Remote System Monitor Applications

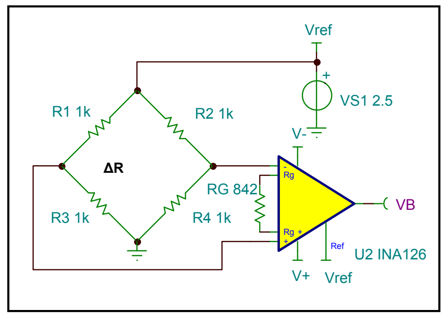
Section 2

Welcome to the 2005 Precision Analog Applications Seminar. This portion of the seminar will focus on Remote System Monitor applications. We'll take a look at sensors and analog circuits that can be applied in monitoring the operating conditions of a remotely located system.

Remote System Monitor Applications
Outline

Presentation subjects

- The Data Acquisition System (DAS)
- A measurement basis
- System attributes to be monitored
- Sensor characteristics
- Analog interface



This seminar will focus on the task of remotely measuring and monitoring a system's operating parameters. An integrated data acquisition system (DAS) IC will be included in the discussion, as it serves as the conduit for collecting and converting the signals from the various sensor channels.

The measurement bridge circuit that serves as the fundamental circuit for many sensors will be reviewed. Several types of sensors that work as an integral part of the measurement bridge will be discussed. The sensor response characteristics will be discussed in some detail.

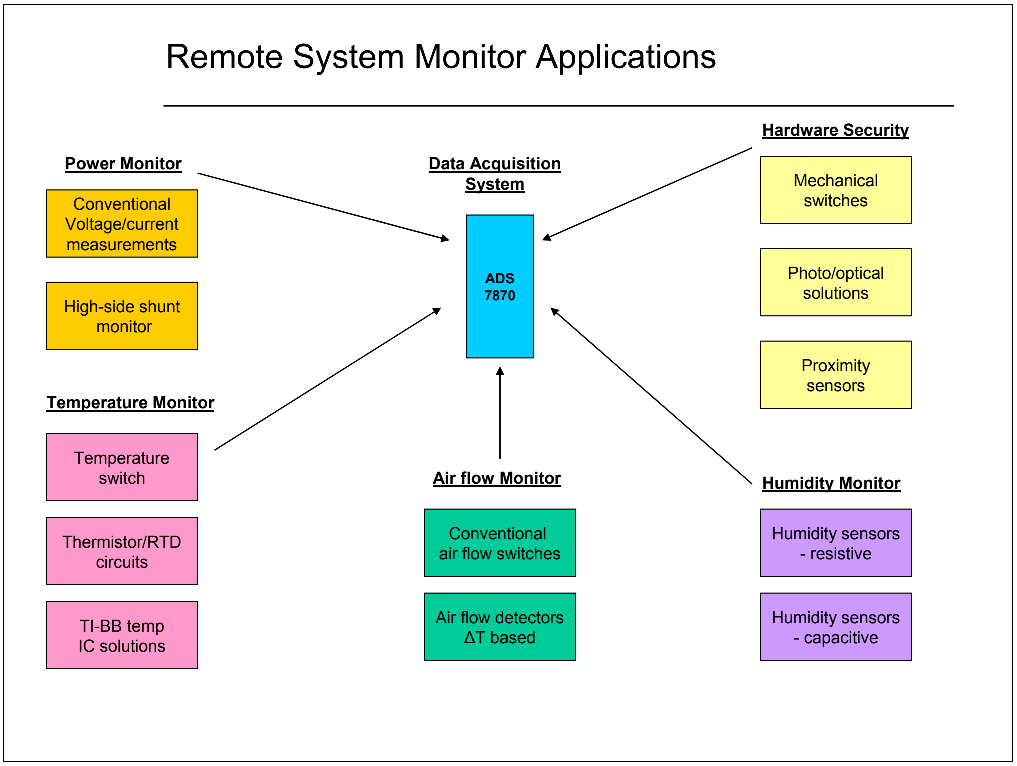
The bridge response to a stimulus is then conditioned by an analog interface circuit where it may be amplified, filtered, level shifted, etc, before being applied to a DAS input. Various circuits for accomplishing these tasks will be presented.

Remote System Monitor Applications

Examples of remote systems

- Cell phone base stations
- Microwave repeaters
- AM, FM and TV transmitter sites
- Server sites
- Factory and industrial facilities
- Farm and agricultural equipment
- Any application where monitoring is accomplished from afar

A remote system may be any system that requires monitoring from a different location. Connection to the remote system may be made via cable, telephone lines, fiber optic lines, or wireless links.

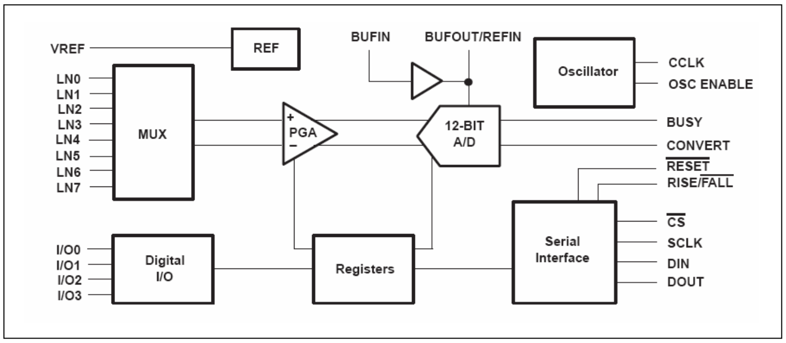


Here are some examples of different system attributes that may be monitored in a remote installation. An ADS7870 data acquisition system IC (DAS) collects and converts the information from the sensors to a digital serial format. Although some sensors may have sufficient output to directly drive the analog input scale of the DAS, many won't. Most often an analog interface is required to amplify and condition the sensor outputs before they are applied to the DAS inputs.

Remote System Monitor Applications

ADS7870 Data Acquisition System

- 12-bit, 52k-samples/sec DAS with A/D, MUX, PGA and reference
- PGA gains 1, 2, 4, 5, 8, 10, 16 and 20V/V
- Programmable inputs - Up to 4-ch differential or 8-ch single ended
- Selectable internal reference of 1.15V, 2.048V, or 2.5V (or ext input)
- 2.7V to 5.5V single supply operation
- 4-bit digital I/O serial interface - SPI™, QSPI™, Microwire™ and 8051-family protocols, without glue logic



ADS7870 Data Acquisition System Diagram

Shown here is the ADS7870 DAS block diagram. The 4 differential (8 single-ended) multiplexer inputs allow for a corresponding number of analog channels to be simultaneously monitored.

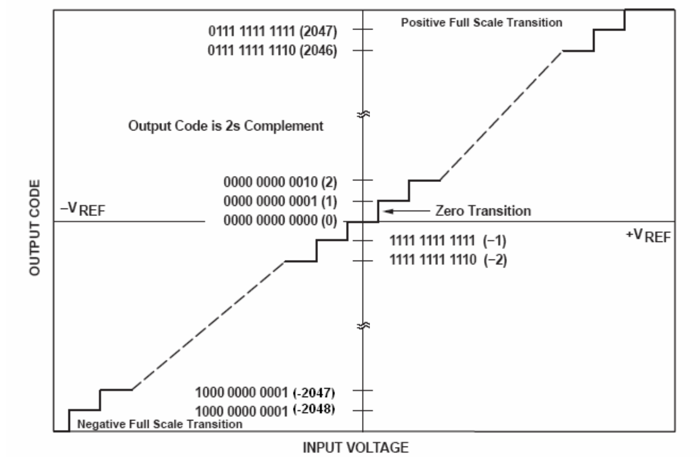
The ADS7870's PGA features selectable gain levels that are electronically set. Thus, a wide range of input signals can be accommodated. The internal reference, selectable at 1.15V, 2.048V and 2.5V, provides a convenient reference voltage that can be used to bias the reference pin of instrumentation amplifiers.

For many remote monitoring applications the 12-bit A/D resolution will provide adequate resolution.

Remote System Monitor Applications

ADS7870 Data Acquisition System

ADS7870 output codes vs. input voltage



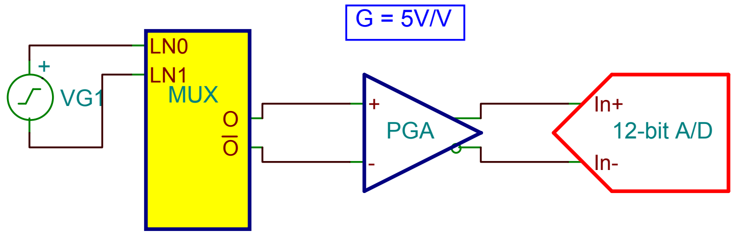
Diff. input:	**-2048 ≤ Code ≤ 2047**	***for***	**$-V_{REF}/G \le V_{IN} \le (V_{REF}$ -1 LSB)/G**
Single input:	**0 ≤ Code ≤ 2047**	***for***	**$0 \le V_{IN} \le (V_{REF}$ -1 LSB)/G**

The ADS7870's internal 12-bit, A/D converter provides 2^{12}, or 4096 distinct output codes, for an input range of –FS (full scale) to +FS. Depending on the input mode, single-ended or differential, the code range is 0 to 2047 or -2048 to 2047, respectively. The converter's output code is a 2's complementary binary format.

Remote System Monitor Applications

ADS7870 Data Acquisition System

Establishing the ADS input voltage range



Let: PGA gain (G) = 5V/V, V_{REF} = 2.5V

For Diff. input: $-V_{REF}/G \le V_{IN} \le (V_{REF} - 1LSB)/G$

where: $1LSB = FSR/2^n = 5V/4096 = 1.221mV$

$-2.5V/5.0 \le V_{IN} \le (2.5V - 1.22mV)/5.0$

$= -0.5V \le V_{IN} \le +0.4497V$

Then with V_{REF} = 2.5V the input range is 2.000V to 2.9998V

Whenever possible use the maximum input range to capitalize on the A/D converter's full-scale resolution. The slide shows how to establish the A/D converter's input voltage, taking into account the selected reference voltage and PGA gain.

Remote System Monitor Applications

ADS7870 Data Acquisition System

Some system considerations:

- Sensor characteristics
- Analog interface to sensor
- Analog output to ADS7870 multiplexer input
- ADS7870 PGA function
- ADS7870 A/D performance
- The intended data acquisition system control response:
  - Provide orderly power shut down
  - Turn cooling fan on, off or increase/decrease speed, etc.
  - Provide warning

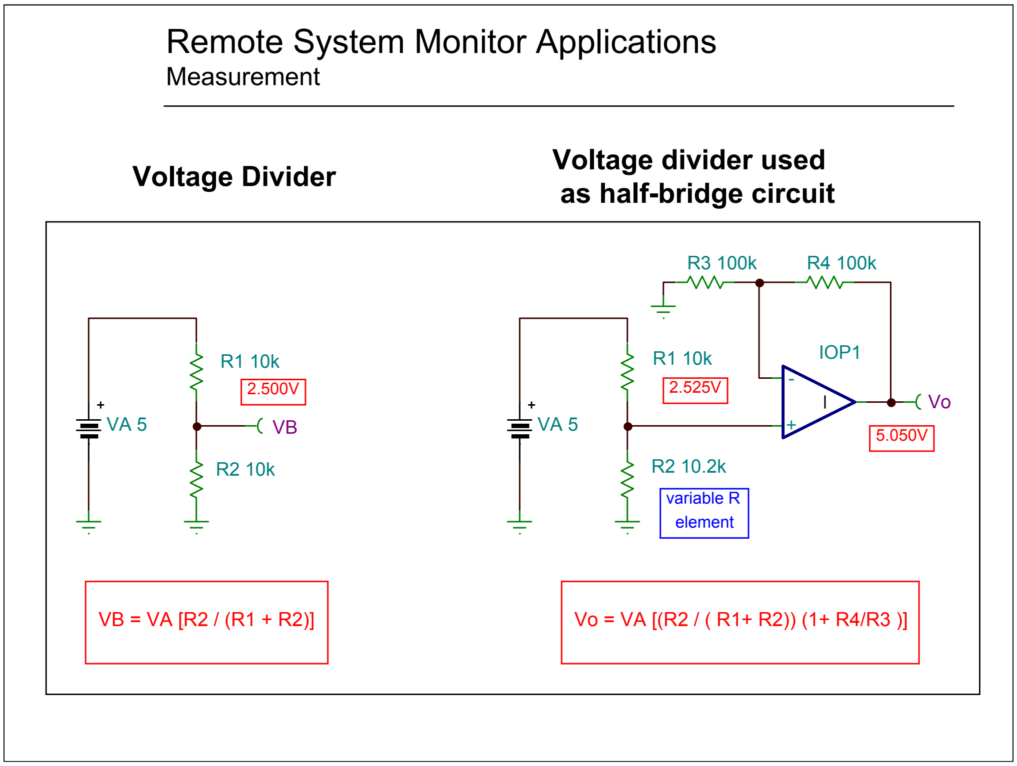
The various sensors and transducers have widely different electrical characteristics. This ultimately dictates the analog interface circuit design and DAS set up for that measurement channel. The DAS should be set up to use the full A/D input range. This improves the system signal-to-noise ratio.

Should the DAS output code indicate an out-of-range or fault condition a decision needs to be what the system response will be.

Remote System Monitor Applications

A Measurement Basis

It is helpful to establish a measurement basis before proceeding with the sensors and analog interface circuits.

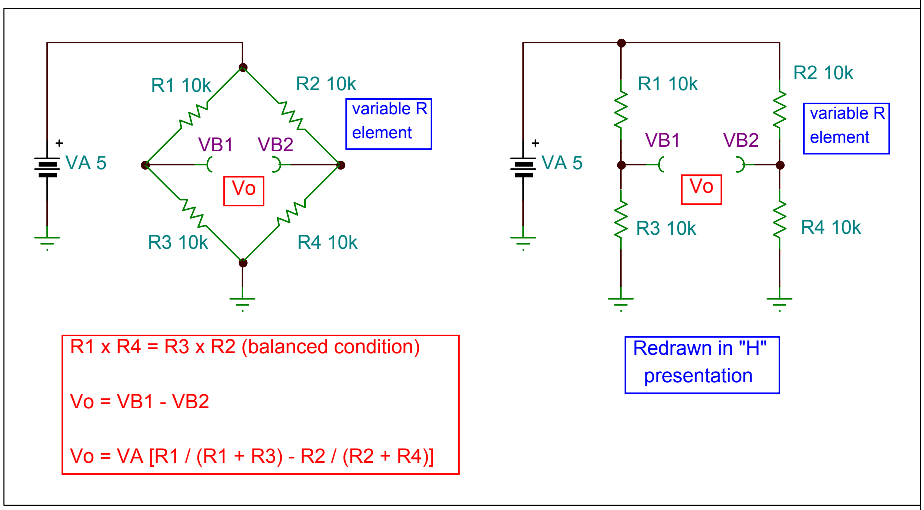


The basis for many sensor circuits is the simple voltage divider; where one of the resistors in the divider is a resistive sensor. The voltage at the divider union, VB, changes in response to a change in the sensor resistance. This simple circuit is often referred to as a half bridge. Note that a load connected to VB will reduce the normal unloaded value measured and must be taken into consideration.

The half bridge output can be buffered with an operational amplifier which also can be configured for a voltage gain. The op-amp should be selected to minimize the loading on the divider *i.e*. have low input bias current.

Remote System Monitor Applications
Measurement

Full-bridge Circuit



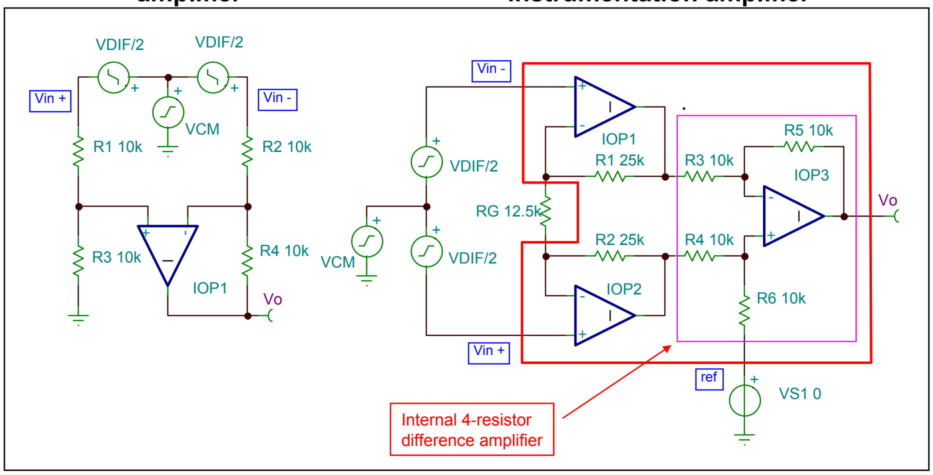
If we take the simple voltage divider, or half-bridge, and place 2 of them back-to back a full-bridge is created. When all resistors are equal, the output voltage at each half is identical. Changing one or more resistors unbalances the bridge resulting in a differential voltage change (Vo).

The full-bridge is sometimes referred to as a measurement bridge. And although it has a similar appearance to a Wheatstone bridge, the two perform different functions.

The Wheatstone bridge incorporates a current meter at points VB1 and VB2, and is used to indicated when a balanced condition is achieved. At that point the voltage at VB1 and VB2 are equal resulting in no current flow through the meter path. Unknown resistance or reactance can be inferred by knowing the resistances or reactances in the other bridge legs.

Remote System Monitor Applications
Measurement

Four-resistor, difference amplifier | **Three op-amp, instrumentation amplifier**



A difference amplifier is formed when the 4-resistor bridge is connected to an op-amp as shown. A common mode voltage (Vcm) applied to the two op-amp inputs, will be cancelled by the equal and opposite responses of the two inputs. If all resistors are exactly equal in value and the common mode rejection is very high the output voltage will be nearly zero. A differential voltage applied to the difference amplifier inputs appears out of phase at the amplifier and is thus amplified.

The difference amplifier has an output voltage relationship:

Differential	Vo_{Dif} = (Vin+) – (Vin-)
Common-mode	Vo_{CM} = [(Vin+) + (Vin-)] / 2

The VDif and Vcm source arrangement shown in the diagrams is an analysis model that conveniently allows both the differential and common-mode sources to be simultaneously applied. A split differential source is not a practical circuit in reality.

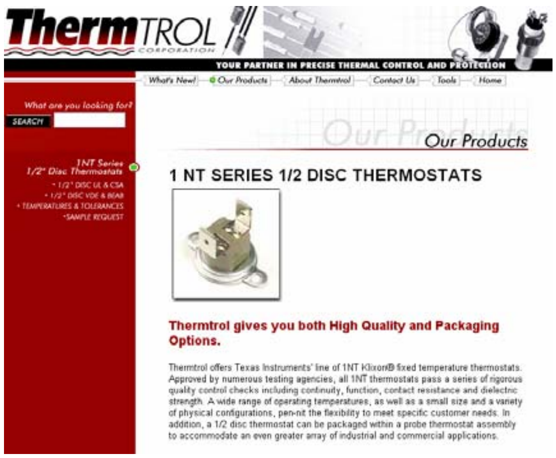
By buffering the difference amp with a differential input gain stage a three op-amp, instrumentation amplifier is created. The instrumentation amplifier serves as the interface between the bridge and any subsequent signal conditioning circuits. It provides excellent common-mode rejection and high gain accuracy.

Remote System Monitor Applications

Temperature Monitoring

Remote System Monitor Applications

Temperature control and monitoring – on/off solution



Features

- **Mechanical Solution – bimetal switch**
- **Fixed temperature thermostats**
- **On-off operation from 0°C to 200°C**
- **AC power switching**
- **Low voltage DC power switch available**
- **Manufactured by Thermtrol, Airpax, Selco, Thermodisc, Matsuo and others**

1. The thermal switch is an easily implemented, on/off control.

2. Tolerance is different for open and close.

   Automatic reset type

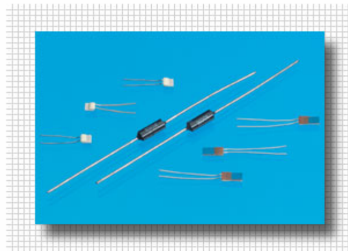
Temp range C	open ± C	close ± C
0 -93	3.0	4.0
94-121	3.5	4.5
122-149	4.0	5.5
150-204	5.0	7.0

3. Suppliers include Thermtrol, Airpax, Selco, Termodisc, Matsuo and others.

Remote System Monitor Applications

Temperature monitoring – RTD

Resistance Temperature Devices - RTDs



Source: Advanced Thermal Products, Inc.

- RTD: resistance temperature device
- Linear resistance change with temperature
- Positive temperature coefficient
- Wire-wound or thick film metal resistor
- Manufacturers: Advanced Thermal Products, U.S. Sensors, Sensing Devices Inc.

The resistance temperature device, RTD, provides accurate, moderate cost temperature sensing. An important characteristic of the RTD is its near linear resistance change across temperature, $\Delta R/\Delta T$. Note, however, that the best linearity is achieved within portions of the full operating temperature range.

Remote System Monitor Applications
Temperature monitoring – RTD

Advantages

- Accuracy available to ±0.1˚C
- High linearity over limited temperature range; ex. -40˚C to +85˚C
- Wide temperature range: -250˚C to 600˚C (ASTM) 850˚C (IEC)

Remote System Monitor Applications
Temperature monitoring – RTD

Disadvantages (mostly minor)

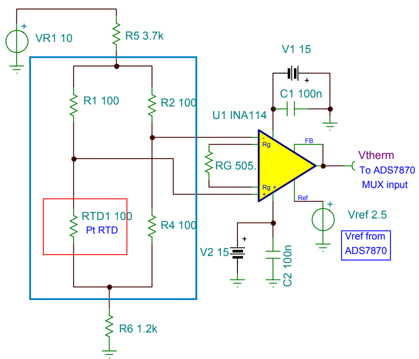
- Limited resistance range 100Ω to 1kΩ (typically)
- Low sensitivity, about +0.4Ω/°C for a 100Ω Pt100 RTD
- Requires linearization for wide range; ex. -200°C to +850°C
- Wire wound RTDs tend to be fragile
- Lead wire resistance may introduce significant errors
- Cost is high compared to a thermistor

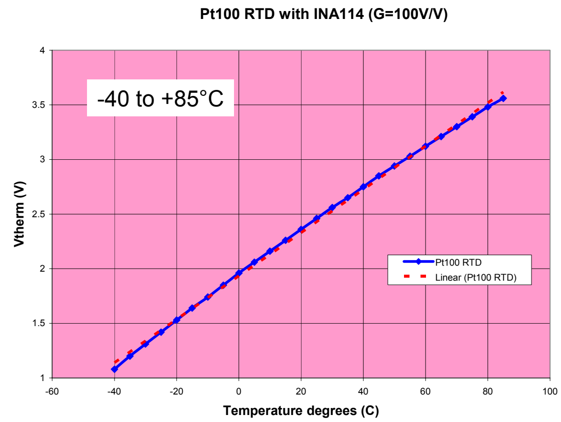
Since the RTD is a low resistance device long lead wires can add resistance in the sensors path and cause errors. Three and 4 wire solutions exist and can be used to correct for this additional resistance component.

Remote System Monitor Applications

Temperature monitoring – RTD

RTD in full-bridge circuit





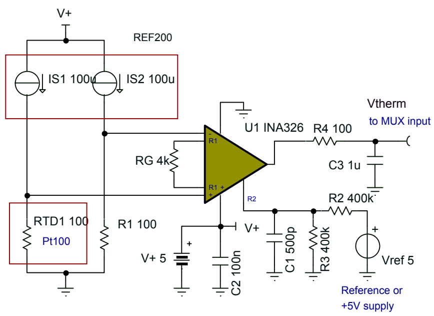
- Simple full-bridge bias using DC source and resistors
- RG can be selected to set output range
- Linearity suffers a little with this simple bias arrangement
- Non-linearity <2.5% end points, <1.3% other points

The schematic shows an RTD connected in a full-bridge circuit. The resistors above and below the bridge were selected such that the voltage at both INA114 inputs is 2.5V when the bridge is balanced. This matches the reference voltage which was selected as the mid scale voltage for the ADS7870 A/D converter. Reasonably good linearity performance is achieved from -40 to +85°C.

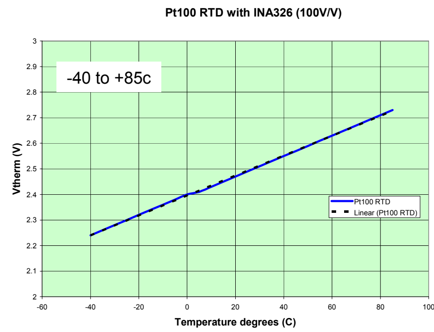
Remote System Monitor Applications

Temperature monitoring – RTD

Single-supply RTD solution



$A_v = 2\,((R_2 \,||\, R_3) / R_G)$



- Single supply - mid scale centered at 2.5V
- C1 and C3 combine to form a 2nd-order, 1kHz LP filter
- Very low non-linearity, about 1% or less

This schematic illustrates a more precise approach to biasing the RTD. The upper resistors in the full-bridge have been replaced by two equal, low current, current sources. This is easily accomplished with a REF200. The bridge bias current is low, 100μA, so the RTD dissipates little power, and an improvement in linearity is had over the previous circuit.

An INA326 is employed as a single-supply, bridge amplifier. The INA326 circuit can be configured to include a 2^{nd}-order, low-pass filter, which can be helpful in reducing the noise response. The output of this sensor circuit can be further amplified using the ADS7870’s internal PGA.

Remote System Monitor Applications

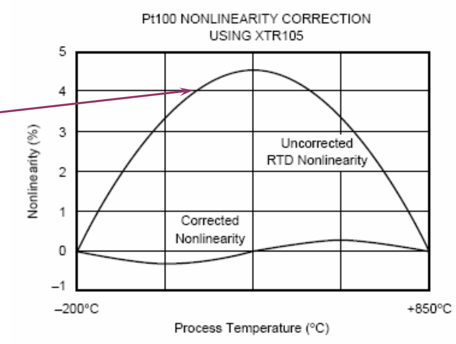
Temperature monitoring – RTD

RTD linearization for wide temperature ranges

For $T < 0°C$ $R_T = R_o [1 + \alpha T + \beta T^2 + \chi T^3(T-100)]$

For $T \geq 0°C$ $R_T = R_o [1 + \alpha T + \beta T^2]$

where: **R_T = resistance at temperature T**
R_o = nominal resistance of RTD
α, β, χ are constants used to scale the RTD



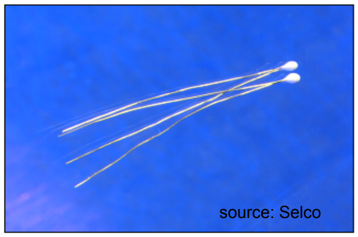
Coeff	American	DIN 43760	ITS-90
α	3.9692E-03	3.9080E-03	3.9848E-03
β	-5.8495E-07	-5.8019E-07	-5.8700E-07
χ	-4.2325E-12	-4.2735E-12	-4.0000E-12

Although the intended application of this seminar is a remote system monitor where temperature ranges are likely to be quite limited, there may be applications where wide temperature ranges must be monitored with high accuracy.

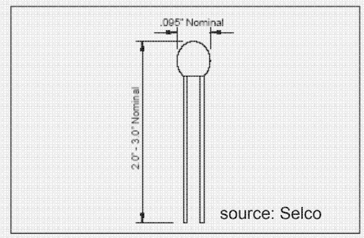
The RTD linearity has a predictable quadratic characteristic with a peak deviation approaching 5%. This quadratic curvature is shown in the accompanying diagram. Since it is predictable it is possible to reduce the error by applying linearization techniques.

The second curve in the diagram shows the reduction in the linearity error after linearization is applied. This particular RTD linearization technique is applicable to an XTR105, 4-20mA, 2-wire transmitter. The technique of summing a secondary current into the RTD across temperature reduces the error to that shown in the second curve.

Remote System Monitor Applications
Temperature monitoring – Thermistor



FEATURES:
- High accuracy tolerances to +/- 0.10°C
- Operating ranges from -50°C to 150°C
- Small size with ease of handling
- Proprietary processes produce top of the line quality and stability



Interchangeable refers to how accurately thermistors guarantee (R/T) curve over a range of temperatures. This allows every thermistor to be interchangeable with every other thermistor of the same series specifications without re-calibration of instrumentation.

- Thermistor – Thermally sensitive resistor
- Sintered metal oxide or passive semiconductor materials
- Suppliers – Selco, YSI, Alpha Sensors, Betatherm

The thermistor serves well as an economical temperature sensor for less critical applications. It's available in a wide range of resistance values and with tolerance values to 0.1%. Note, however, that this is the tolerance specified at a specific temperature and not over a wide temperature range.

Remote System Monitor Applications
Temperature monitoring – Thermistor

Advantages

- Low cost option for less critical applications
- Rugged construction
- Available in a wide range of resistances: 100Ω to 40MΩ
- Available with negative (NTC) and positive (PTC) temperature coefficients. NTC is most common.
- Highly sensitive: –3.9% / ˚C to –6.4% / ˚C for an NTC thermistor

Three YSI Inc Thermistors

The NTC thermistor is by far the most common and is often used as a temperature sensor. The PTC thermistor is often employed as a temperature sensitive element within a circuit. It is often used to alter the bias of a circuit in response to temperature.

Remote System Monitor Applications
Temperature monitoring – Thermistor

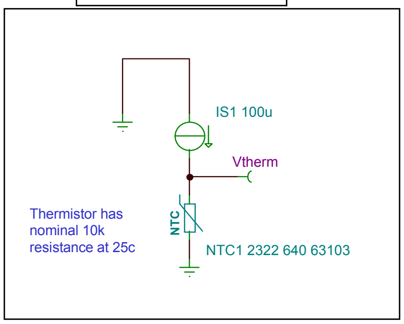
Disadvantages
- Limited temperature range: –100˚C to 200˚C
- Highly non-linear response
- Linearization nearly always required

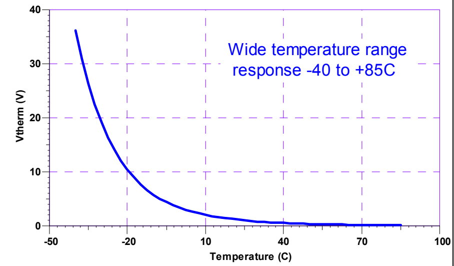
Considering the attractiveness of thermistor's low cost, often less than $1.00, the downside isn't too bad. The primary drawback of the device is the poor linearity performance if the application calls for monitoring a wide temperature range.

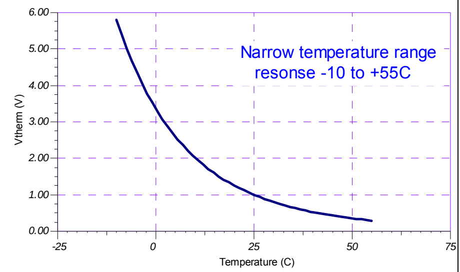
For many limited remote monitoring applications, the thermistor's usable range and linearity is completely adequate - once simple linearization techniques are applied.

Remote System Monitor Applications
Temperature monitoring – Thermistor

Thermistor biased by a constant current source







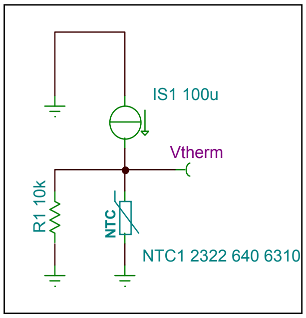
- Log function response
- Poor linearity beyond a 5 to 10°C range

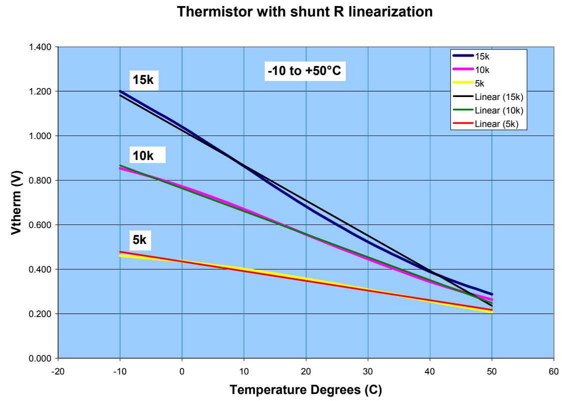
These plots depict the thermistor's response to temperature over a narrow and then wider temperature range. Thermistor biasing is by a simple current source. As is, the linearity suffers with temperature spans greater than 5 to 10°C.

Remote System Monitor Applications

Temperature monitoring – Thermistor

Shunt R linearization





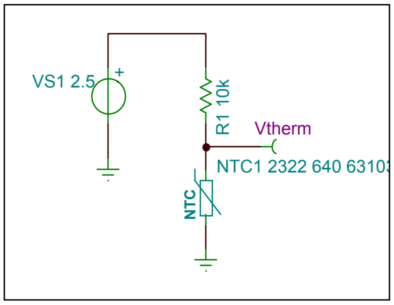
- Much improved linearity with shunt resistance added (limited temp range)
- Non-linearity is under 3% for example when R-shunt equal to the thermistor nominal resistance
- Heavy shunting reduces output

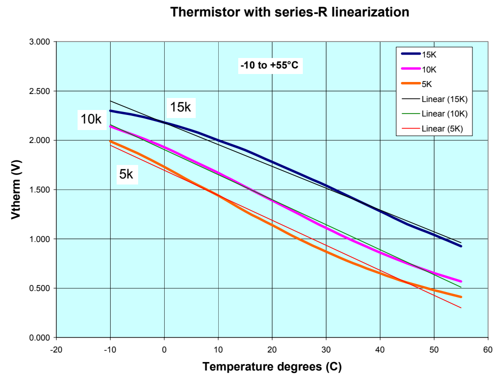
Shunting the thermistor with a resistor drastically improves the linearity across temperature. Note that the output voltage range is reduced as the shunt resistor is reduced in value. The best compromise between linearity and output voltage is achieved when the shunt resistor is equal to the thermistor resistance.

Remote System Monitor Applications

Temperature monitoring – Thermistor

Series-R linearization

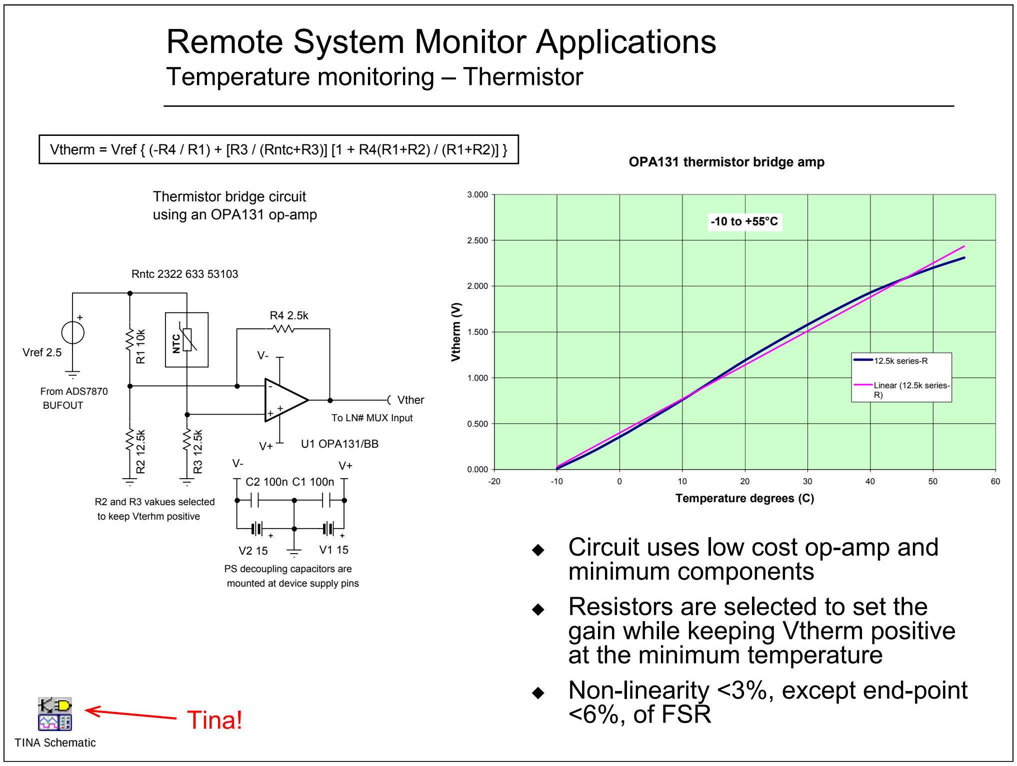




- The voltage source and resistor are equivalent to a non-ideal current source
- Non-linearity is under 4% for this example when R-series equal to the thermistor nominal resistance
- Keep the bias current low to minimize self heating *i.e.* Pd less than 1/10 the power rating

A thermistor may also be biased by a voltage source. A series resistor is added to establish the current through the thermistor. The voltage source and series resistor create the equivalent of a simple current source.

Like the shunt linearization circuit the series implementation provides improved thermistor linearity performance across temperature. Again best results are had when the series resistor is made equal in value to that of the thermistor.

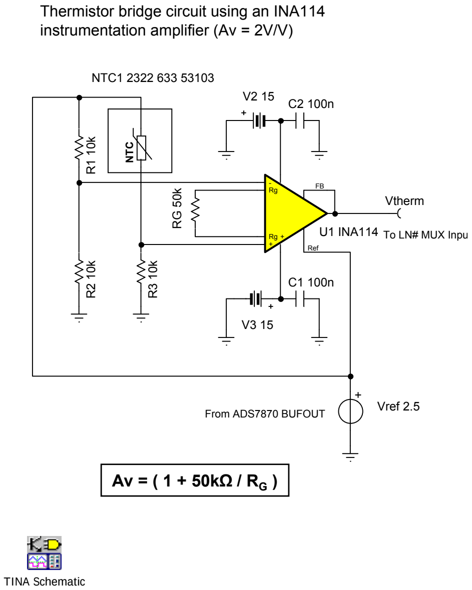


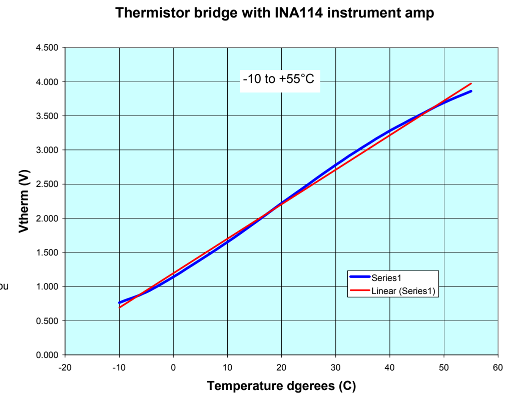
This is a low cost, full-bridge circuit for a thermistor temperature sensor. The OPA131 that follows the bridge amplifies the voltage difference at the centers of the 2 legs in the bridge.

The circuit is a little tricky to set because the resistor values must be selected to set the gain and mid-scale voltage. The plot shows a linearity response that is adequate for many non-critical applications.

Notice the Tina Schematic symbol on the lower left corner of the slide. Tina is a powerful simulation tool that was used to analyze many of the circuits in this presentation. It is ideal for analyzing the sensor circuit performance across temperature.

Remote System Monitor Applications
Temperature monitoring – Thermistor





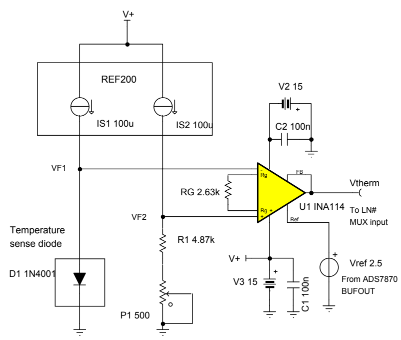
- The INA provides gain and establishes the mid-scale voltage
- Ratiometric capability
- R_G can be set to adjust FS range
- Non-linearity <4% of FSR

The INA114 instrumentation amplifier is an ideal interface between the bridge and the DAS system:

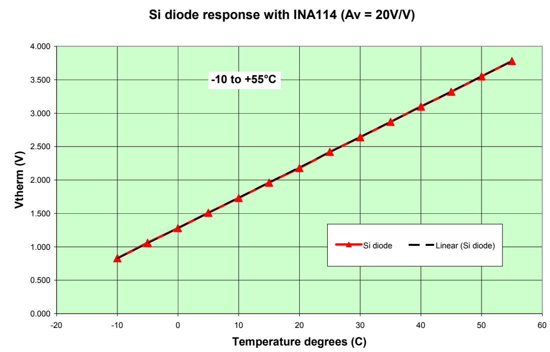
1. The INA voltage gain can be set as needed. Keep in mind that the DAS has the internal PGA as well.
2. A reference voltage can be applied to INA's Ref pin, to match the DAS mid-scale voltage.
3. The reference voltage can also be used to bias the bridge allowing the bridge bias to respond in a ratiometric fashion. Since the reference is established in the DAS, the internal A/D, the INA114 reference voltage, and the bridge bias voltage all track.

Remote System Monitor Applications
Diode temperature monitor

Diode temp sensor circuit
INA114 G = 20V/V



Vtherm= [(VF1 - VF2) (1 + 50kΩ / RG)] + VREF



- Highly linear temperature response – tenths of a degree
- The diode temperature coefficient is constant at ≈ -2.2mV/°C
- The useable temperature range is approximately -55°C to about 175°C

TINA schematic

A silicon diode can also be used as a temperature sensor. The forward biased PN junction has voltage temperature coefficient of approximately -2.2mV/°C and is highly consistent over the useable temperature range, -55°C to +175°C. It offers very good linearity performance.

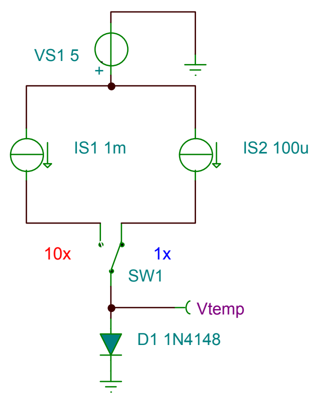
This is basically the same full-bridge circuit that was applied to a thermistor. Note that this circuit doesn't directly measure temperature, but rather temperature change. It must be calibrated using a temperature reference.

Remote System Monitor Applications

Diode temperature monitor

Determining temperature using 2-current method

Single Diode Temperature Sensing



Advantages

- Single diode improves accuracy
- no matching

Disadvantages

- Small voltage change in presence of large diode voltage
- Switching circuit

$T(°K) = \Delta V \cdot q / N \cdot k \cdot \ln(I_1 / I_2)$

$T(°C) = [\Delta V\ (1.160e4) / 1.7 \cdot \ln(I1 / I2)]\ -273°C$

Where: $\Delta V = (V_1 - V_2)$ at I1and I2 the 2 current levels
k = 1.3085e-23j /°K q = 1.6e-19C,
N = 1.7 for 1N4148

A single diode can be used to indicate the actual temperature. The simple circuit presented here shows how this is accomplished.

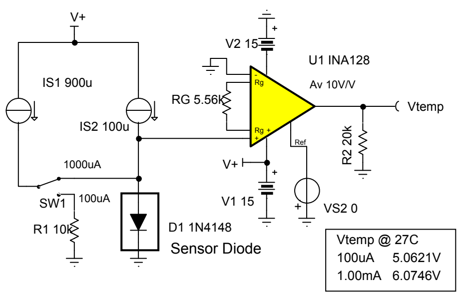
The diode is subjected to a temperature environment and then the diode forward voltage is measured at 2 significantly different current levels. The current ratio is usually on the order of 10:1 to 100:1. The main consideration with high ratios is the current may be quite high in the high current measurement. This high current can cause the junction to self heat which introduces an error.

The resulting forward voltages are entered into the equation from which temperature is derived.

Remote System Monitor Applications

Diode temperature monitor

Conceptual implementation of the single-diode temp sensor (using 2-current method)



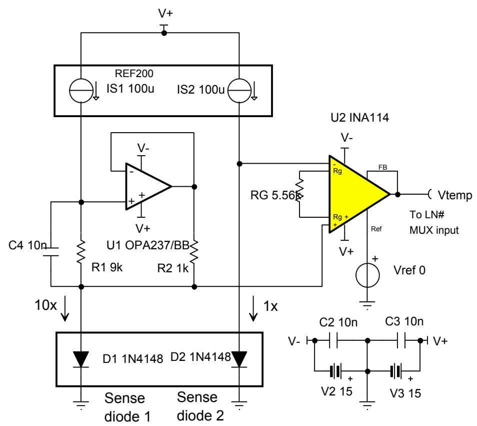
- Current source switching is required
- Diode forward voltage will be amplified by INA
- INA ref voltage can be adjusted to match ADS mid-scale voltage
- There's an easier way…

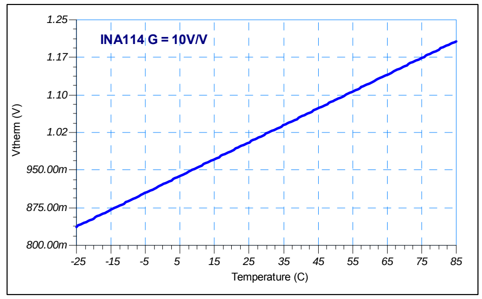
This circuit shows the concept of switching the 2 current levels. An INA114 instrumentation amplifier follows the diode and provides a gain of 10V/V.

The diode's forward voltage is large compared to the voltage change that occurs at the 2 current levels. The instrument amp will gain this relatively large voltage up as well and this results in a large DC value at the output. A reference voltage can be applied to the ref pin to provide an offset so that the instrumentation amplifier's output can be set to the Analog-to-Digital Converter (ADS) mid-scale voltage.

Remote System Monitor Applications
Diode temperature monitor

Dual diode direct temperature sense circuit





- Direct temperature (°C) measurement
- D1 and D2 should be a matched pair
- 1N4148 switching diode is a good choice for sense diodes
- Use Pspice diode models and check temp performance with TINA

$T(°C) = [((V_{temp} / A_V) - V_{REF})(1.160e4)) / ((N)(\ln(I_{D1}/I_{D2})]- 273°C$

Emission coefficient: N = 1.7 for 1N4148

The requirement to switch currents can be eliminated by using 2 temperature sensing diodes, one operating at 1x current and the other at a higher current such as 10x. The diodes should be matched for the application.

One-half of a REF200 establishes the 1x (100µA) current for one diode. The other half of the REF200 supplies a reference current for a voltage-to-current converter which in turn supplies the 10x (1000µA) current to the other diode.

The INA114 inputs connect to the anode of the two diodes in differential fashion. The INA responds to the difference voltage at these 2 nodes and amplifies it. A reference voltage can be applied to the ref pin to match the INA output with the ADS mid-scale voltage. Also, the INA gain can be adjusted for the appropriate input range.

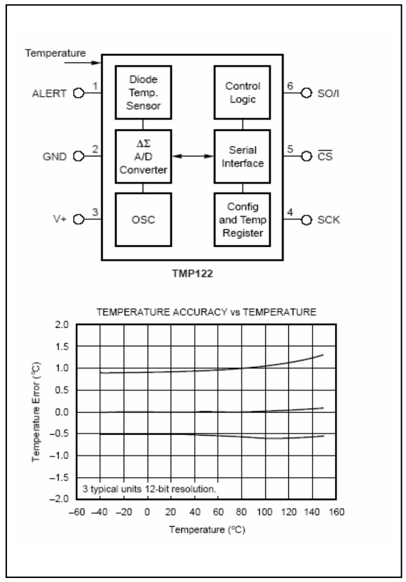
The temperature can be calculated using the equation.

Remote System Monitor Applications

TMP temperature sensor

TMP Sensors

- Diode temp sensors with built-in A/D
- Resolution – programmable, 9- to 12-bit + sign bit
- Accuracy
  - ±1.5˚C -25˚C to +85˚C
  - ± 2.0˚C -40˚C to +125˚C
- Digital output – SPI compatible
- 2.7V to 5.5V supply



The TMP family of integrated temperature sensors offers an easily applied, highly accurate temperature measurement solution. A/D conversion is accomplished by the integrated ΔΣ converter. Therefore, in a remote monitor application, this would be a stand alone function not requiring the ADS7870 A/D function. The SPI compatible, serial output could be directly communicated back to the monitoring station.

Remote System Monitor Applications

Air flow monitoring

Remote System Monitor Applications
Air flow monitoring

Klixon® Solid-State Airflow Sensors
Updated August 12, 2004

Klixon's solid-state vane switch is ideal for recognizing loss or reduction of airflow in electronic equipment. Typically used in power supplies, data processing equipment, and large electronic cabinets.

Unlike its electro mechanical vane switch predecessor, our solid-state switch continues to provide reliable switching even in the dirtiest of environments.

KLIXON

FEATURES

- Solid-state design for improved reliability
- SPST or SPDT configuration
- Normally open or closed
- Commercial or military grades available
- Low power dissipation (approximately 3 watts)
- Excellent shock and vibration resistance

PERFORMANCE

- Supply voltage: 30 VDC maximum
- Switching capacity: up to 400 milliamps
- Operating temperature range: +10°C to +50°C
- Ambient temperature range: up to 150°C
- 100,000 life cycle
- Weight: approximately 20 grams

APPLICATIONS

Klixon air flow sensors are designed to recognize loss or reduction of airflow in:

- Power supplies
- Data processing units
- Commercial electronic equipment
- Military electronic equipment

APPROVAL

- Military
- Aerospace
- Commercial customer specifications and source control drawings

◆ Classical on/off or on/off/on switch functions

◆ Switching capability to 400mA

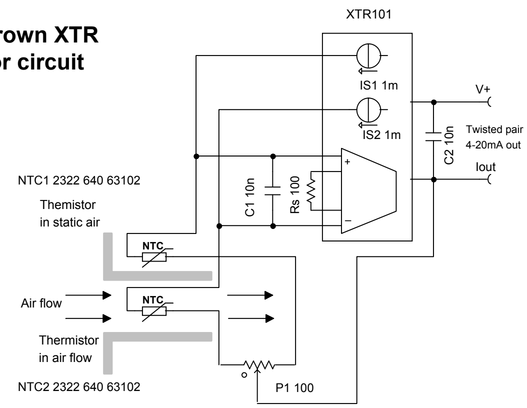
◆ Power dissipation ≈ 3 Watts

This is a classical solid-state, vane type air flow sensor. It provides an on/off or on/off/on switch function.

Remote System Monitor Applications

Air flow monitoring – Thermistor based

Original Burr-Brown XTR air flow sensor circuit



- Thermistor thermal resistance proportional to air flow rate
- P1 balances “zeros out” output with zero flow rate
- RS selected to provide desired output level
- RS selection depends on thermistor characteristics and air flow dynamics

The air flow monitor shown here is an outgrowth of the temperature monitors presented in the previous section. A thermistor serves as the air flow sense element. This circuit uses an XTR101, 4-20mA current loop transmitter implementation originally presented in Burr-Brown applications bulletin AB-032A.

Two thermistors are used in the bridge. One thermistor is located in the still environment while the other is placed in the air stream. The thermistor environments should be at the same temperature so as not to introduce a temperature gradient error. Both thermistors have a small bias current flowing through them and self heat to a small degree. This is an important point to keep in mind.

Air flowing past will add or remove heat to the exposed thermistor, changing its temperature relative to the thermistor in the static air environment. The amount of temperature change will be related to the air flow dynamics.

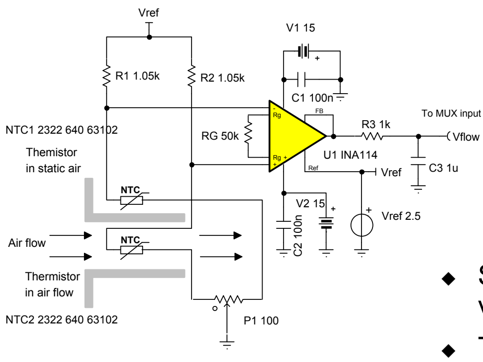
The change in thermistor temperature leads to a resistance change that imbalances the bridge, which in turn appears as a voltage difference to the instrumentation amplifier inputs.

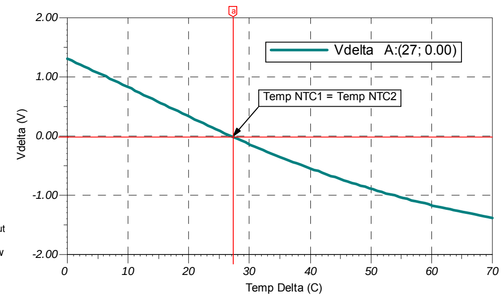
An XTR can be used in remote system monitoring applications. However, for use with the ADS7870 DAS, the current output (4-20mA) would have to be converted to a voltage.

Remote System Monitor Applications

Air flow monitoring – Thermistor based

Instrumentation Amplifier implementation of air flow sensor





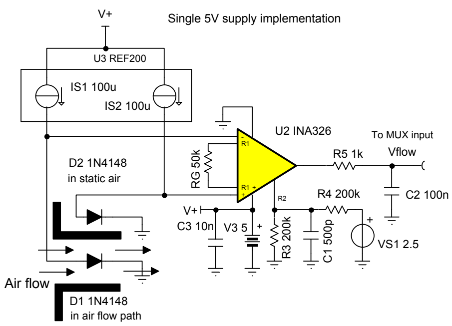
- Similar to XTR101 function but with voltage output
- Temperature change is due to air flow
- Direct interface to ADS7870 DAS

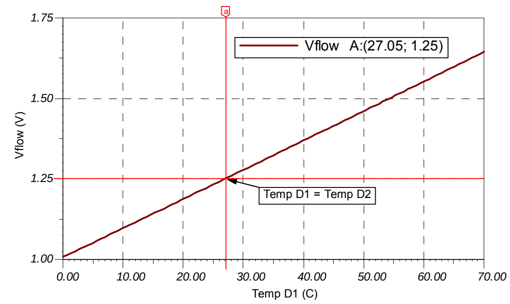
This is an implementation of the previous thermistor bridge, but now used in conjunction with an instrumentation amplifier. The instrumentation amplifier provides a voltage output which can be directly interfaced with the ADS7870 DAS.

The plot shows the delta voltage relative to the Vref voltage. The voltage change is directly related to the heating or cooling of the sense response to the air flow. The “delta” is zero when the temperature of the two thermistors is exactly the same. Air flow will cause a temperature delta in accordance with the plot.

Remote System Monitor Applications
Air flow monitoring

Diode air flow sensor





- D1 and D2 are in the same temperature environment
- D1's junction temperature and voltage are set by the air flow
- The air flow must be correlated to the change in D1 voltage
- Temperature linearity within tenths of a degree

As previously mentioned, the silicon diode exhibits a linear junction voltage change with temperature of approximately -2.2mV/°C. This was shown to be a direct indicator of junction temperature change. In similar fashion to the thermistor, and by virtue of the junction's voltage change in response to heating or cooling, the diode can be used as an air flow sensor.

The air flow dynamics dictate how much the voltage will increase or decrease for a given flow rate. Therefore, the relationship between temperature and flow rate would have to be established for a method such as this to be useable.

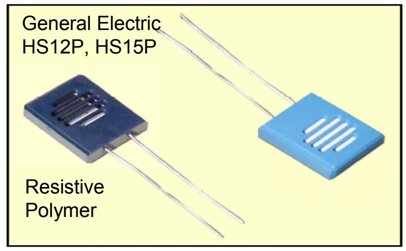
Remote System Monitor Applications

Humidity Monitoring

Humidity sensors are typically resistive or capacitive sensors. Their characteristics are much different than the previously discussed sensors and require a different approach in converting their output to something that can interface directly with the ADS7870 DAS.

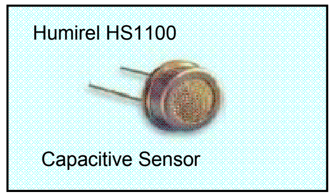
Remote System Monitor Applications
Humidity monitoring

Humidity sensor types
- Resistive – ceramic
- Resistive – polymer
- Capacitive - ΔC
- Capacitive with built-in electronics – V output



Source: General Electric

Suppliers
- Resistive
  - GE, ESI, Ohmic
- Capacitive
  - Humirel, ESI, Ohmic
- Capacitive with built-in electronics
  - Honeywell, Ohmic



Source: Humirel

Resistive humidity sensors usually consist of a hygroscopic (absorbs moisture) medium such as conductive salt or polymer deposited over noble metal electrodes on a nonconductive substrate.

When the sensor is in the presence of water vapor, the vapor is absorbed causing the functional ionic groups to disassociate, resulting in increased conductivity. Response times are slow ranging from 10 to 30s for a 63% step change.

Most resistive sensors use an AC excitation to prevent sensor polarization. The resulting current is rectified and converted to DC where it can then undergo linearization and be amplified as necessary. The AC signal applied to the bridge ranges from 30Hz to 10kHz.

The capacitive sensor is constructed of a thin polymer or metal oxide deposited between two conductive plates on a ceramic, glass or silicon substrate. The sensing surface is then coated with a porous metal coating to protect it from contamination and exposure to condensation. An incremental change in the dielectric constant of the dielectric takes places in the presence of moisture.

A 3rd humidity sensor type is based on a 2-thermistor design. One thermistor is sealed in dry nitrogen and serves as the reference, while the other is exposed to the ambient air. The “dry” thermistor has a greater capacity to sink or release heat than the exposed “wet” thermistor. The thermistors are biased to self heating levels. Since their ability to dissipate heat is different the resistance of each will take on a unique value that unbalances the bridge.

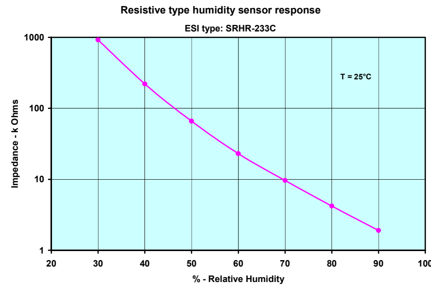
(source sensormag.com/articles)

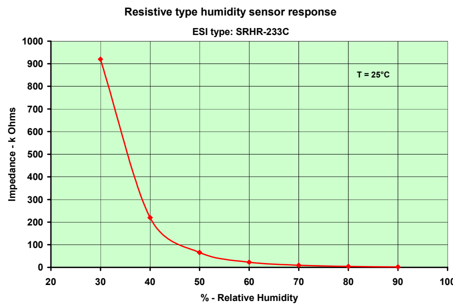
Remote System Monitor Applications

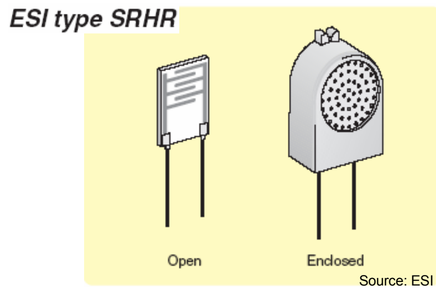
Humidity monitoring – resistive sensors

Resistive Humidity Sensors

- Resistance changes in response to water vapor level
- Limited humidity range
- Nearly log response
- High sensitivity at low humidity





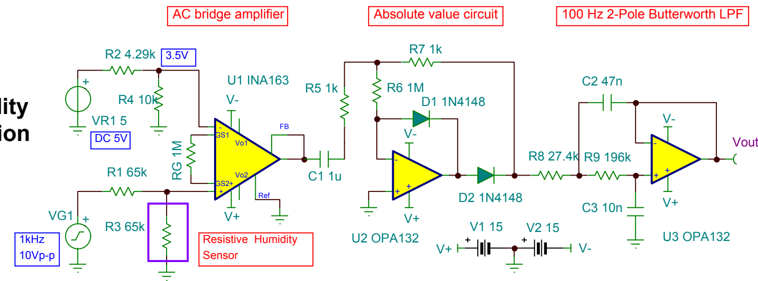


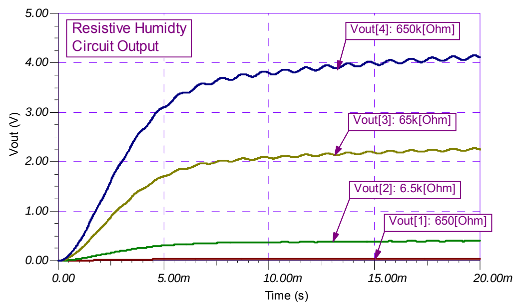
The resistive type humidity sensor has a very nonlinear response for a uniform change in relative humidity. When the points are re-plotted on a logarithmic scale the response has a more linear appearance.

Remote System Monitor Applications

Humidity monitoring – resistive sensors

Resistive Humidity Sensor Application





- An AC signal excites the sensor
- The sensor output is highly non-linear
- A log function may be applied to linearize the response

A 1kHz AC sine wave is used to excite a half-bridge which includes the resistive humidity sensor. As can be seen from the graphs the output voltage is proportional to the voltage divider voltage established by the upper resistor and resistive sensor. The resistive humidity sensor is excited with an AC signal, instead of a DC voltage, to prevent sensor polarization.

A DC pedestal voltage is applied to the inverting input by way of a voltage divider. This DC voltage is subtracted from the AC voltage by the instrumentation amplifier and a difference voltage appears at the output. The DC level assures that the difference voltage at the two inputs results in an increasing output voltage as the voltage difference increases.

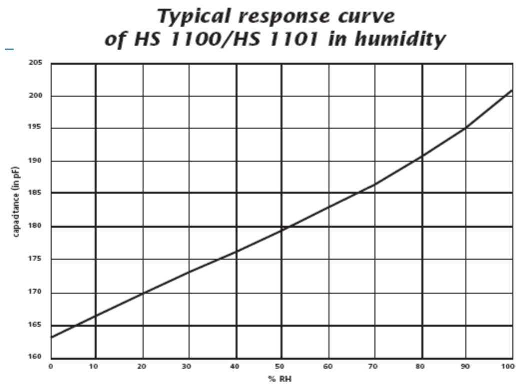
The output of the AC bridge amplifier is AC coupled, to the absolute value circuit which performs a full-wave rectifier function. The rectified voltage is then applied to the input of a 2-pole, low-pass filter. This removes most of the 1kHz ripple.

Since the humidity sensor produces a highly non-linear resistance change with a linear change in humidity level, the output voltage is non-linear as well. A log amplifier could be employed to help improve the output voltage versus humidity response.

Remote System Monitor Applications
Humidity monitoring

Capacitive Humidity Sensors

- Useful range from 0 to 100% RH
- 100 - 500pF bulk capacity at 50% RH, 25˚C
- For example, Humirel HS1100, 180pF at 50% RH, 25˚C
- Delta capacitance function
- 0.2 - 0.5pF for 1% RH change
- Low TC
- Moderate linearity
- Requires capacitance to voltage or current conversion

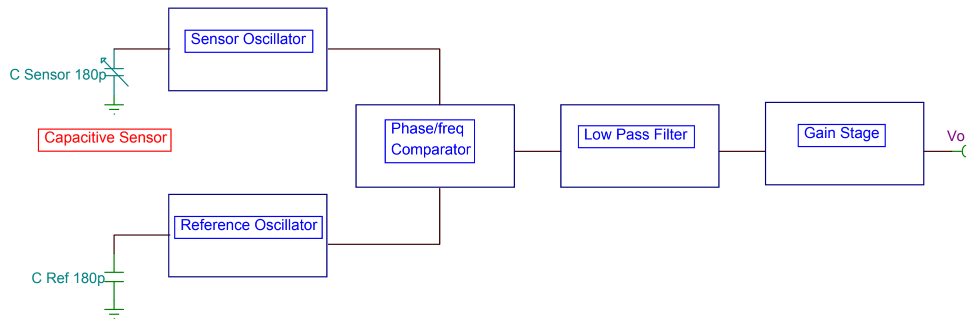


Source: Humirel

The capacitive humidity sensor has a more linear response than the resistive sensor. It is also usable over the entire range of 0 to 100% relative humidity, where the resistive element is limited to about 20 to 90% relative humidity.

Remote System Monitor Applications
Humidity monitoring

Capacitance-to-voltage conversion method for the capacitive sensors



Capacitive sensors produce a capacitance change, a “delta-C,” in response to a change in the monitored attribute. This capacitance change is then often converted to a different electrical property that can be more directly measured. Often this is a voltage which necessitates a capacitance-to-voltage (C-V) conversion.

One technique employed for the C-V conversion involves placing the capacitive sensor in the frequency determining circuit of an oscillator. Then, any capacitance change will alter the oscillator frequency.

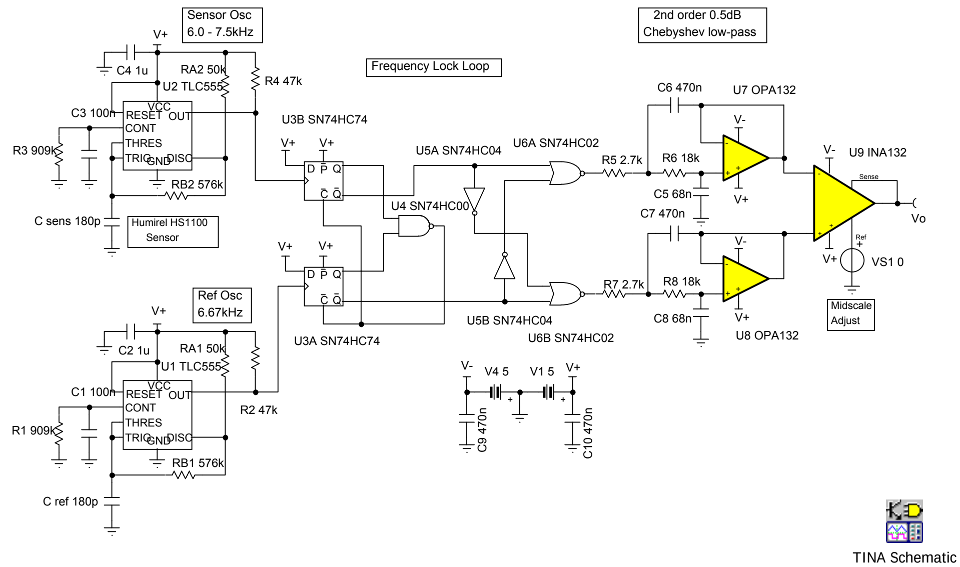
In the accompanying diagram a reference oscillator with a fixed frequency and a sensor oscillator with a variable frequency are shown. The output signals from the two oscillators are then compared by a phase or frequency comparator, sometimes referred to as a phase discriminator.

The phase/frequency discriminator will produces a DC level or pulse-width modulated (PWM) pulse train that is a function of the phase or frequency difference of the two oscillator signals - depending on the design. The output is then applied to a low-pass filter, to filter or integrate the discriminator output. It may then be amplified by a gain stage as needed.

Remote System Monitor Applications

Humidity monitoring

A capacitance to voltage conversion



Here is an implementation of the C-V conversion just described. It uses two TLC555, bi-stable multivibrators as the oscillators and a frequency lock loop (FLL), as a frequency difference detector.

The reference oscillator has a fixed frequency of 6.7kHz, while the sensor oscillator has a frequency that changes from 6.0 to 7.5kHz with a ±20pF sensor capacitance change.

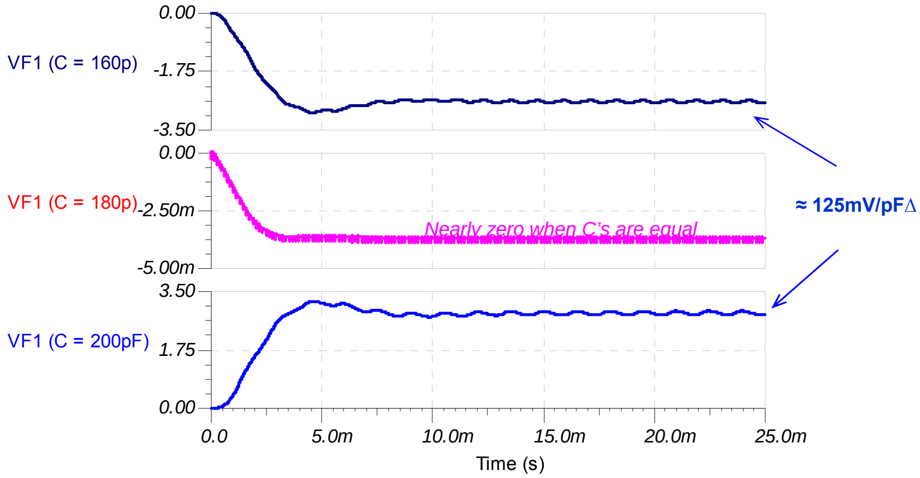
If the sensor oscillator frequency moves relative to the reference frequency one or the other NOR gate in the FLL begins to output a series of pulses whose width increases with larger frequency differences. This is essentially a pulse width modulated (PWM), pulse train. When the oscillators are operating at the same frequency the FLL does not produce an output.

The pulse train then passes through the second-order low pass filter, which serves as an integrator. The integrator function produces a DC level in proportion to the pulse width. Then, the differential amplifier amplifies the differential DC level while rejecting any common responses.

Remote System Monitor Applications

Humidity monitoring

Voltage output from C to V converter as C_{sense} is varied ± 20pF



This is the output response for the C-V circuit with a ±20pF capacitance change. The center plot shows that the output voltage is nearly zero when the 2 oscillators are on the same frequency.

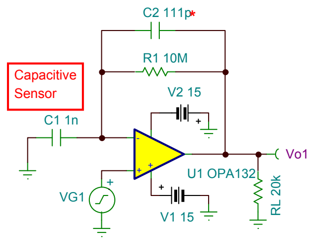
However, if the sensor oscillator is at either one of the frequency extremes, then the output voltage moves off zero to approximately ± 2.5V. The circuit exhibits excellent sensitivity, about 125mV/pF.

Remote System Monitor Applications

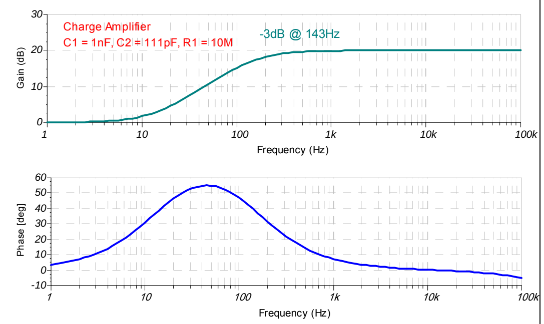
Humidity monitoring

Another C – V conversion approach

Charge Amplifier



* C2 111pF non-standard, 110pF ok



$f_{-3dB} = 1 / (2\pi R_1 C_2)$

Set : $R_1 \geq 10 \cdot | X_{C2} |$ and $f_{GEN} \geq 10 (f_{-3dB})$

Then: $A_V = 1 + (X_{C2} / X_{C1})$ where $X_C = 1 / (2\pi f C)$

Another approach to C-V conversion is the Charge Amplifier. Here, the op-amp, closed-loop voltage gain (Av) is a ratio function of the capacitive reactances ($-jX_C$) in the feedback and inverting input circuits.

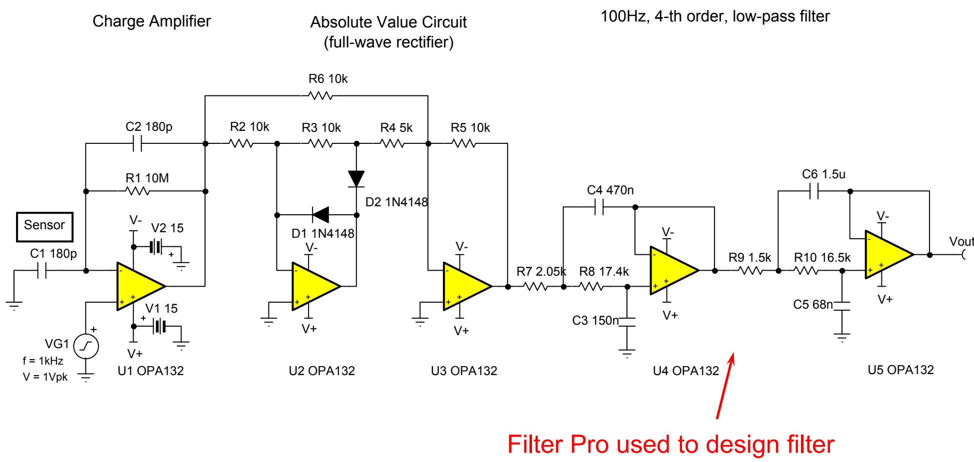
If either reactance changes the Av of the amplifier will change as well. A carrier signal applied to the non-inverting input will be amplified, but by different gain levels depending on the reactance ratio.

This varying amplitude AC signal can then be rectified to extract a DC voltage level.

Remote System Monitor Applications

Humidity monitoring

Charge amplifier implementation with capacitive humidity sensor



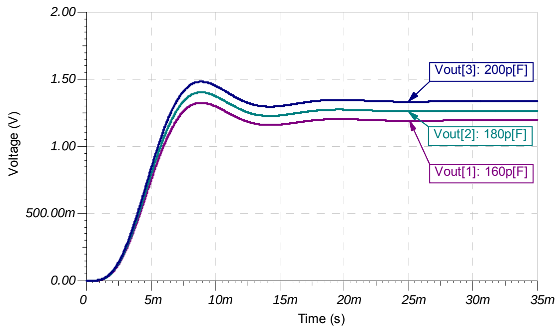
This is a complete charge amplifier circuit useful for detection of a capacitive sensor's capacitance change.

The charge amplifier is followed by an absolute value circuit which serves as a full-wave rectifier. This converts the varying AC signal from the charge amplifier to a DC level. However, the DC level is unfiltered at this point and contains the carrier frequency ripple.

The rectified DC is then passed through a 2-stage, 4-pole low pass filter to remove the ripple. This results in a DC voltage that is a function of the charge amplifier gain. TI's Filter Pro tool was used to design this 4th order filter.

Remote System Monitor Applications
Humidity monitoring

Output voltage for ±20pF capacitance change



Single input charge amp circuit

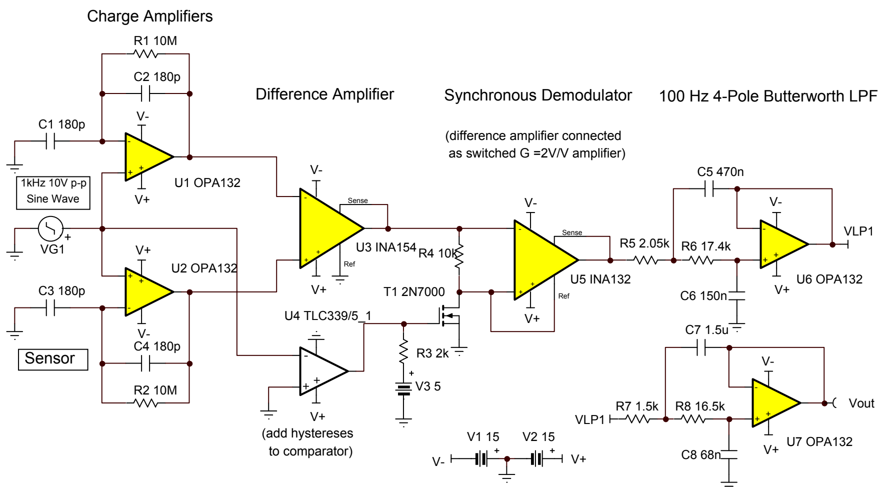
- About 140mV Vout delta for a ±20pF change
- The DC voltage is 2x the Vin RMS value
- The nominal DC level may be an issue

The previous charge amplifier circuit produces a stable DC level for a fixed charge amp gain. Here the input sensor capacitance is changed to 3 different values; 160, 180 and 200pF, resulting in three different charge amplifier gains and corresponding DC levels.

The circuit is not overly sensitive and a large DC level is present. Adding gain would help exaggerate the DC change that results from the capacitance change, but the large DC level would be gained up as well. This would have to be dealt with in a subsequent stage.

Remote System Monitor Applications
Humidity monitoring

Differential capacitance sensor amplifier



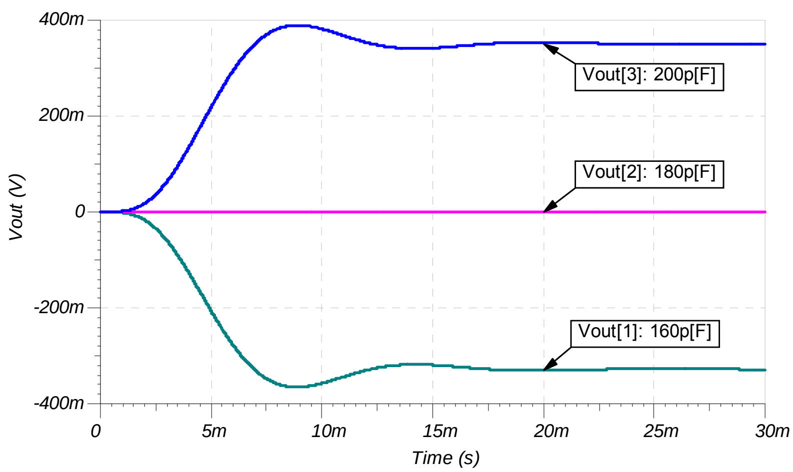
A unique differential implementation of the charge amplifier is shown here. The output from the sensor charge amplifier is compared to that of a reference charge amplifier. Differential signals applied to the differential amplifier (U3) inputs are amplified, while common mode signals are rejected. This removes the large common-mode DC voltage had with the previous, single-ended charge amplifier circuit.

The resulting AC output is converted to a rectified DC level by a synchronous demodulator consisting of U4, T1 and U5. As with the earlier circuit, carrier ripple is present and must be filtered. The 100Hz, 4-pole, Butterworth filter accomplishes this task.

Remote System Monitor Applications

Humidity monitoring

Output from Differential Capacitance Sense Amplifier



The output from the differential capacitance sensor amplifier is shown in the accompanying graph. The plots show that after approximately 20ms the DC level stabilizes to a final value. When the charge amplifier capacitances are equal the circuit is balanced and the output is zero.

When the sensor capacitance is at its minimum (nominal -20pF) the output voltage is approximately -350mV. The output voltage is opposite and equal at +350mV when the sensor capacitance is at its maximum (nominal +20pF).

Remote System Monitor Applications

Power Monitoring

Voltage and current levels can be easily and precisely monitored using analog techniques.

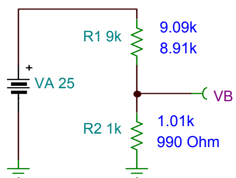
Remote System Monitor Applications

Power monitoring

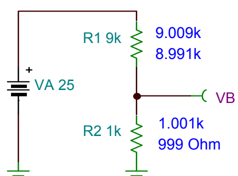
Voltage Monitoring

10:1 Resistive Dividers

1% Resistors



0.1% Resistors



10:1 with +/-1% resistors

RA (%)	RB (%)	VB (V)	error (mV)	error (%)
0	0	2.500	0	0
-1	-1	2.500	0	0
-1	1	2.455	-45	-1.8
1	-1	2.545	45	1.8
1	1	2.500	0	0

10:1 with +/-0.1% resistors

RA (%)	RB (%)	VB (V)	error (mV)	error (%)
0	0	2.5000	0	0
-0.1	-0.1	2.5000	0	0
-0.1	0.1	2.4955	-4.5	-0.18
0.1	-0.1	2.5045	4.5	0.18
0.1	0.1	2.5000	0	0

The DAS is capable of handling input voltages of 0 to 5V when powered with a 5V supply and a 2.5 reference voltage is employed. Often, the voltage exceeds this level and simple voltage divider can be inserted before the DAS to reduce the voltage to a level it can safely handle.

This slide provides an example where the supply voltage is 25V and it is desired to divide that by a factor of 10. Two dividers are shown in the example and the resistor tolerances at ±1% and ±0.1%, respectively.

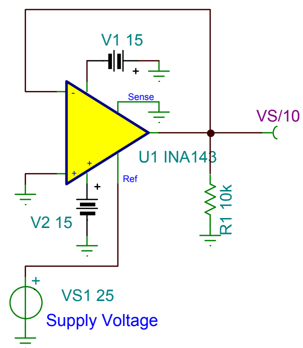
Depending on the direction of each resistor's tolerance it is seen that resistors with a 1% tolerance can result in a divider error as high as ±1.8%. Similarly, the 0.1% tolerance resistors may result in an error as high as ±0.18%. Either may be acceptable. It just depends on the system requirements.

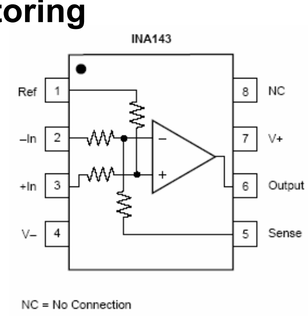
Remote System Monitor Applications

Power monitoring

Voltage Monitoring

INA143 Difference Amplifier
Voltage Monitor Circuit (G = 0.1V/V)





- The INA143 provides an active 10:1 voltage divider solution
- Note connections of inputs, sense and ref pins
- The internal resistors are matched better than 0.01%
- Worst-case errors total about 1.6mV for the INA143 U-grade in this application

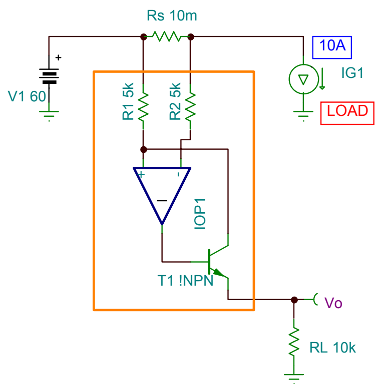
The INA143 may be configured in a manner such that it will provide a precise, 10:1, voltage-divider function which is useful for monitoring voltage. This is accomplished by reversing the feedback and input resistor on the inverting input and the divider resistors on the non-inverting input which results in a gain of 0.1V/V.

One might wonder why one would resort to this approach. Mostly, it comes down to the accuracy required and the cost. One-percent resistors cost about 10 cents or less, in quantity, at this time. One-tenth percent resistors cost about a half dollar to over a dollar, and 0.01% resistors cost $5 to $10 a piece. And 2 resistors are required for the voltage divider.

Considering the INA143 internal resistors are matched to better than 0.01%, at a cost around $1.50, it offers an accurate, buffered, cost effective solution.

Remote System Monitor Applications
Power monitoring

High-side Measurement
Current Shunt Monitor



Vo = (Is) (Rs) (200uA/V) (RL)

Current shunt monitor concept
- High-side CMV capability to supply rail
- Very high common-mode rejection amplifier
- A small differential voltage is developed in response to load current
- Monitor voltage (Vo) is proportional to current

The high-side measurement, current shunt monitor provides a convenient means to monitor a load current. In a sense, the circuit performs a function similar to a classical ammeter. In a classical ammeter circuit a sensitive voltmeter, with a full-scale range of 50 to 100mV, is shunted by a very low value current shunt resistor. The meter voltage is proportional to the current flowing through the shunt resistor.

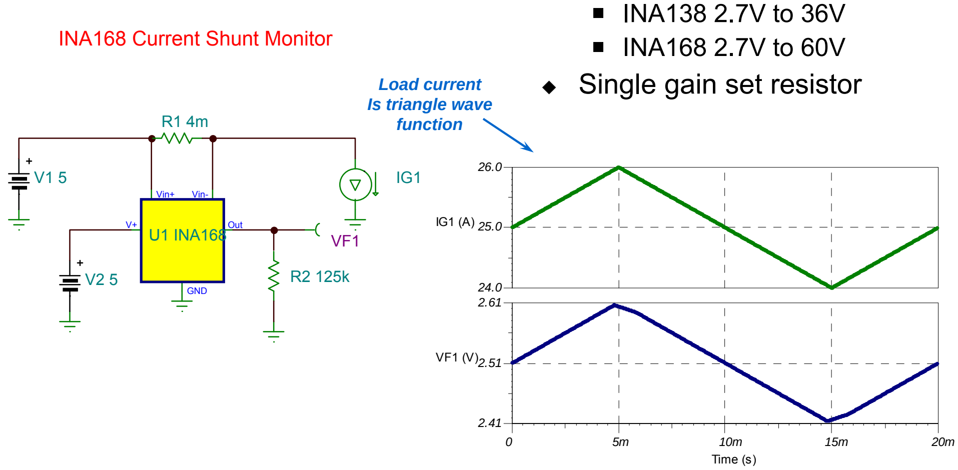
A high CMV tolerant operational amplifier replaces the meter with the current shunt monitor IC. Current flowing though the shunt resistor produces a differential voltage that is amplified by the op-amp and scaled as needed to indicate the current magnitude.

Remote System Monitor Applications

Power monitoring

Current Monitoring

- Complete unipolar high-side current shunt monitor
- Wide supply and common-mode range:
  - INA138 2.7V to 36V
  - INA168 2.7V to 60V
- Single gain set resistor

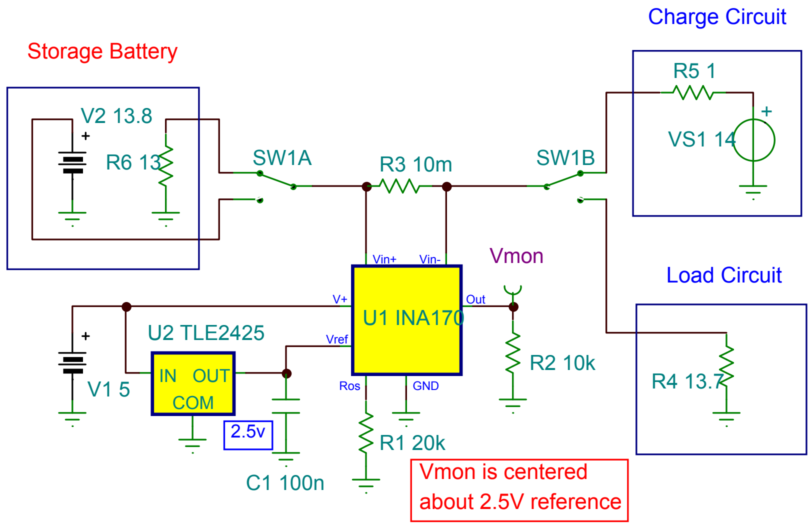


The INA138 and INA168 are examples of high-side measurement, current shunt monitor ICs. This TINA example shows that they can be employed not only in DC but AC applications as well.

The common-mode voltage (CMV) input range is independent of the supply voltage. This high voltage capability of the shunt monitor allows input voltages well above the supply voltage to be monitored.

Remote System Monitor Applications
Power monitoring

Bidirectional battery charge/discharge monitor



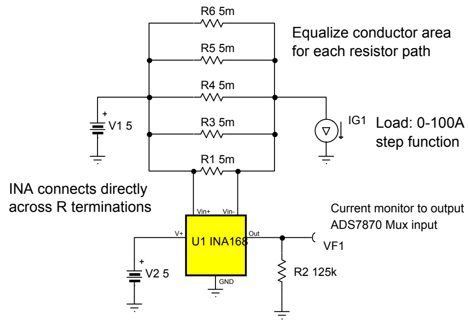
The INA170 is a high-side, bidirectional current shunt monitor IC that is useful for applications such as battery charge and discharge rate monitoring and power management in portable devices.

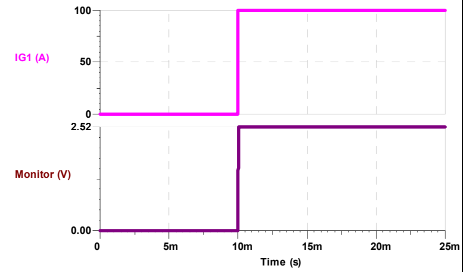
The bidirectional current measurement capability is made possible by output offsetting. This offset is established with an external resistor, Ros, and an external reference voltage. Doing so allows the INA170 to be powered by a single power supply.

Remote System Monitor Applications

Power monitoring

INA168 Current Shunt Monitor
100Amp Application





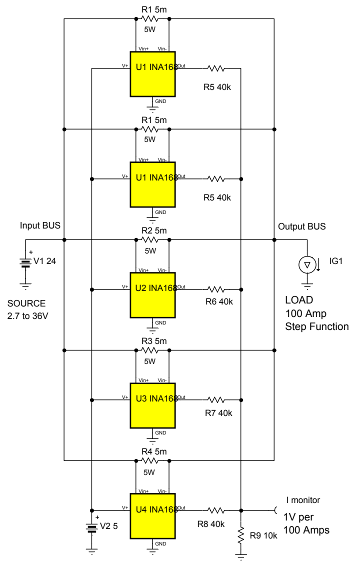
- Paralleling resistors can be used to achieve very low values R's
- Uses available 5mΩ resistors
- Keeping path Ω's equal and low may be difficult
- Heat dissipation must be accommodated

When monitoring very large current levels, hundreds-of-amperes or more, it may be difficult to find suitable, high power shunt resistors. Shunt resistors with values below 5mΩ are less available than higher value resistors. One option is to split the shunt resistor up among several resistors connected in parallel. In this example the 1mΩ resistance is satisfied by 5 equal value, paralleled resistors, each with 1/5 the power rating requirements of a single resistor.

There is some risk that unequal resistor contact resistance could affect the current through each resistor path.

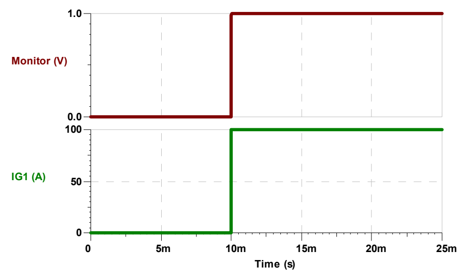
Remote System Monitor Applications

Power monitoring



TINA Schematic

100A Current shunt monitor using parallel INA168's



- Resistor tolerance and INA168 errors are reduced to RMS values
- Common current monitor 1V/100A

A separate INA168 current shunt monitor has been assigned to each of the 5 shunt resistor current paths. The circuit has the advantage over the previous in that errors such as resistor tolerance and those associated with the IN168's, gain, offset, noise, drift, etc, will now be the statistical average, or root mean squared (RMS) value of all the components. This, in general, will be less than most of the like component population.

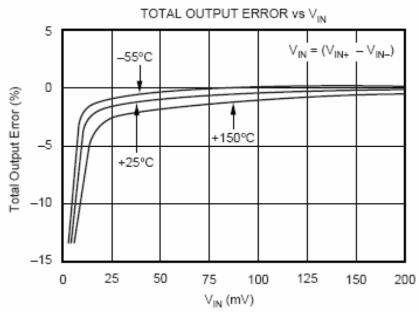
Remote System Monitor Applications

Power monitoring

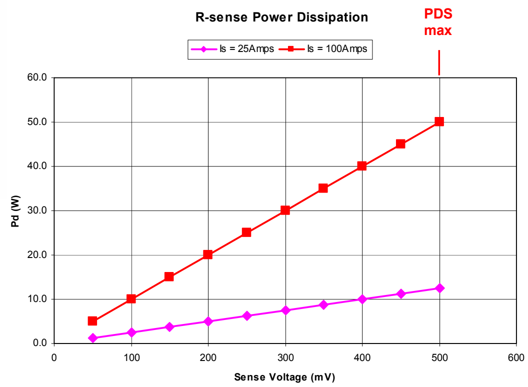
INA168 Sense Resistor Requirements								
	Sense I (A)		Vo			Sense I (A)		Vo
	25		2.5			100		2.5
Sense V	**Sense R**	**Pd**	**Rl**		**Sense V**	**Sense R**	**Pd**	**Rl**
mV	**Ω**	**W**	**k @2.5Vo**		**mV**	**Ω**	**W**	**k @2.5Vo**
50	0.002	1.25	250.0		50	0.0005	5.00	1000.0
100	0.004	2.50	125.0		100	0.0010	10.00	500.0
150	0.006	3.75	83.3		150	0.0015	15.00	333.3
200	0.008	5.00	62.5		200	0.0020	20.00	250.0
250	0.010	6.25	50.0		250	0.0025	25.00	200.0
300	0.012	7.50	41.7		300	0.0030	30.00	166.7
350	0.014	8.75	35.7		350	0.0035	35.00	142.9
400	0.016	10.00	31.3		400	0.0040	40.00	125.0
450	0.018	11.25	27.8		450	0.0045	45.00	111.1
500	0.020	12.50	25.0		500	0.0050	50.00	100.0

This table provides the details for the sense resistors required for specific sense voltages, at the 2 different current levels; 25A and 100A. Keeping the INA168 sense voltage to 50 or 100mV results in lower power dissipation, but also at very high current levels results in minute resistor values which may be difficult to realize.

Remote System Monitor Applications
Power monitoring



Selecting the INA168 sense voltage



There is a tradeoff between minimizing the INA168 total output error and the sense resistor power dissipation. Increasing the sense voltage minimizes the errors (to a point), but power dissipation in the sense resistor increases. Even though the lowest output errors are attained by using a larger sense voltage, there is little reason for using a sense voltage above 200mV - even though the product has a 500mV maximum specification.

Remote System Monitor Applications

Power monitoring

Example of current sense resistors available from CADDOCK

Current Sense Resistors

- Must withstand high current levels
- May dissipate significant power
- May require heat sinking
- Often require values 5mΩ or less
- Sources: Caddock, IRC, Riedon, Ohmite, Willow Technologies

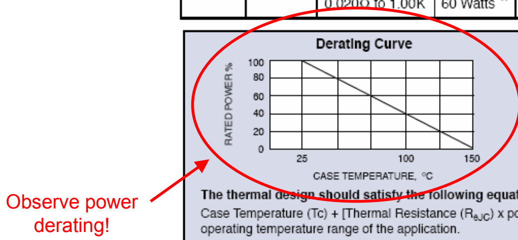
Selection of the shunt resistor boils down to the resistance value, power dissipation requirements, tolerance and physical installation limitations. Shown here is a line of current sense resistors offered by Caddock. The particular power resistor shown, the MP2060, has a 60W rating when attached to a suitable heat sink. It handles currents up to 60 amperes with a resistance as low as 5mΩ.

The resistor tolerance availability depends on the resistance range. For very low values, such as 5mΩ, ± 5% is often the tolerance specification.

Remote System Monitor Applications

Power monitoring

Model	Package	Resistance	Power Rating	Max. Current Rating (Amps)	Max. Voltage	Thermal Resistance $R_{\theta JC}$ Film (J) to Case (C)
MP2060	TO-220 Style	0.005Ω	18 Watts *	60 A_{rms}	Current Limited	6.94°C/Watt
		0.010Ω	36 Watts *	60 A_{rms}	Current Limited	3.47°C/Watt
		0.015Ω	54 Watts *	60 A_{rms}	Current Limited	2.31°C/Watt
		0.020Ω to 1.00K	60 Watts *	$I = \sqrt{P/R}$	250 V_{rms}	2.08°C/Watt



*** Derating Using Case Temperature (T_C):** All power and associated overload ratings are derated based upon case temperature using the derating curve. The case temperature is measured at the center of the ceramic mounting surface, with the part properly mounted and under electrical load. Without a heat sink, when in free air at +25°C, the MP2060 is rated for 2.5 watts.

The thermal design should satisfy the following equation:

Case Temperature (Tc) + [Thermal Resistance ($R_{\theta JC}$) x power applied (Watts)] ≤ 150°C, considering the full operating temperature range of the application.

Mounting Note: Mount on a smooth, clean and flat heat sink surface with a thermal interface material, such as thermal grease. The entire exposed ceramic portion must be in contact with the heat sink. When using a spring clip, it is recommended that a mounting force of 8 to 30 pounds (35 to 130 N) be applied to the center of the package. The clip should be round or smooth in the contact area to avoid concentrating the load on a small point of the plastic body of the package. Another mounting option is to use a pressure bar method which can achieve a greater mounting force with a greater contact area.

For additional applications information regarding mounting and pulse handling see the Caddock Applications Notes at caddock.com or contact Applications Engineering.

Source: Caddock

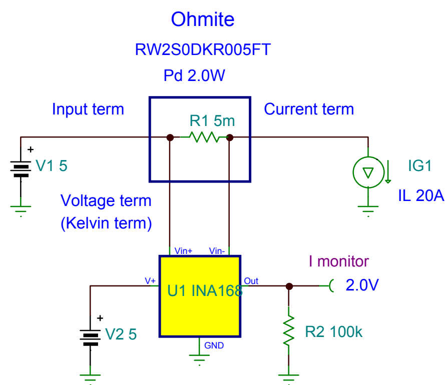
Even though a sense resistor may have a high power rating, that rating will only apply up to a specific case or ambient temperature; in many cases that temperature is 25°C. Above this the power rating is de-rated falling linearly to zero at some higher temperature. Usually this occurs at 125°C or 150°C.

Therefore, cooling in the form of heat sinking or fan must be employed to reduce the resistor's operating temperature to acceptable levels.

Remote System Monitor Applications
Power monitoring

- Specially constructed 4-terminal current sense resistors
- Optimized design for high currents
- Available in through hole, surface mount & other
- Ohmite, Stackpole, Micro-Ohm and Willow Technologies (UK)

4-terminal current sense resistor



A shunt resistor configuration that is becoming more readily available is the 4-terminal current sense resistor. It not only has the 2 high current “in” and “out” terminals, but two additional that connect internally, directly to the resistive element termination end-points.

These two terminals are then connected to an active sensing circuit such as the INA168. The voltage measured by the INA is nearly devoid of any voltage drop associated with the resistor conductors - the “in” and “out” terminals. This provides an accurate measure of the voltage across the resistor element and not the combined voltages across the resistor element and termination conductors.

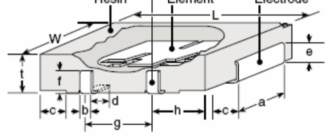
Remote System Monitor Applications

Power monitoring

OHMITE®

Four-terminal Current Sense Resistor

RW Type



Type	Power Rating (watts)	Resistance Range E-12 (mΩ)	Resistance Tolerance	Dielectric Withstanding Voltage	TCR (ppm/°C) Max.
RW1S0CK	1	5mΩ - 50mΩ	1%	500V	±50
RW2S0DK	2	5mΩ - 50mΩ	1%	500V	±50

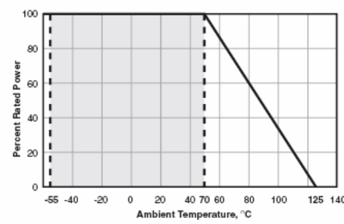
FEATURES

- Extremely low resistance and high precision tolerance
- Low T.C.R. achieved (±50ppm/°C)
- Flameproof UL94-V-0
- Marking: Black body color with white marking

SPECIFICATIONS

TCR max.: ±50 ppm/°C
Rated Ambient Temp: +70°C
Oper. Temp. Range:
-55°C - +125°C

DERATING



Source: Ohmite®

This excerpt from the Ohmite 4-terminal current sense resistor data sheet shows the construction details of this type of sense resistor. This is a low power resistor rated at 1 or 2 Watts. Notice that the tolerance is rated at ±1%, which is much better than typical ±5% associated with the high power dissipation sense resistors.

Remote System Monitor Applications

Security Monitoring

In the unlikely event that the security of a remote site is breached it is important that the event be detectable as soon as possible, so that a preplanned course of action can be taken to minimize damage to the site equipment and assure the safety of personnel.

Remote System Monitor Applications
Security monitoring

Purpose
- Alert monitoring station of an intrusion
- Place installation in predetermined state

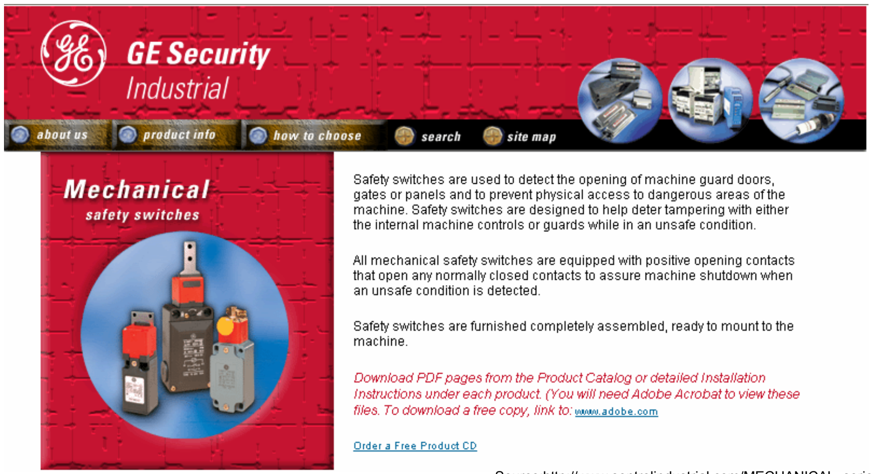
Some sensor options
- Switches – plunger, reed, mercury, etc.
- Magnetic – Hall Effect
- Optical – photo cells
- Pressure
- Capacitive and inductive proximity switches

Various sensor types exist that will help detect the presence of intruders at the site. Most sensors when triggered provide a “1” or “0” response and activate an alarm response. Sometimes it may be desirable to have a more analog response such that one can discriminate between a person and small animal. The response would likely be much different for the two.

Remote System Monitor Applications

Security monitoring

An electromechanical solution - Security Switches



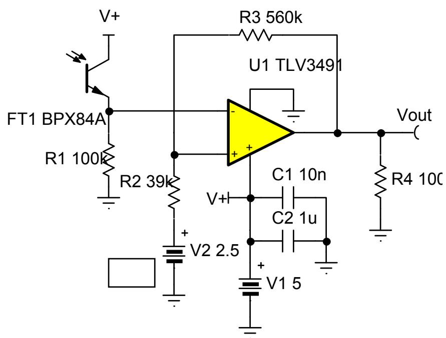
Source:http://www.sentrolindustrial.com/MECHANICAL_series.htm

Mechanically actuated switches provide a simple means for detecting a change in state at the remote site. They are often manually actuated plunger type or magnetically actuated reed switches.

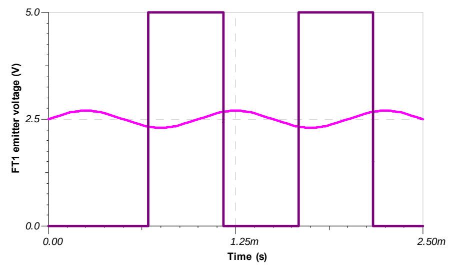
Remote System Monitor Applications

Security monitoring

Phototransistor dark/light sensor



TLV4391 micro power comparator with hystereses



- Intrusion is usually a “0” or “1” event – cabinet opened
- Comparator function may satisfy application
- Little, if any, A/D conversion may be necessary
- The ADS can be driven to FS indicating a fault

A photo optical device such as a phototransistor can be used to detect the presence of light such as when a cabinet door is opened, or when the lighting changes at the remote installation.

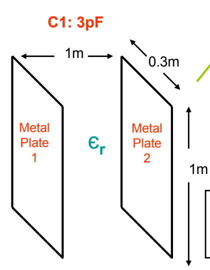
A TLV3491 comparator switches state when the phototransistor conducts subjected to a light source. The comparator has a “1” or “0” output, thus an A-to-D conversion is not required. Hysteresis, added to the comparator circuit, reduces the circuit’s noise sensitivity at the threshold.

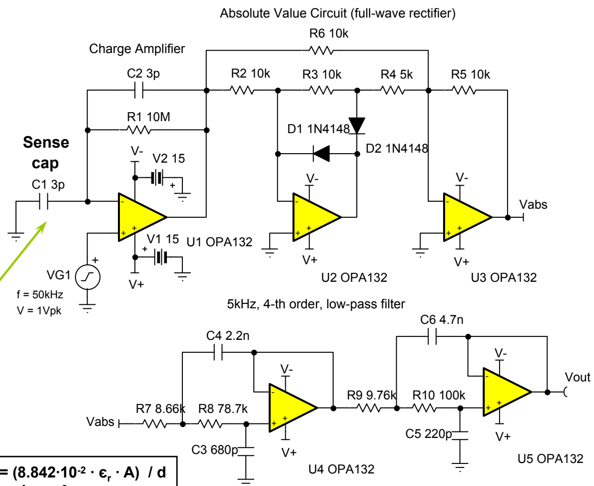
Remote System Monitor Applications

Security monitoring

A linear capacitive proximity sensor proposal

Dielectric	Relative Permittivity
Vacuum	1.0
Air	1.0006
Teflon™	2.0
Glass	7.5
Water	80





$C_{(pF)} = (8.842 \cdot 10^{-2} \cdot \epsilon_r \cdot A) / d$
A: area in cm²
d: plate distance in cm

Presented here is a proposal for an analog capacitive proximity sensor. Unlike most conventional capacitive proximity sensors that produce a “1” or “0” output, this sensor produces a DC output that is a function of the size and relative permittivity of an object passing between the sense capacitor plates. Different sized and density objects will produce a different output voltage.

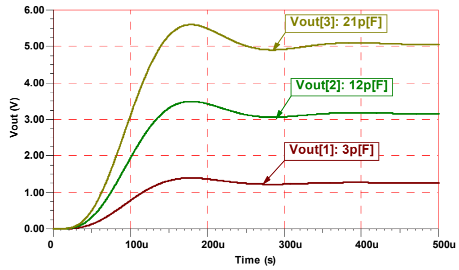
The oscillator input for this circuit is a 50kHz sine source. The low frequency and sine characteristic keep RFI problems at a minimum.

This proximity detector may prove difficult to construct because of the very small capacitances involved, parasitic capacitances in the sensor circuit, and noise pick up. An actual circuit would benefit from larger charge amplifier capacitances, but they may be difficult to fabricate and physically locate. Nonetheless, if this can be overcome then the circuit implementation is viable.

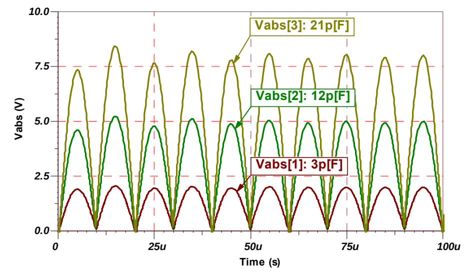
Remote System Monitor Applications
Security monitoring

Capacitive proximity sensor output as a function of sense capacitance

Low Pass filter output (DC)



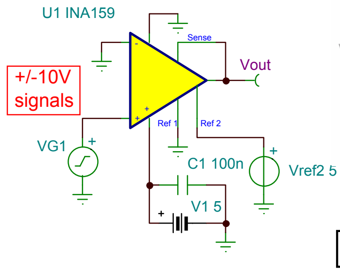
Absolute value circuit output

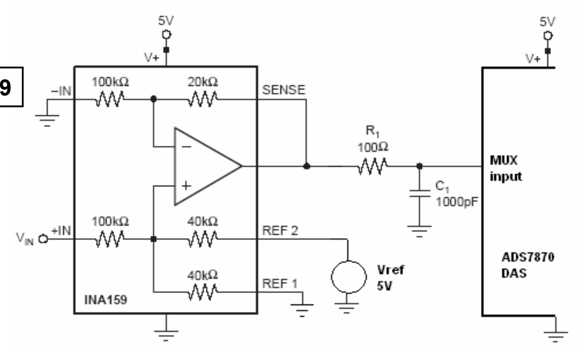


These plots show the distinct output levels associated with a change in sensor capacitance. When an object passes between the plates the dielectric's relative permittivity increases, increasing the sense capacitance and gain of the charge amplifier. After rectification by the absolute value stage the pulsating DC voltage is then filtered by the low pass stages. A corresponding DC level appears at the output.

Remote System Monitor Applications
Security monitoring

Interfacing a ±10V sensor circuit output to a 0 to +5V input





$V_o = V_{in}(0.2) + V_{ref}(0.5)$

The output from the capacitive proximity sensor circuit can be large enough to overdrive the DAS input - especially when the dielectric permittivity is very high compared to air. When using sensor circuits that have a high unipolar or bipolar output voltage the INA159 may be the perfect interface between it and the DAS.

The INA159 has the transfer function: $V_o = V_{in}\ (0.2) + V_{ref}\ (0.5)$

Thus, the output signal will be 1/5 the input value plus a DC level equal to ½ the voltage applied to the Ref 2 input. This DC level can be conveniently set to the DAS mid-scale input voltage. If the Ref 2 voltage is set to 5V, then this DC level will be 2.5V, which works nicely with the ADS7870. It is perfect for interfacing high output, such as ±10V ($20V_{p-p}$) sensor outputs to a 0 to 5V input range device.

The INA159 has precision gain scaling and a low voltage offset (±100µV).

Remote System Monitor Applications

Summary

- Data Acquisition System (DAS)
  - convenient MUX, PGA, A/D, reference and I/O functions
- Measurement basis
  - measurement bridge and instrumentation amplifier
- Many system attributes can be monitored without excessive cost
  - power, temperature, air flow, etc.
- Understand sensor characteristics
  - response over range, output voltage or current, linearity, etc.
- Analog interface
  - instrumentation amplifiers and op-amps make the task easy

Monitoring a remote system's measurement attributes can be accomplished without adding excessive circuit complexity and cost. An integrated data acquisition system (DAS) makes the collection of sensor outputs, subsequent signal conditioning and data conversion easy.

A measurement bridge, in conjunction with an op-amp or instrumentation amplifier, can provide the basis for a measurement system. The amplifier can be configured to provide the required signal conditioning such as amplification, level shifting and filtering. Since the DAS has a built in amplifier even further voltage gain can be applied to any channel.

The sensors may be fairly simple in design and application as demonstrated in the circuit examples. And as long as their characteristics and limitations are well understood, then they can be properly applied to the measurement task.