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1X3 Bridge Amplifier

Resistive bridge amplifier with integrated excitation and power conditioning.

Logos Electromechanical

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Introduction

A bridge circuit is a common arrangement in a variety of different measurement applications, but particularly in force and pressure transducers. The output of these sensor types is proportional to the excitation voltage applied, and is on the order of millivolts in any case. Interfacing these sensors with a microcontroller or a data acquisition system requires a precision voltage source and a precision high gain amplifier stage. This board provides both in a convenient package.

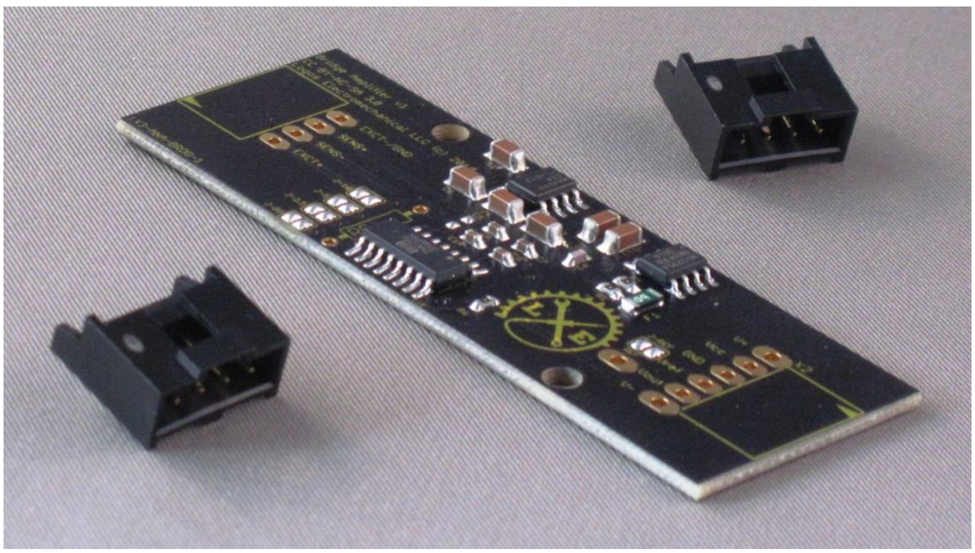

Figure 1: Kit Contents

In addition to force and pressure transducers, this bridge circuit can be used with strain gauges, thermistors, RTDs, or hot wire anemometers. The versatility of this module is further increased by onboard charge pump that allows it to develop ±10V bipolar output from a 6V to 30V single-ended voltage supply.

Board Overview

This board is built around the Texas Instruments INA125, which combines a precision voltage reference stage with a precision high-gain amplifier. This board provides the support circuitry required to use it in your system with an absolute minimum of external support.

It is supplied as a kit, with the gain resistor not installed in order to permit the end user to install a gain resistor appropriate for their desired purpose. The board is provided as a kit with precision resistors. The 182Ω resistor corresponds to a gain of 333 and the 121Ω resistor corresponds to a gain of 500.

Board Layout

The board is roughly divided into three sections – the input power stage, the bipolar power stage, and the amplifier stage. The input power stage contains a low dropout regulator along with a resettable PTC fuse and a diode to prevent reverse connection of the power from damaging the regulator. This produces a 5.75VDC output that feeds into the bipolar power stage.

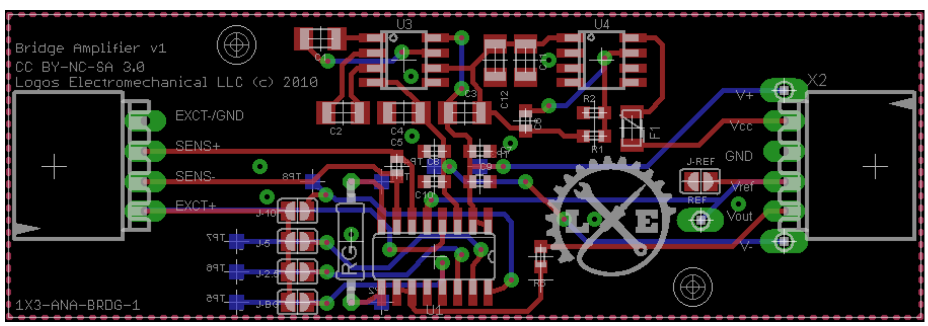

Figure 2: Board Layout

The bipolar power stage uses a MAX680 switched capacitor voltage converter. This uses an array of capacitors to produce a ±11.5V bipolar supply for the amplifier stage. This allows the amplifier to read in both directions for sensors such as push-pull load cells and RTDs. Also included are filter capacitors to reduce switching and transient noise on the amplifier power inputs.

The amplifier stage consists of the INA125, a precision gain setting resistor, an output protection resistor, input filter, and excitation selection jumpers. The solder jumper block allows the user to use any of the four excitation voltages provided by the INA125 – 10V, 5V, 2.5V, or 1.24V. Excitation voltage should be chosen in order insure that excitation current is less than 10 mA.

Like all 1X3 series boards, this board is designed for convenient mounting. The mounting holes and connectors are arranged to facilitate mounting the board inside an enclosure with the connectors projecting out on each side. Files for 3D printing a suitable enclosure will be coming soon to Thingiverse.

Pinout

Both input and output connectors are 4-pin Molex C-Grid III right angle connector (Molex p/n 90136-2104). They are left unsoldered in order to allow the user to configure them as desired. The mating housing is Molex p/n 90156-0144; crimp pins are Molex series 90119.

Table 1: Sensor connector pinout

Sensor Pin	Name	Functions
1	Excitation	Selected excitation voltage, positive
2	Sense -	Negative sense voltage
3	Sense +	Positive sense voltage
4	Excitation Return/Ground	Excitation voltage return/ground (connected to pin 2 on output side)

Table 2: Output connector pinout

Output Pin	Name	Functions
1	V_{cc}	Power supply, 6 – 30VDC
2	Ground	Circuit ground (connected to pin 4 on sensor side)
3	V_{ref}	Reference voltage – shorted to ground for most applications
4	V_{out}	Output voltage

Electrical Characteristics

Table 3: Electrical characteristics

Symbol	Parameter	Max	Typ	Min	Units
V_{in}	Maximum Supply Voltage (range)	60		-20	V
G	Gain (range)	10,000		4	
	Safe sense voltage		±40		V
$I_{excitation}$	Excitation Current	10			mA

This table covers parameters required to successfully hook up this circuit without damaging it or impairing its operation. For further performance information on the performance of the INA125 amplifier and voltage reference stages, please see the INA125 datasheet.

Board Usage

Selecting Gain

The gain of the INA125 is programmed with a gain resistor. This really wants to be a precision resistor – 1% or 0.5% tolerance; anything more is not only absurdly expensive but also pointless, because it is more precise than the amplifier stage. The resistors supplied with the kit are 1%. Likewise, a temperature coefficient of greater than 25 ppm/°C is not generally useful as the tempco of the INA125 is typically ±25 ppm/°C with a maximum of ±100 ppm/°C. The gain of the amplifier stage is equal to $4 + \frac{60\ k\Omega}{R_g}$, where R_g is the resistance of the gain resistor in kΩ.

The two resistors included with the kit are both 0.1% metal film resistors with a temperature coefficient of 50 ppm/°C. The 182Ω resistor corresponds to a gain of 333 and the 121Ω resistor corresponds to a gain of 500. If the 10V excitation is selected, these produce a 5V full scale output from a 3mV/V or 2 mV/V full-scale sensor, respectively. These are common full range values for load cells and pressure transducers. No gain resistor is installed by default; either select the appropriate one from the two provided or acquire an appropriate one for your application.

Selecting Excitation

The INA125 provides four excitation modes. In addition, the default excitation modes can be augmented with external circuitry. The default modes are 10V, 5V, 2.5V, or 1.24V (BG). The appropriate voltage is selected by making one of the four provided solder jumpers. These are on the output side of the board next to the end of the INA125, and are labeled J-10, J-5, J-2.5, and J-BG. Never make more than one at a time. They are left unmade by default in order to ease customization by the end user. Choose your excitation voltage such that the excitation current is always less than 10 mA.

Selecting Reference

Since the INA125 is factory trimmed for extremely low offset and drift. Therefore, no offset adjustment will be required for most applications. When no offset is desired, the V_{ref} pin should be shorted to ground. A solder jumper, J-REF, (unmade by default) is provided for this purpose. When an offset is desired, it is set by providing a voltage to this pin. The voltage on this pin is added to the output signal. It is imperative that the value provided to this pin not be outside of the range of internal power supply rails (i.e. greater than +11.5V or less than -11.5V). A low impedance voltage source is desirable in order to provide good common-mode rejection. The voltage rails are provide on contacts in-line with the normal output connector and on the same spacing, so a 6-pin connector can be installed if desired.

You can also do a quick and dirty approach with a resistor from each power rails to the offset pad located just below the jumper. This is less desirable than an external circuit, because the impedance will necessarily be higher.

Output Limiting

Many microcontroller inputs require a single-ended 0-5V output rather than the full ±11V output that the amplifier is capable of outputting. The gain and reference voltages should be selected such that the desired input produces an output within the range of the analog input you are reading it with. However, it is still possible for a fault condition to drive the output of amplifier out to the internal bipolar power rails. In order to prevent the amplifier from damaging the analog input, place a 5.1V zener diode between the amplifier output and the analog input reference (typically ground). Attach the cathode end of the zener to the voltage output and the anode end to the analog reference. The output resistor will protect the amplifier circuitry. If the output voltage goes below ground, the zener goes into forward conduction and limits the voltage to on diode drop below ground. If the output voltage goes above 5.1V, the zener diode breaks down and limits the output voltage to 5.1V.

Load Cell/Pressure Transducer Interface

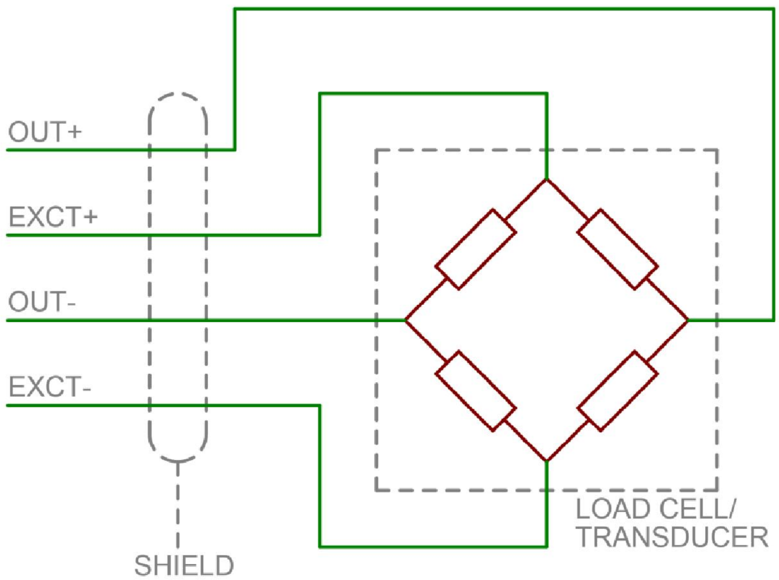

Figure 3: Load cell/Pressure transducer wiring

Typical millivolt output load cells and pressure transducers will have a 4-conductor shielded cable. The wires in the cable will be labeled with a positive and negative excitation and a positive and negative sense. The shield should be firmly bonded to either the electronics enclosure or to the system ground point. Figure 3 shows the appropriate connections.

The sensitivity of the load cell or pressure transducer will typically be expressed in terms of mV of full scale output per volt of excitation. The two most common values are 2 mV/V and 3 mV/V; resistors are provided in the kit for these two scale values that provide 5V full scale output from 10V of excitation. Typically, these types of sensors are calibrated at 10V of excitation. It's best to operate them at their calibration point, so you should select the 10V excitation by making the J-10 solder jumper. Install the gain resistor corresponding to your sensor's scale and the board is ready to use.

Strain Gauge

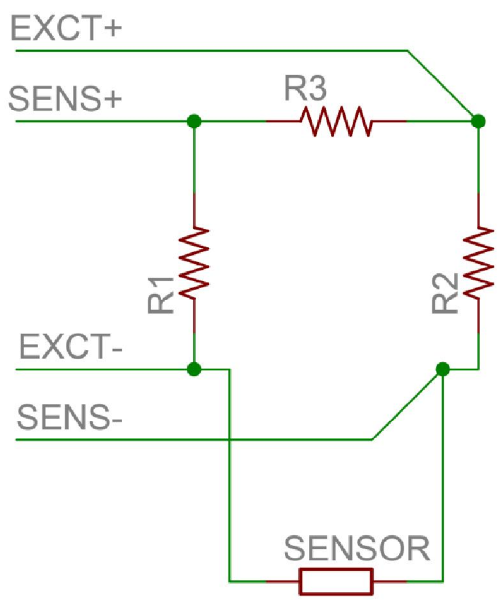

Figure 4: Strain Gauge bridge completion

A strain gauge is a resistive element that changes its resistance when deformed. You will have to provide the other resistors to complete the bridge circuit, as shown in Figure 4. Care must be taken with the sizing of the strain gauge and bridge completion resistors not to overtax the excitation voltage reference.

All of the bridge completion resistors must be equal to each other and should have a similar resistance to the nominal resistance of the sensor. Total resistive load on the excitation will then be approximately equal to the nominal resistance of the sensor. Take care to select sensor resistance values and excitation values that keep the total excitation current below 10 mA.

RTD/Thermistor

RTD (resistance temperature detectors) and thermistors can be wired in exactly the same fashion as strain gauges, and all of the same caveats apply. This is especially tricky since the typical RTD has a nominal resistance of 100 ohms. If excited at 1.24V in a balanced bridge configuration, the circuit would draw 12.4 mA, which would result in substantial voltage sag, sensor self-heating, and inaccurate readings. A dropping resistor in series with the positive or negative excitation will take care of this problem.

Alternately, the excitation voltage can be used to create a precision current source, using a simple transistor current source circuit. This constant current is then run across the RTD and the resulting voltage drop is measured normally with the sense inputs.

References

Datasheet for INA125 instrumentation amplifier http://focus.ti.com/lit/ds/symlink/ina125.pdf

Datasheet for MAX680 charge pump http://pdfserv.maxim-ic.com/en/ds/MAX680-MAX681.pdf

Datasheet for MIC2954 voltage regulator http://www.micrel.com/_PDF/mic2954.pdf

How load cells work http://www.sensorland.com/HowPage005.html