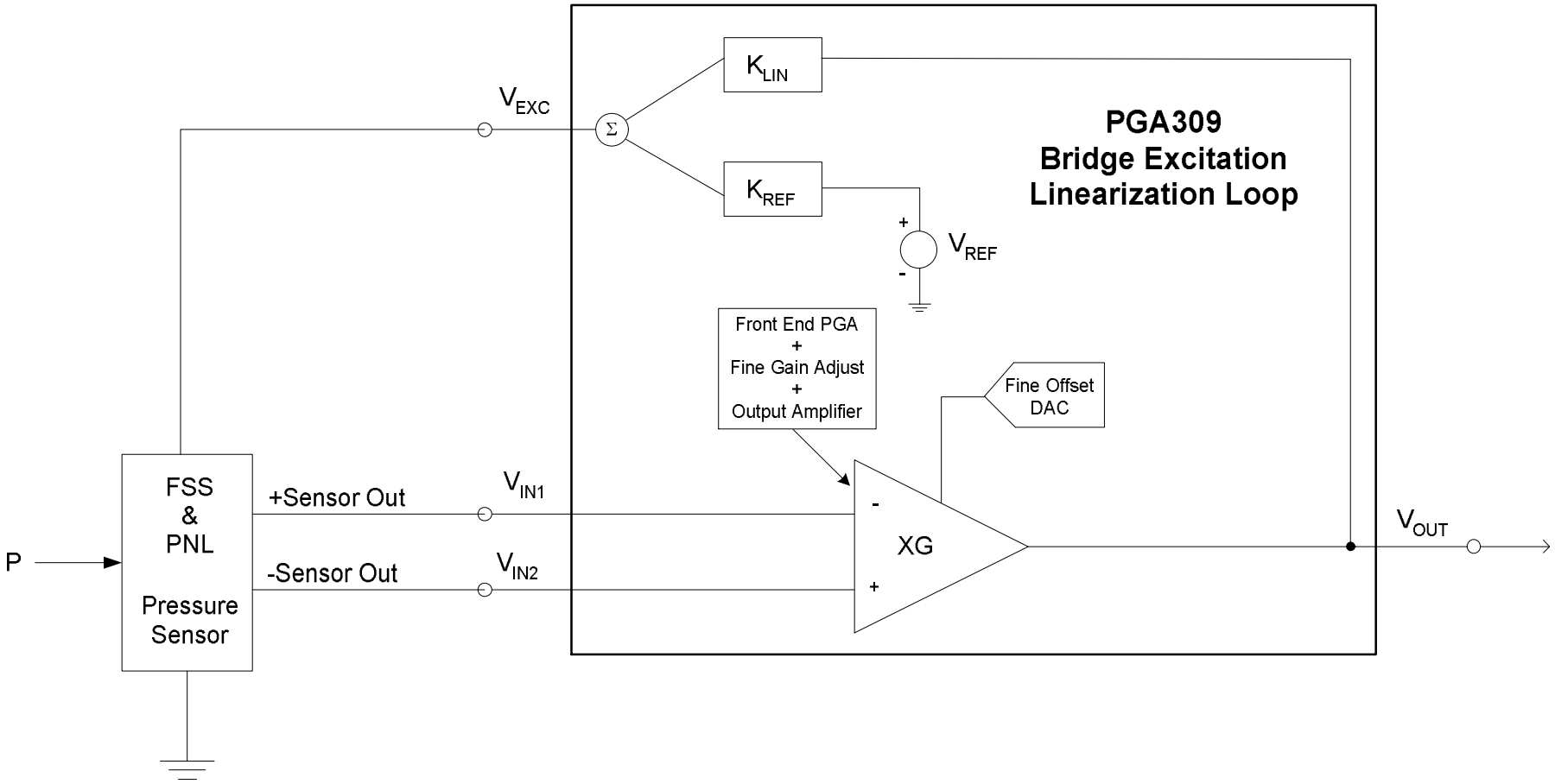




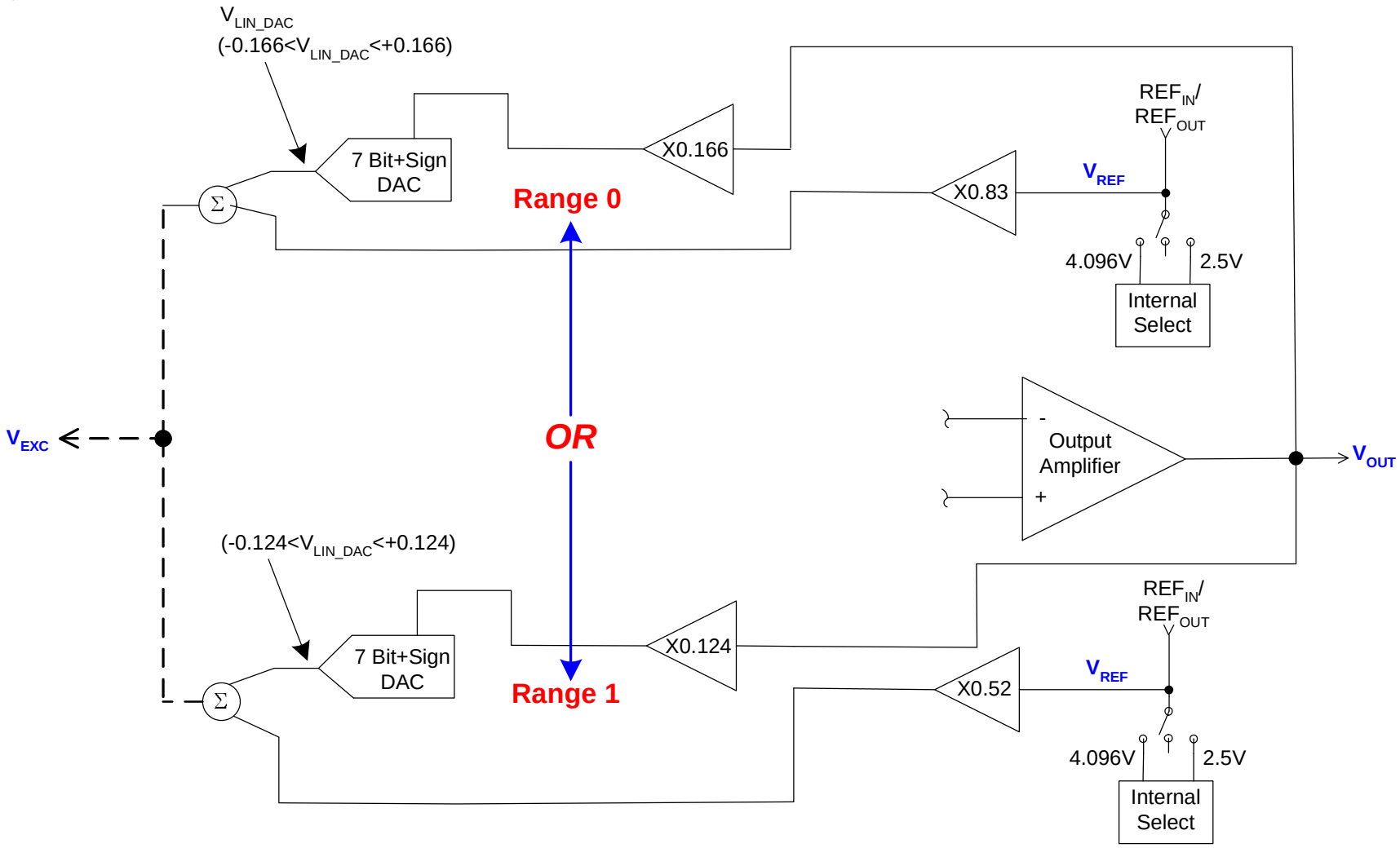




PGA309 *Linearization* Loop Diagram

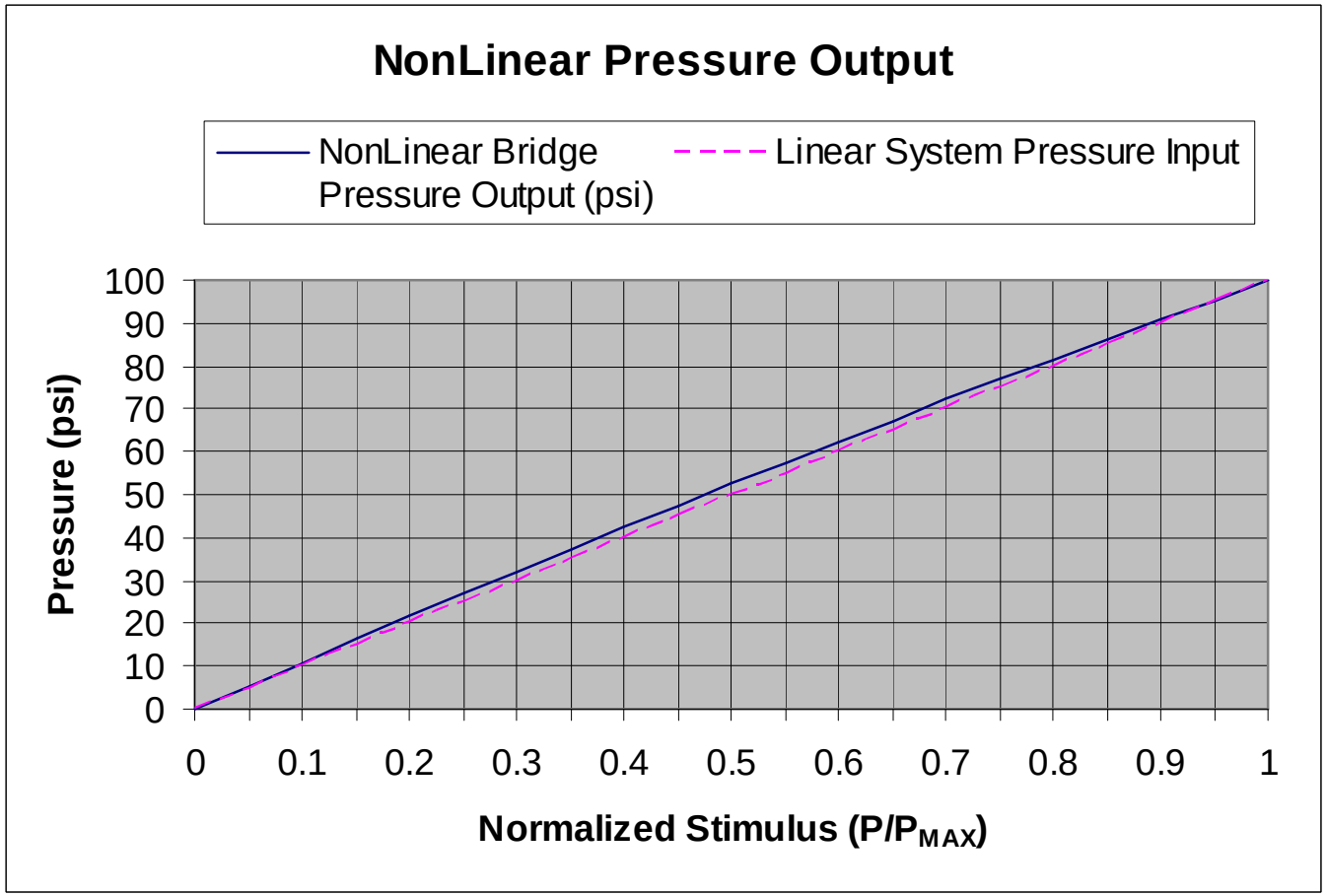


Linearization Circuit Details



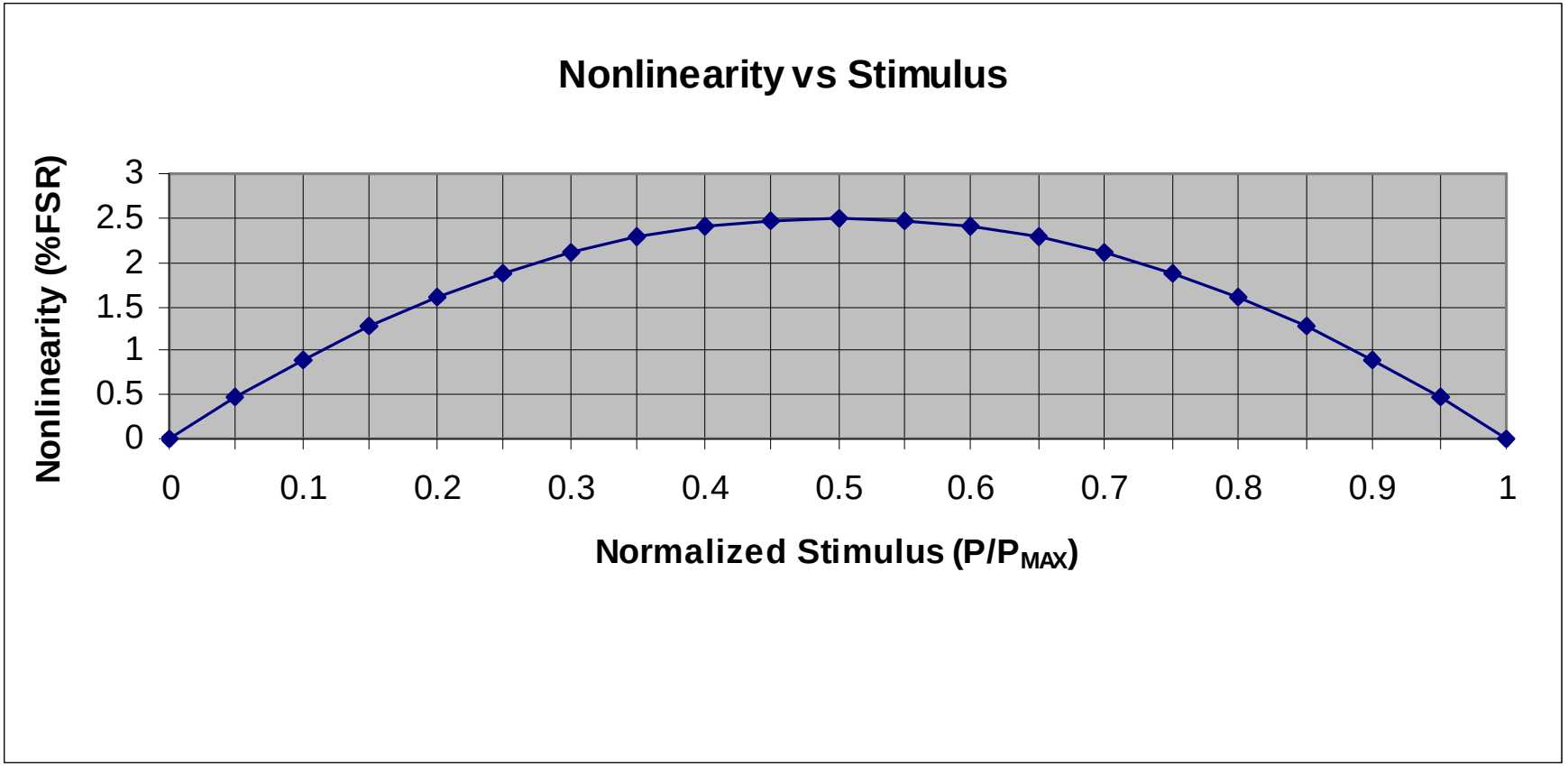
PGA309 V_{EXC} Linearization

- **Example of Non-Linear Bridge Output vs Pressure Input**
- **P_{MIN} = 0psi, P_{MAX} = 100psi, %NL = +2.5%**

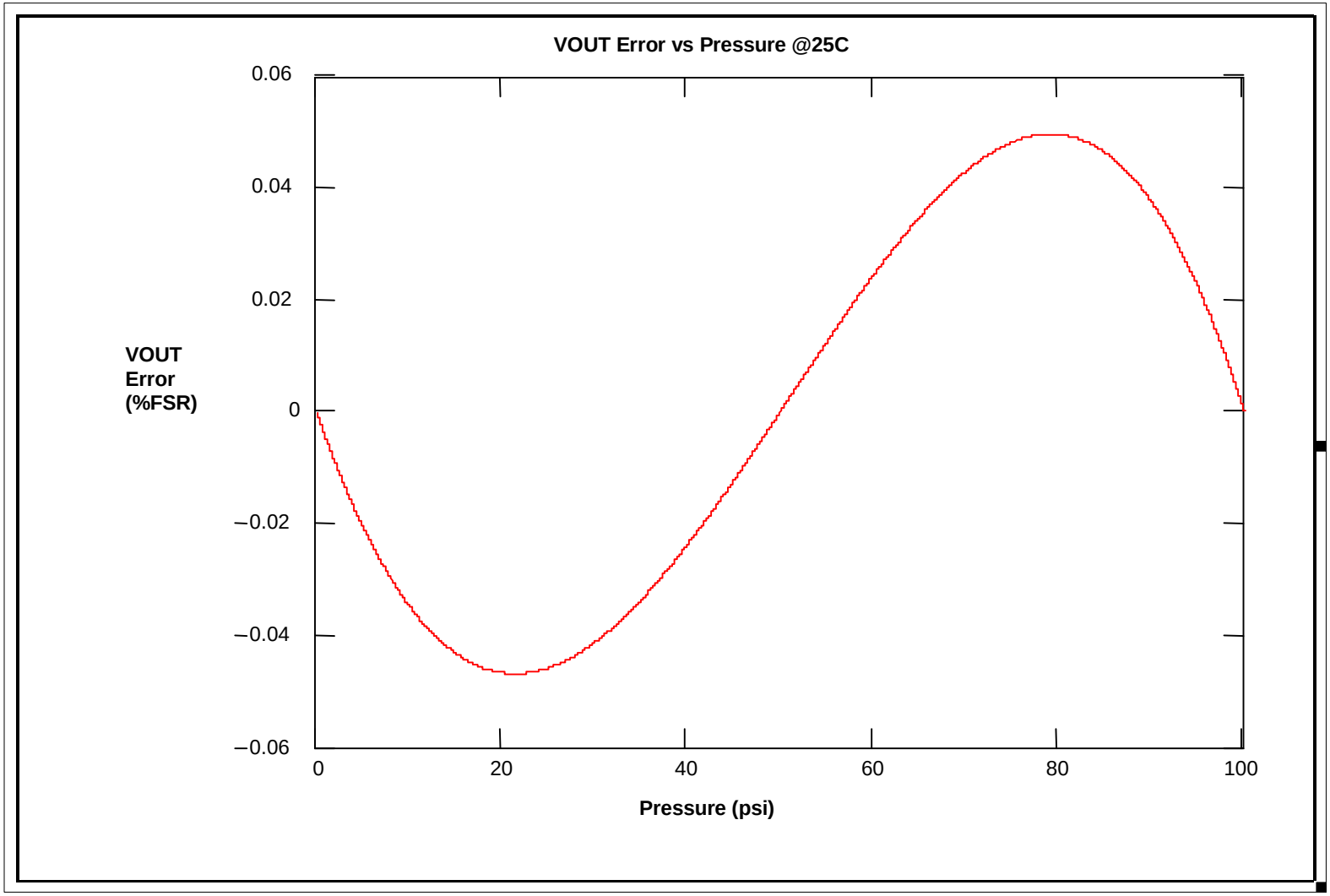


PGA309 V_{EXC} Linearization

- Example Bridge Output Non-Linearity vs Pressure Input
- PMIN = 0psi, PMAX = 100psi, %NL = +2.5%



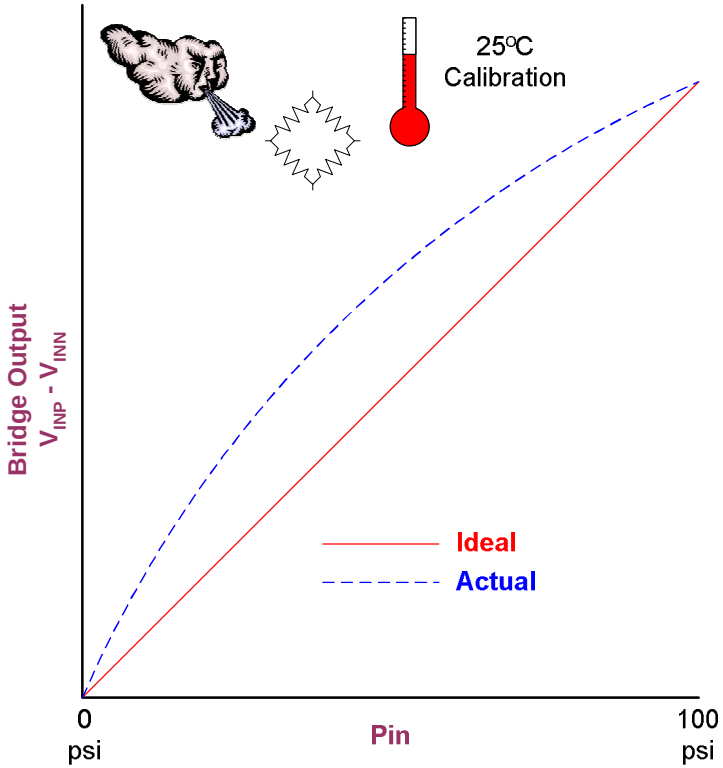
PGA309 Final Sensor V_{EXC} Linearization



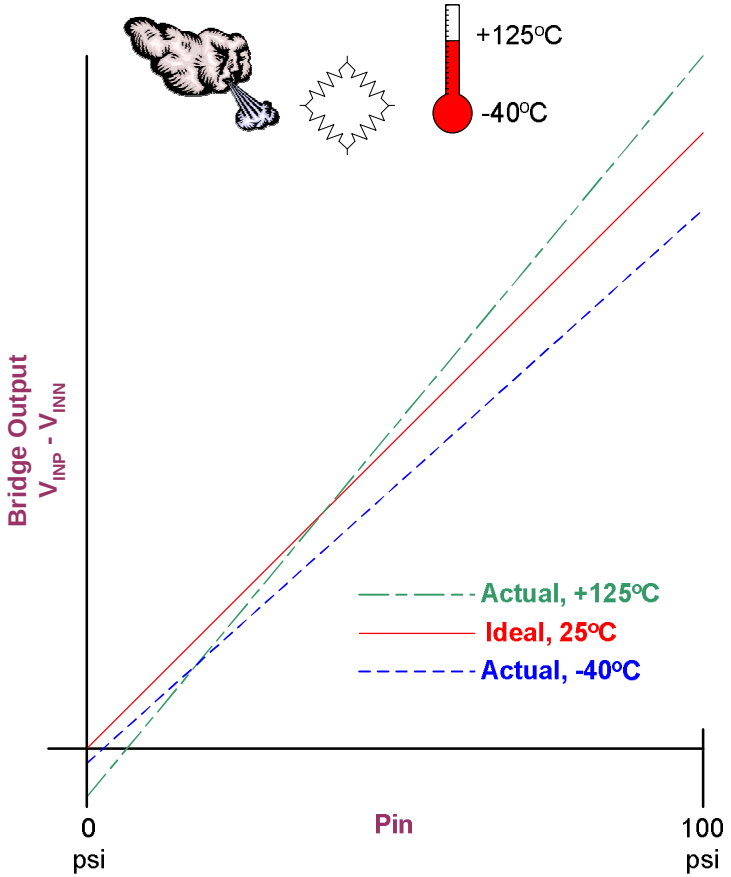
Summary of PGA309 + Sensor Calibration

PGA309 Linearization Circuitry
compensates
Sensor Error with Applied Pressure

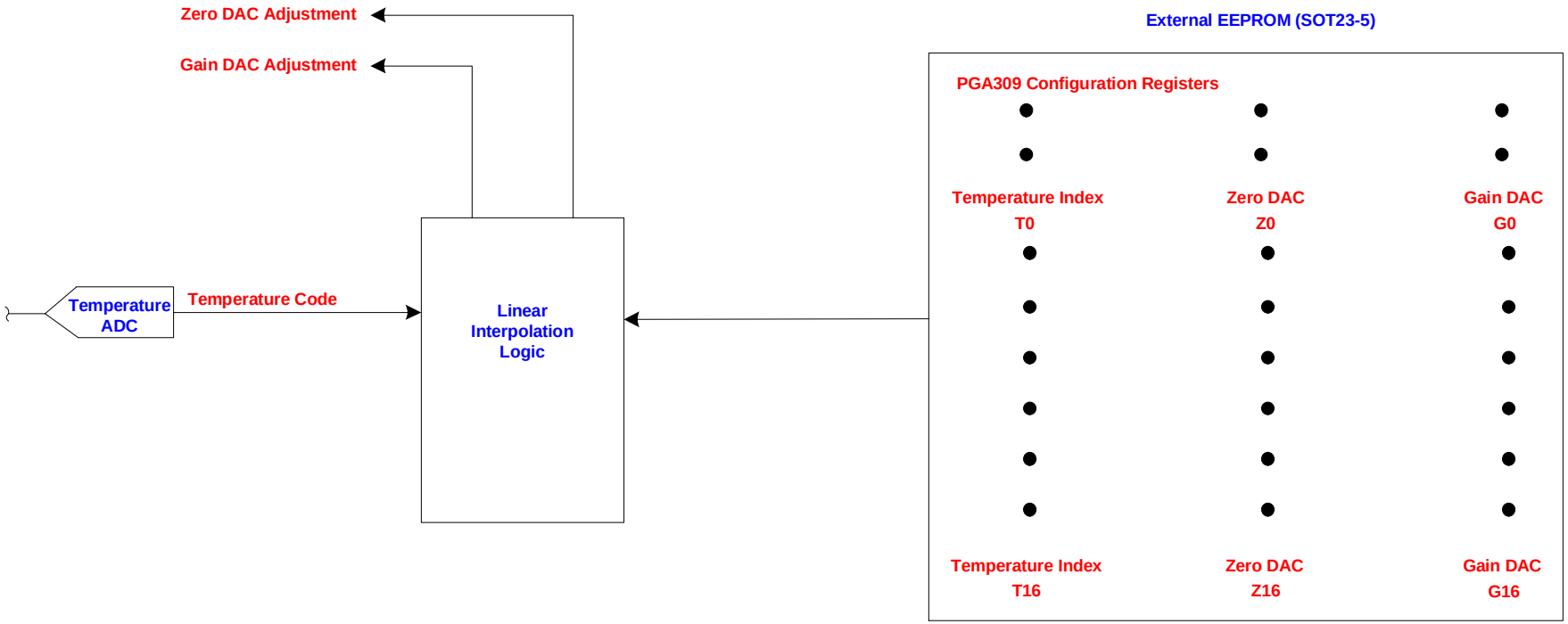
Calibrate at 25°C.
Tempco of this error is negligible



PGA309 Temperature Compensation
compensates
Sensor Span & Zero Error over Temperature



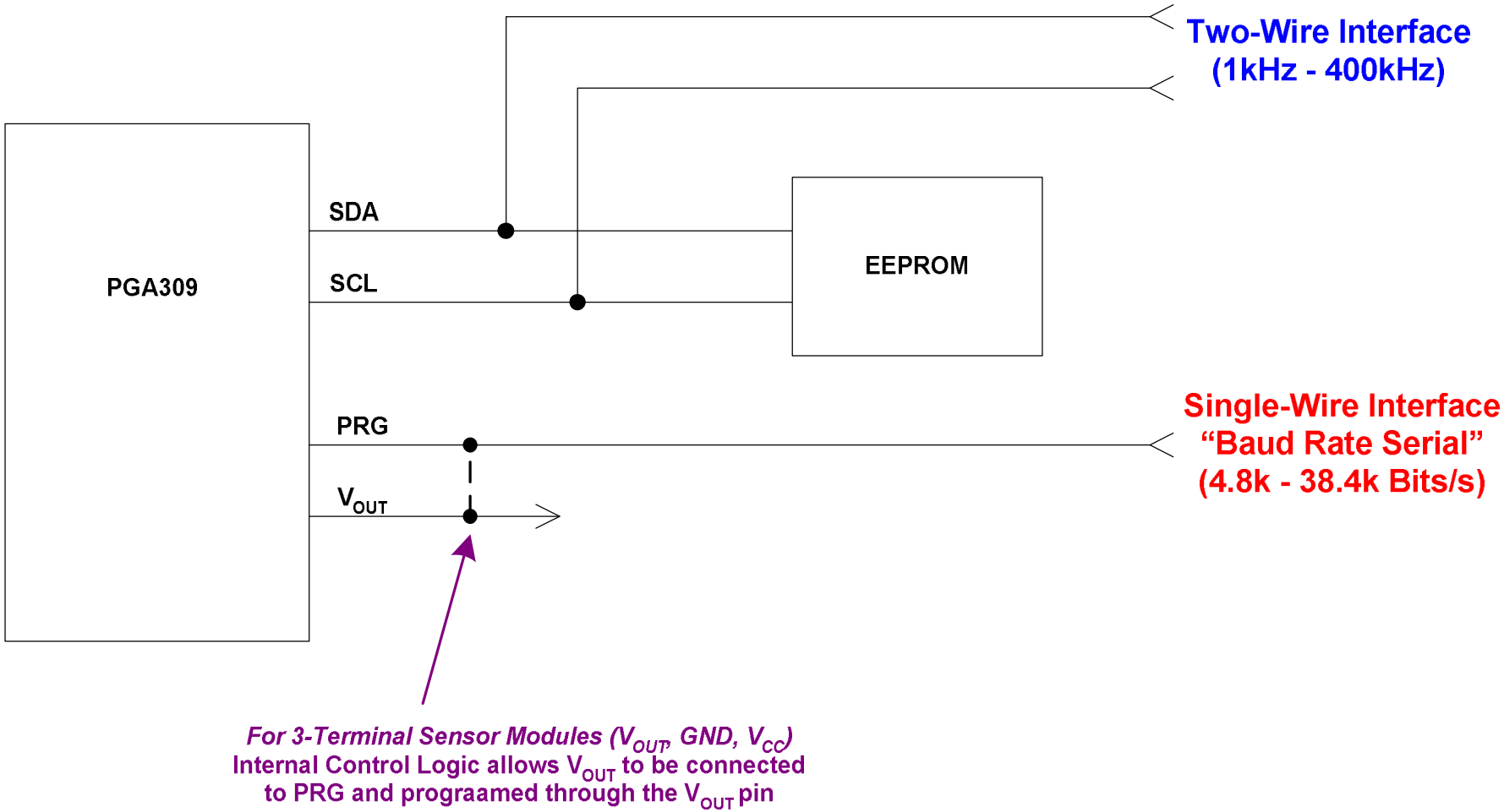
Dynamic Digital Temperature Compensation



Temperature Compensation Cycle:

- Every 150mS Temperature ADC converts (Temperature Code)
- Temperature Index values are read
- Linear Interpolation algorithm between closest Temperature Index values occurs
- Final Zero DAC and Gain DAC Adjustment Values computed

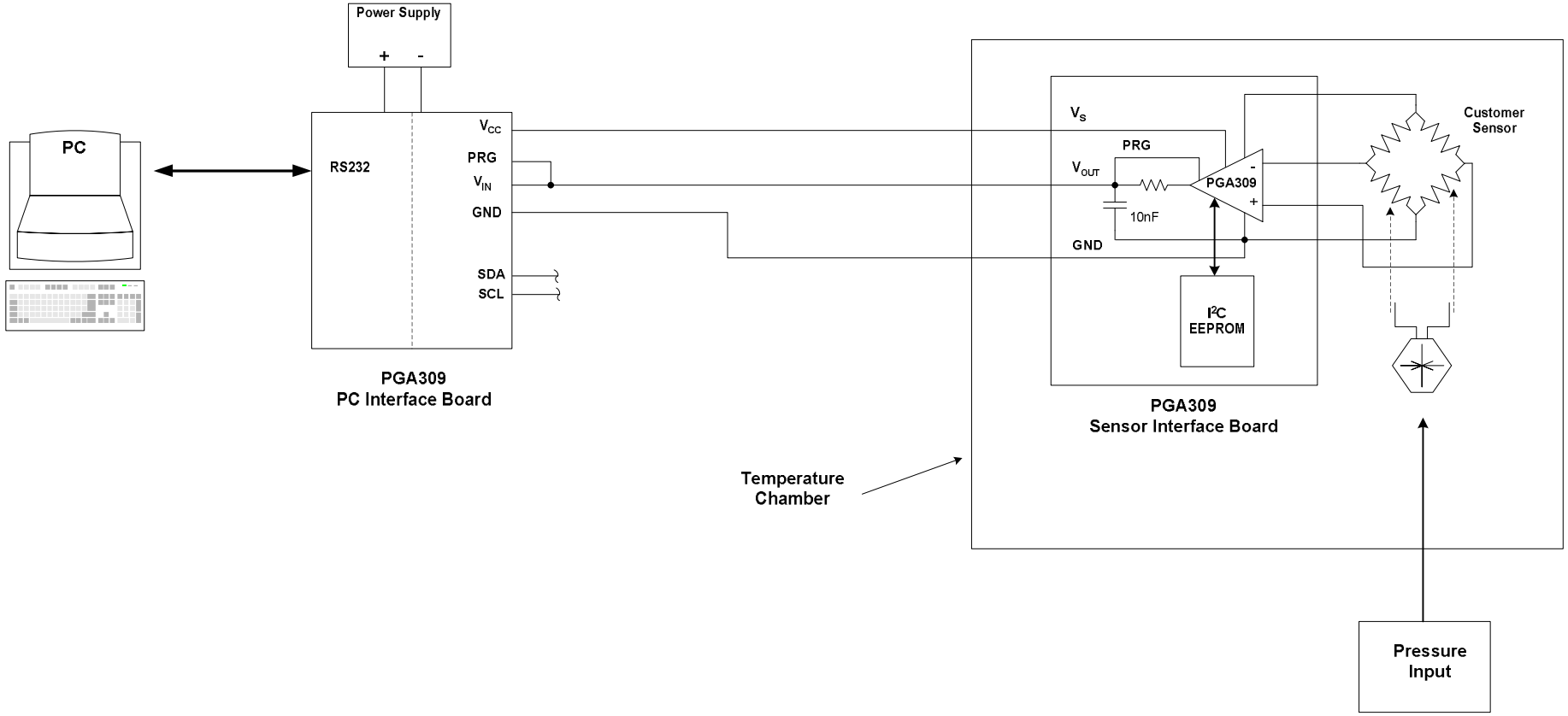
Digital Interface Options for Calibration



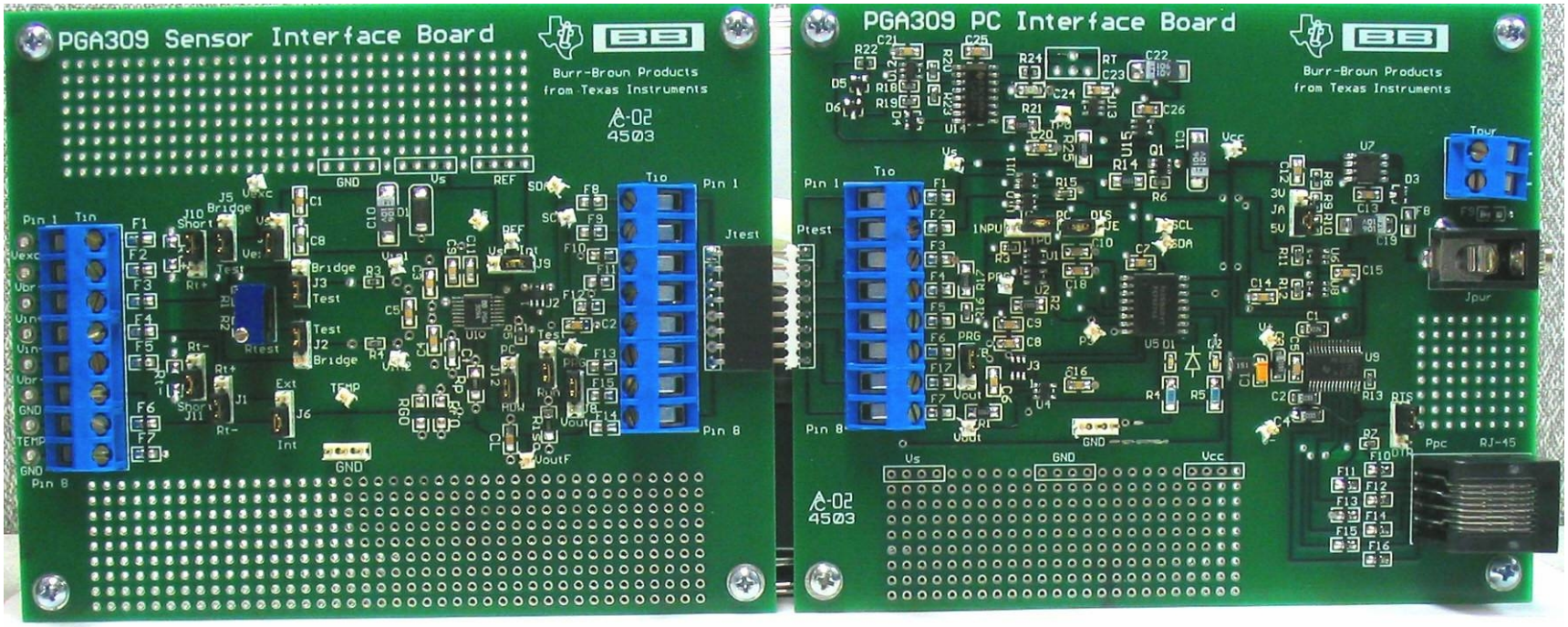
PGA309DK (Designer's Kit)

Allows User:

- Ø Complete Evaluation of PGA309 + Sensor
- Ø Ease of Temperature Coefficient Calculations
- Ø Immediate Program/Test Bench to Ship First Production Units

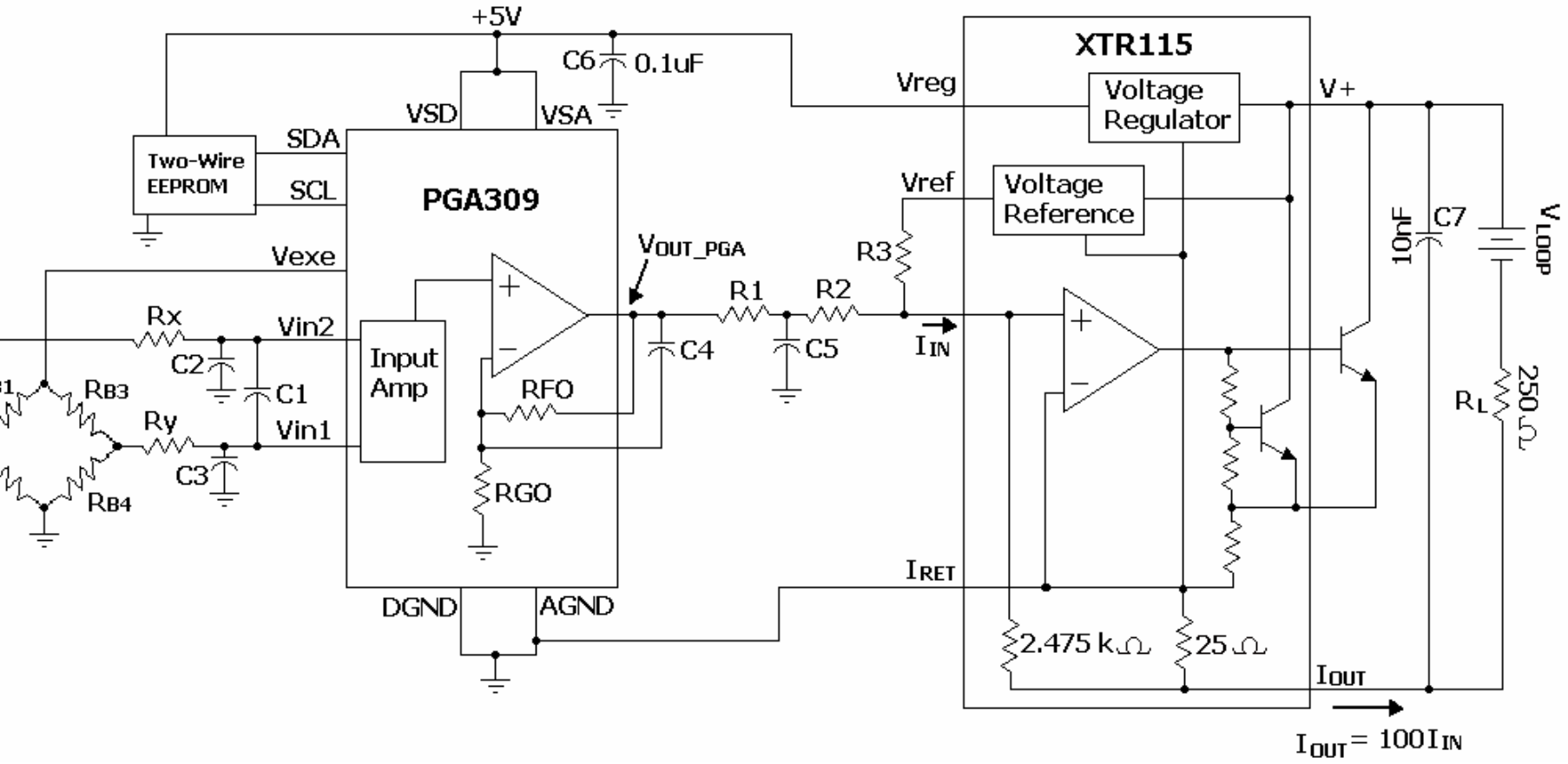


PGA309DK

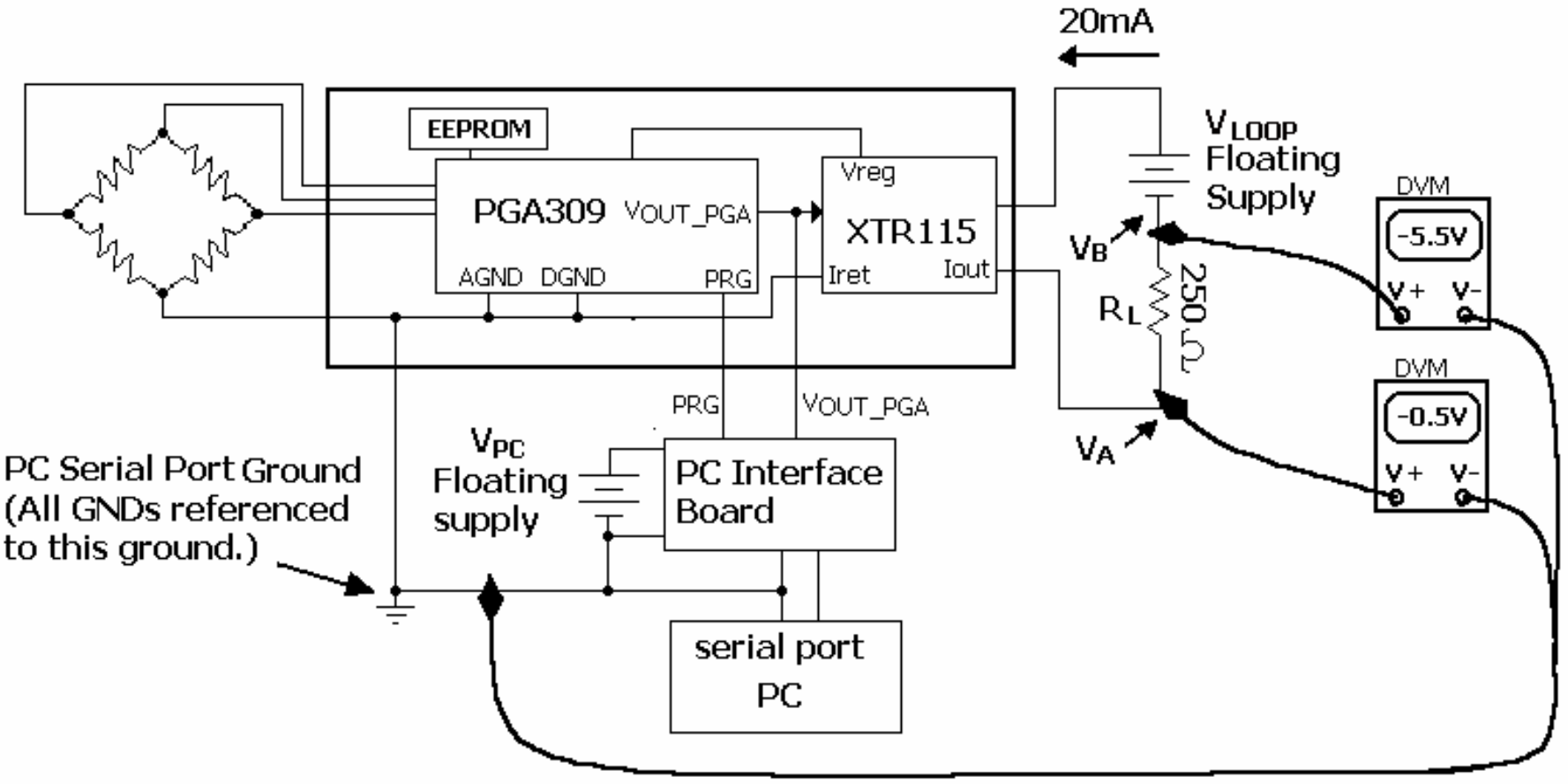


- **Hardware Designer's Kit (PGA309DK)**
  - Evaluate PGA309 and Sensor
  - Full Temperature Evaluation
- **Software Control For Designer's Kit**
  - Program PGA309 for Evaluation
  - Program PGA309 for First Production Run
  - Sensor Computation Analysis Tool

Easy 4-20mA PGA309 Application



PGA309 + XTR115 Programming w/PGA309DK



PGA309 Key Features

- Gain Range: X2.7 (700kHz BW) to X1152 (60KHz BW)
- Fine Gain Adjust: 16-Bit DAC, 0.33 to 1 Range
- Fine Offset Adjust: 16-Bit DAC, 0.1V to 4.9V Range (V_{REF}=5V)
- Coarse Offset Adjust: +/-60mV (V_{REF}=5V)
- Bandwidth: 700kHz (X2.7), 60kHz (X1152)
- Reference Voltage: Internal (2.5V/4.096V) or External
- Internal or External Temperature Sense
- Temperature Calibration – Span & Offset
  - Look-up Table Logic w/Linear Interpolation
  - Up to 17 Temperature Coefficients
- Digital Calibration: Single-Wire or Two-Wire Interface
- Voltage Output: Ratiometric or Absolute
- Small TSSOP-16 Package
- -40°C to +125°C Operation
- +2.7V to +5.5V Operation
- Fault Monitor/Detection
- Over/Under-Scale Limits
- Excitation Linearization

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