STRAIN GAUGE & LOAD CELL AMPLIFIER

SGAMP-V2

The Izze-Racing 24-Bit ADC-to-CAN Amplifier is designed to measure the voltage signal from a strain gauge or load cell with class-leading precision & ultra-low noise, and outputs the raw voltage, temperature, and user-calibrated output with advanced temperature compensation via CAN.

The amplifier measure's differential voltages with a resolution of 1μV and RMS noise of only ±750nV at a sampling frequency of 100Hz. The differential voltage and temperature is broadcasted via CAN but it may also be programmed to simultaneously transmit a calibrated output (convert voltage to strain/force) with linear or advanced tabular temperature compensation.

AMPLIFIER SPECIFICATIONS

Differential Voltage Measurement Range, ΔV	±32 mV (limited by 16-bit CAN output)
Maximum Differential Voltage, ΔV_{max}	±5.0 V
Resolution	1 μV (limited by 16-bit CAN output)
Accuracy	±60 μV
RMS Noise (For 350Ω full-bridge strain gauge / load cell with excitation)	±6 μV at 800Hz ±750 nV at 100Hz
Filter	1st Order LP Filter, f_c = 1.6kHz
Supply Voltage, V_s	5 to 8 V
Supply Current, I_s (typ)	34 mA
Bridge Excitation Voltage, V_B	4 V
Maximum Bridge Excitation Current Draw, $I_{B.max}$	40 mA
Input Impedance, R_I	110 kΩ
Recommended Strain Gauge / Load Cell Impedance, R_B	350 Ω
Resolution, Temperature Sensor	0.4˚C
Accuracy, Temperature Sensor	±2.0˚C

MECHANICAL SPECIFICATIONS

Weight (excluding wiring harness)	19 g
L x W x H (max), Amplifier	54 x 22 x 6 mm
Protection Rating	IP66
Operating Temperature Range, T_p	-40 to 85˚C

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CAN SPECIFICATIONS

Standard	CAN 2.0A (11-bit identifier), ISO-11898
Bit Rate	1 Mbit/s (configurable upon request)
Byte Order	Big-Endian / Motorola
Data Conversion	1μV per bit — Diff. Voltage 0.1 per bit — Calibrated Output 0.1˚C per bit — Temperature (all variables signed)
CAN ID (Default)	1250 (Dec) / 0x4E2 (Hex)
Termination	None

CAN ID: 0x4E2 (Default)

Differential Voltage (μV)		Calibrated Output, F		Internal Temperature		Opt. External Temperature	
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4 (MSB)	Byte 5 (LSB)	Byte 6 (MSB)	Byte 7 (LSB)

WIRING SPECIFICATIONS:

Wire	26 AWG M22759/32, DR25 jacket
Cable Length (typ.)	500 mm (CAN output side) 250 mm (strain gauge / load cell side)
Connector	None

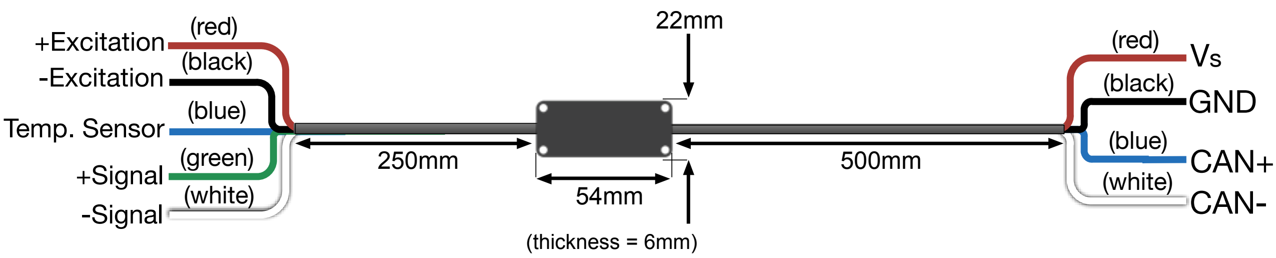
STRAIN GAUGE / LOAD CELL

Excitation +	Red	(twisted)
Excitation -	Black	
Signal +	Green	(twisted)
Signal -	White	
Temperature	Blue	

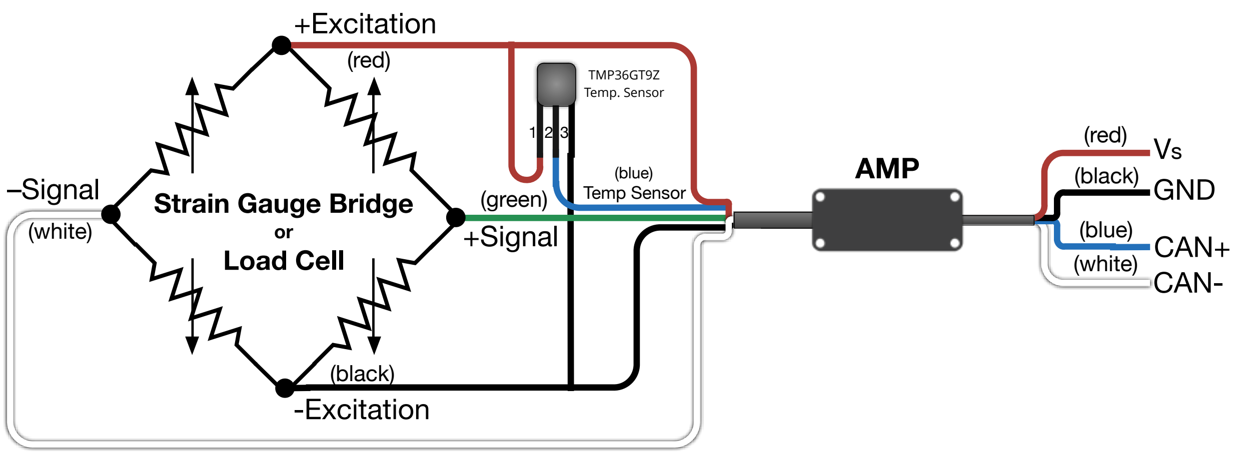
CAN

Supply Voltage, V_s	Red	(twisted)
Ground	Black	
CAN +	Blue	(twisted)
CAN -	White	

DIMENSIONS AND WIRING LAYOUT:



WIRING DIAGRAM:



- External Temperature Sensor: Analog Devices TMP36GT9Z
- The external temperature sensor, along with soldering tabs for strain gauge attachment, may be attached to the amplifier upon request.

SENSOR CONFIGURATION:

To modify the sensor's configuration, send the following CAN messages at 1Hz for at least 10 seconds and then reset the sensor by disconnecting power for 10 seconds:

CAN ID: Current Base ID

Programming Constant		New CAN Base ID (11-bit)		Update Rate	Temp. Comp.	Temp. Sensor	Bit Rate
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5	Byte 6	Byte 7
30000 = 0x7530		1 = 0x001 ⋮ 2047 = 0x7FF		1 = 100Hz 2 = 200Hz 3 = 400Hz 4 = 800Hz	1 = None 2 = Linear 3 = Tabular	1 = Internal 2 = External	1 = 1 Mbit/s 2 = 500 kbit/s 3 = 250 kbit/s 4 = 125 kbit/s

CAN messages should only be sent to the sensor during the configuration sequence. **DO NOT continuously send CAN messages to the sensor.**

LINEAR CALIBRATED OUTPUT, F:

$$F = M \times V + C$$

(F has resolution of 0.1)

where,

V = 16-bit voltage in μV

The gain, M, and offset, C, are specified in scientific notation:

$$M = m_M \times 10^{n_M}$$

$$C = m_C \times 10^{n_C}$$

where the respective coefficient, m, and exponent, n, are specified by sending the following CAN messages to the amplifier (send at 1-10Hz for 10 seconds, then cycle power to sensor):

CAN ID: Current Base ID

Programming Constant		Gain, Coefficient [m_M]		Gain, Exponent [n_M]	Offset, Coefficient [m_C]		Offset, Exponent [n_C]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20000 = 0x4E20		0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)

<u>EXAMPLE:</u>

$$M = 1.234\ N/\mu V = 1234 \times 10^{-3} \quad \Rightarrow m_M = 1234,\ n_M = -3$$

$$C = -5600\ N = -56 \times 10^{2} \quad \Rightarrow m_C = -56,\ n_C = 2$$

$$m_M = 1234 = 1234\ \text{(DEC) or 0x4D2 (HEX) for Byte 2-3}$$

$$n_M = -3 \rightarrow \text{2's Compliment} \Rightarrow (2^8 - 3) = 253\ \text{(DEC) or 0xFD (HEX) for Byte 4}$$

$$m_C = -56 \rightarrow \text{2's Compliment} \Rightarrow (2^{16} - 56) = 65480\ \text{(DEC) or 0xFFC8 (HEX) for Byte 5-6}$$

$$n_C = 2 = 2\ \text{(DEC) or 0x02 (HEX) for Byte 7}$$

Resultant CAN Message:

Programming Constant		Slope, Coefficient [m_M]		Slope, Exponent [n_M]	Offset, Coefficient [m_C]		Offset, Exponent [n_C]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20000 = 0x4E20		1234 = 0x4D2 (Value = 1234)		253 = 0xFD (Value = -3)	65533 = 0xFFC8 (Value = -56)		2 = 0x02 (Value = 2)

LINEAR TEMPERATURE COMPENSATION of CALIBRATED OUTPUT, F:

$$F = M(T) \times V + C(T)$$

where,

$$V = \text{16-bit voltage in } \mu V$$

$$M(T) = (T - 25^{\circ}C) \times \frac{M_L}{100} \times M_0 + M_0$$

$$C(T) = (T - 25^{\circ}C) \times C_L + C_0$$

- M_0 and C_0 are the linear gain and offset constants (referenced at 25˚C) programmed in the previous section.
- T is the temperature measured by the internal or external temperature sensor.
- M_L is the percent change in gain, M, per degree Celsius, $M_L \doteq \left[\frac{\%}{^{\circ}C}\right]$
- C_L is the correction in offset, C, per degree Celsius, $C_L \doteq \left[\frac{\Delta C}{^{\circ}C}\right]$
- M_L is approximately -0.034 % /˚C for steel and -0.067 % /˚C for aluminum. The temperature correction in offset, C_L, is application specific but typically linear in behavior.

The gain's temperature sensitivity, M_L, and temperature correction in offset, C_L, are specified in scientific notation:

$$M_L = m_{ML} \times 10^{n_{ML}}$$

$$C_L = m_{CL} \times 10^{n_{CL}}$$

where the respective coefficient, m, and exponent, n, are specified by sending the following CAN message to the amplifier (send at 1-10Hz for 10 seconds, then cycle power to sensor):

CAN ID: Current Base ID

Programming Constant		M_L, Coefficient [m_{ML}]		M_L, Exponent [n_{ML}]	C_L, Coefficient [m_{CL}]		C_L, Exponent [n_{CL}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20001 = 0x4E21		0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)

EXAMPLE:

M_L = -.067 % / °C = -67×10^{-3} $\Rightarrow m_{ML} = -67,\ n_{ML} = -3$

C_L = 4.53 N / °C = 453×10^{-2} $\Rightarrow m_{CL} = 453,\ n_{CL} = -2$

$m_{ML} = -67 \rightarrow$ 2's Compliment $\Rightarrow (2^{16} - 67) = 65469$ (DEC) or 0xFFBD (HEX) for Byte 2-3

$n_{ML} = -3 \rightarrow$ 2's Compliment $\Rightarrow (2^{8} - 3) = 253$ (DEC) or 0xFD (HEX) for Byte 4

$m_{CL} = 453 = 453$ (DEC) or 0x1C5 (HEX) for Byte 5-6

$n_{CL} = -2 \rightarrow$ 2's Compliment $\Rightarrow (2^{8} - 2) = 254$ (DEC) or 0xFE (HEX) for Byte 7

Resultant CAN Message:

Programming Constant		Slope, Coefficient [m_{ML}]		Slope, Exponent [n_{ML}]	Offset, Coefficient [m_{CL}]		Offset, Exponent [n_{CL}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20001 = 0x4E21		65469 = 0xFFBD (Value = -67)		253 = 0xFD (Value = -3)	453 = 0x1C5 (Value = 453)		254 = 0xFE (Value = -2)

TABULAR TEMPERATURE COMPENSATION of CALIBRATED OUTPUT, F:

$$F = M(T) \times V + C(T)$$

where,

$$V = \text{16-bit voltage in } \mu V$$

M(T) and C(T) vary with temperature according to the table below (with linear interpolation):

Temp.	Gain, $M_{T\#}$	Offset, $C_{T\#}$
-25˚C	M_{T0}	C_{T0}
0˚C	M_{T1}	C_{T1}
25˚C	M_{T2}	C_{T2}
50˚C	M_{T3}	C_{T3}
75˚C	M_{T4}	C_{T4}
100˚C	M_{T5}	C_{T5}
125˚C	M_{T6}	C_{T6}
150˚C	M_{T7}	C_{T7}

The gain and offset at different temperatures, $M_{T\#}$ and $C_{T\#}$, respectively, are specified in scientific notation:

$$M_{T\#} = m_{MT\#} \times 10^{n_{MT\#}}$$

$$C_{T\#} = m_{CT\#} \times 10^{n_{CT\#}}$$

where the respective coefficient, m, and exponent, n, are specified by sending the following CAN messages to the amplifier (send at 1-10Hz for 10 seconds, then cycle power to sensor):

Gain and Offset at -25˚C

Programming Constant		M_{T0}, Coefficient [m_{MT0}]		M_{T0}, Exponent [n_{MT0}]	C_{T0}, Coefficient [m_{CT0}]		C_{T0}, Exponent [n_{CT0}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20002 = 0x4E22		0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)

Gain and Offset at 0˚C

Programming Constant		M_{T1}, Coefficient [m_{MT1}]		M_{T1}, Exponent [n_{MT1}]	C_{T1}, Coefficient [m_{CT1}]		C_{T1}, Exponent [n_{CT1}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20003 = 0x4E23		0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2's compliment)		0 = 0x000 ⋮ 256 = 0x100 (2's compliment)

Gain and Offset at 25˚C

Programming Constant		M_{T2}, Coefficient [m_{MT2}]		M_{T2}, Exponent [n_{MT2}]	C_{T2}, Coefficient [m_{CT2}]		C_{T0}, Exponent [n_{CT2}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20004 = 0x4E24		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

Gain and Offset at 50˚C

Programming Constant		M_{T3}, Coefficient [m_{MT3}]		M_{T3}, Exponent [n_{MT3}]	C_{T3}, Coefficient [m_{CT3}]		C_{T3}, Exponent [n_{CT3}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20005 = 0x4E25		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

Gain and Offset at 75˚C

Programming Constant		M_{T4}, Coefficient [m_{MT4}]		M_{T4}, Exponent [n_{MT4}]	C_{T4}, Coefficient [m_{CT4}]		C_{T0}, Exponent [n_{CT4}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20006 = 0x4E26		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

Gain and Offset at 100˚C

Programming Constant		M_{T5}, Coefficient [m_{MT5}]		M_{T5}, Exponent [n_{MT5}]	C_{T0}, Coefficient [m_{CT5}]		C_{T0}, Exponent [n_{CT5}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20007 = 0x4E27		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

Gain and Offset at 125˚C

Programming Constant		M_{T6}, Coefficient [m_{MT6}]		M_{T6}, Exponent [n_{MT6}]	C_{T6}, Coefficient [m_{CT6}]		C_{T6}, Exponent [n_{CT6}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20008 = 0x4E28		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

Gain and Offset at 150˚C

Programming Constant		M_{T7}, Coefficient [m_{MT7}]		M_{T7}, Exponent [n_{MT7}]	C_{T7}, Coefficient [m_{CT7}]		C_{T7}, Exponent [n_{CT7}]
Byte 0 (MSB)	Byte 1 (LSB)	Byte 2 (MSB)	Byte 3 (LSB)	Byte 4	Byte 5 (MSB)	Byte 6 (LSB)	Byte 7
20009 = 0x4E29		0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)	0 = 0x0000 ⋮ 65536 = 0x7FFF (2’s compliment)		0 = 0x000 ⋮ 256 = 0x100 (2’s compliment)

ADDITIONAL INFORMATION:

- Recommended full-bridge strain gauges: 350Ω OMEGA Transducer Quality Strain Gauges
  - Bending/Axial: www.omega.com/pptst/SGT_Full-Bridge_Diaphragm.html
  - Shear: www.omega.com/pptst/SGT_Full-Bridge_Shear.html

- An update frequency of 100 or 200Hz offers a good balance between speed & RMS noise and is recommended for most applications

- The wiring harness length between the amplifier and strain gauge / load cell should be as short as possible

- Do not subject the amplifier module to stress, force, and/or bending

- Avoid mounting the amplifier near hot objects. The temperature of the amplifier should closely match the temperature of the strain gauge if the *internal* temperature sensor is used for temperature compensation.