Technical Note

1.Constant Current Source

For Fujikura pressure sensor, a constant current source as shown in Fig. 1 is recommended. A reference voltage (Vref), which is generated by zener diode or voltage reference device, is applied to the non-inverting terminal of the operational amplifier (A1). The inverting terminal voltage of A1 is equal to the Vref, then the constant current(I) is :

$$I = \frac{Vref}{R2} \quad ..... [1]$$

The output voltage of A1(VA1) is :

$$VA1 = Vref + I \times Rb = I \times (R2 + Rb) \quad ..... [2]$$

where Rb : Bridge resistance

The supply voltage (Vcc) should be sufficiently higher than VA1. In a condition of no pressure (no mechanical stress) to the sensing chip, each output voltage of the bridge terminal(V1), (V2) is calculated by :

$$V1 = V2 = Vref + I \times \frac{Rb}{2} = I \times (R2 + \frac{Rb}{2}) \quad ..... [3]$$

Fig.2 shows a basic circuit for the type FPM. LM385-1.2 is a voltage reference which features 1.235V of Vref, and 150ppm/□ of temperature drift. The voltage across the resistor R2 is equal to Vref. (i.e.1.235V) The recommended constant current for the FPM is 1.5mA. Therefore R2 is :

$$R2 = \frac{1.235V}{1.5mA} = 820\Omega$$

The specified bridge resistance of the FPM is 4,000-6,000Ω, thus the maximum output voltage of A1(VA1) is :

$$VA1\max = 1.5 \times (820 + 6000) = 10.23$$

In this case, 12V DC is chosen for the supply voltage(Vcc), and a 10kΩ resistor is connected between the Vcc and the LM385-1.2 for 1mA operation.

$$R1 = \frac{12V - 1.235V}{1mA} = 10k\Omega$$

One part of the bridge connection of the FPM is opened. If offset calibration is required, a zero balance trimmer should be connected like Fig. 2. Or, a closed bridge connection, like Fig. 1, is also available, if zeroing should be done at the back end signal conditioning circuit.

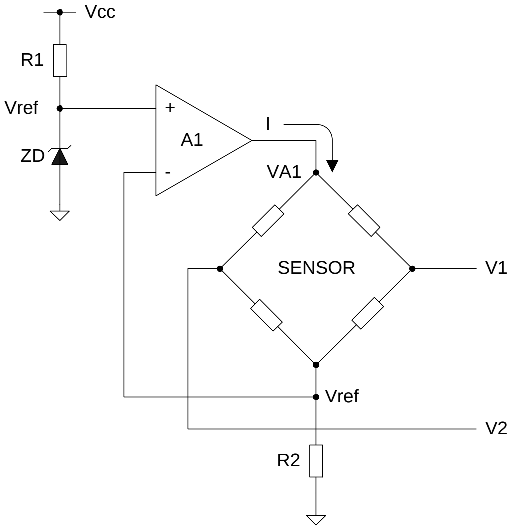


Fig.1 Constant current source

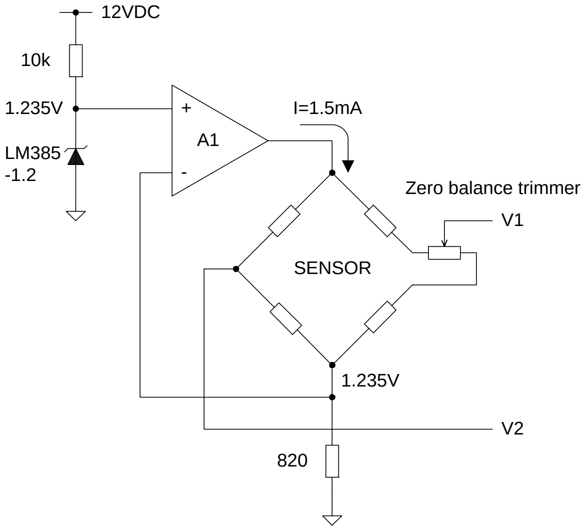
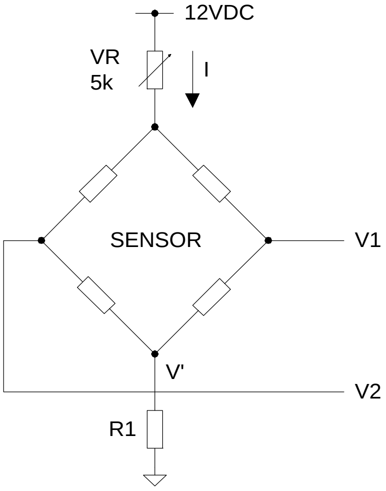


Fig. 2 Basic circuit for type FPM

2.Constant Voltage Source

Fig.3 shows an example of constant voltage source. Please note that temperature characteristic by constant voltage source is much different from the one by constant current source. For further information, please refer to the following 4－2.



*** Example for FPM sensor ***

Vcc:	12VDC
Bridge resistance:	4,000 ~ 6,000 ohm
I:	1.5mA
R1:	100 ohm
V':	150mV
VR:	1,900 ~ 2,500 ohm

or

Vcc:	7.5VDC
VR:	0 ohm
Bridge resistance:	4,000 ~ 6,000 ohm
R1:	0 ohm
I:	1.9 ~ 1.3mA

Fig. 3 Basic circuit of constant voltage source

3.Amplifier Circuit

A differential amplifier shown in Fig 4 is provided to treat low-level and differential signal from a sensing element. The output voltage(Vout) is calculated by the following formula :

$$Vout = \frac{R5}{R3} \times (V1 - V2) \quad \text{.....} [4]$$

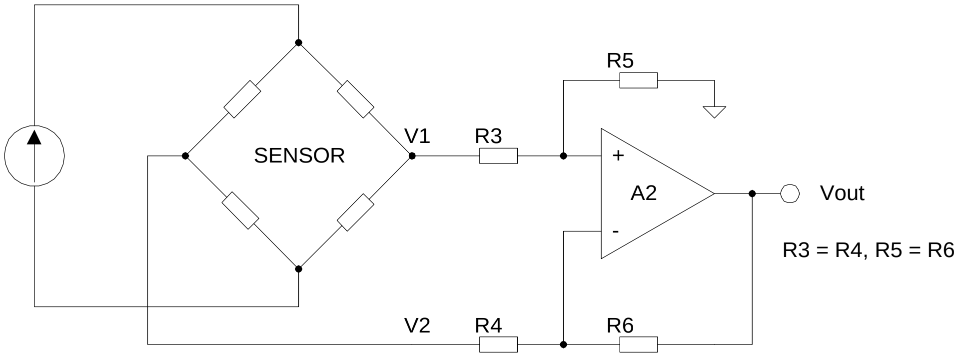


Fig. 4 Simple differential amplifier

Since the input resistance of the amplifier is not very high, an instrumentation amplifier shown in Fig.5 should be used for high precision measurement. Each output voltage of VA1, VA2, and Vout is calculated by :

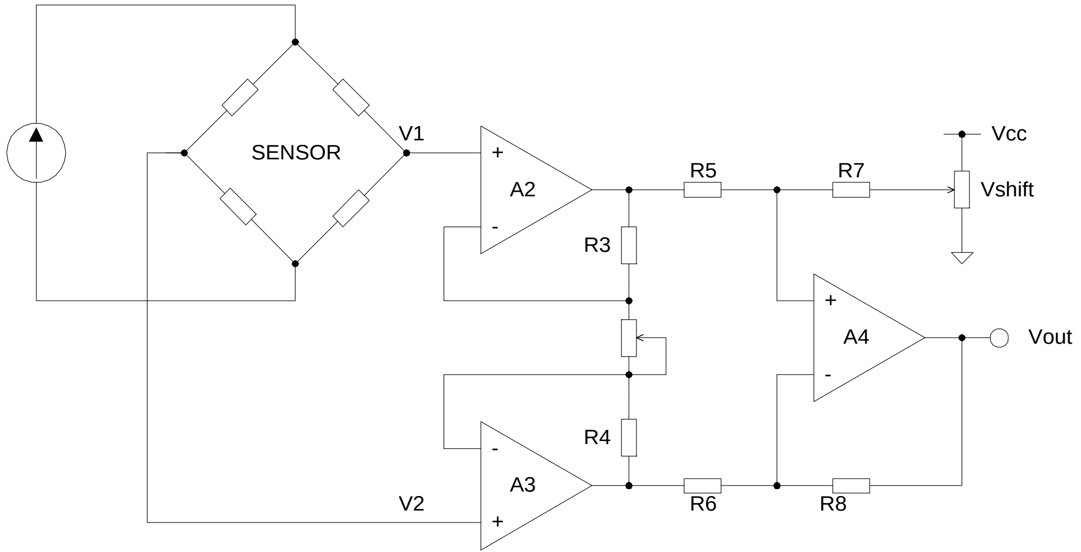
$$VA2 = V1 + \frac{R5}{VR1} \times (V1 - V2) \quad \text{.....}[5]$$

$$VA3 = V2 - \frac{R5}{VR1} \times (V1 - V2) \quad \text{.....}[6]$$

$$Vout = \frac{R7}{R5} \times (VA2 - VA3) = \frac{R7}{R5} \times (1 + \frac{2 \times R3}{VR1}) \times (V1 - V2) \quad \text{.....}[7]$$

In case of positive level shift is required, add Vshift to non-inverting input terminal of the amplifier A4. Then Vout is:

$$Vout = \frac{R7}{R5} \times (1 + \frac{2 \times R3}{VR1}) \times (V1 - V2) + Vshift \quad \text{.....}[8]$$



R3 = R4, R5 = R6, R7 = R8

Fig. 5 Instrumentation amplifier

How to design circuit for FPM-07PG is by the following manner :

[FPM-07PG]

Pressure range(gauge) : -0.492 to +0.492 kg/cm2

Sensor output(I=1.5mA) : -80 to + 80 mV DC (example)

[Amplifier]

Supply voltage(Vcc) : 12V DC

Output voltage(Vout) : 1to9V DC

$$Gain = \frac{1 \sim 9V}{-80 \sim +80mV} = \frac{8V}{160mV} = 50$$

R3=R4=R5=R6=R7=R8=10k

VR1=2k : adjust to approx. 400 ohm

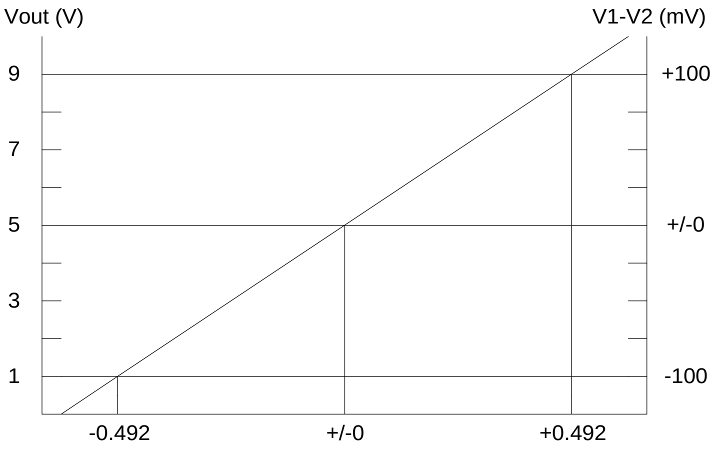
Vref=1.235V (refer Fig.2)

VR2=10k : adjust to approx. 4.2k (Vshift=5V)

*All resistors should be 1/4W and 1% tolerance

*This circuit does not include temperature compensation resistor.

Output characteristic



Gauge pressure (kg/cm2)

4.Temperature Compensation

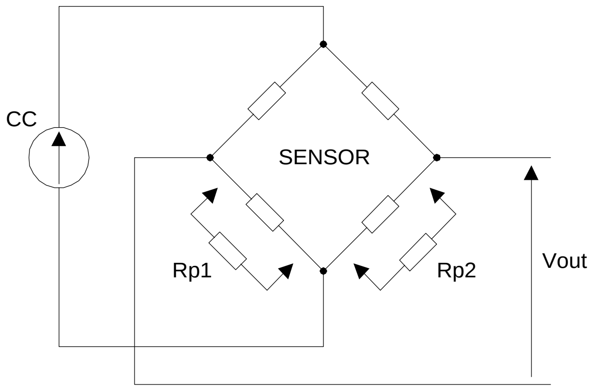
Piezoresistive pressure sensor has two temperature characteristics - Temperature Sensitivity of Offset and Temperature Coefficient of Span output. For high precision measurement, temperature compensation is recommended as below.

4-1 Temperature Sensitivity of Offset (TSO)

TSO is the temperature drift behavior of bridge output at free of pressure. It is caused by :

- Difference of thermal expansion coefficient of each components of the sensor …silicon chip, glass pedestal, bonding resin, and package.
- Difference of thermal expansion coefficient of each material of the sensing chip …silicon substrate, oxidation layer and aluminum pattern.
- Variety of thermal coefficient of the four piezoresistors of the bridge.
- Variety of resistance value of the four piezoresistors of the bridge.

In order to compensate TSO, a resistor such as metal film type, is connected in parallel to the bridge. Fig.6 shows a connection diagram, and the resistance is determined in the following manner,



Rp1, Rp2: Low temperature drift resistor (Metal film type or similar type is recommended)

Fig. 6 Connection for TSO compensation

- V(p,t) refers to the output voltage in pressure "p" and temp "t"
- "p0" refers to a no pressure condition. i.e. V(p0) is the offset voltage.
- "tc" refers to the lower temp. of the operating temp. range, and "th" the higher.

(1) Measure the output voltage at the following 10 points :

Output	*Rp1*	*Rp2*
$V1=V(p0,tc)$	*open*	*open*
$V2=V(p0,tc)$	*500k*	*open*
$V3=V(p0,tc)$	*1M*	*open*
$V4=V(p0,tc)$	*open*	*500k*
$V5=V(p0,tc)$	*open*	*1M*
$V6=V(p0,th)$	*open*	*open*
$V7=V(p0,th)$	*500k*	*open*
$V8=V(p0,th)$	*1M*	*open*
$V9=V(p0,th)$	*open*	*500k*
$V10=V(p0,th)$	*open*	*1M*

(2) Calculate the temperature drift of the offset at each point.

$TCV1=V6-V1$

$TCV2=V7-V2$

$TCV3=V8-V3$

TCV4=V9-V4
TCV5=V10-V5

(3) Plot a temperature characteristic line as in Fig.7.

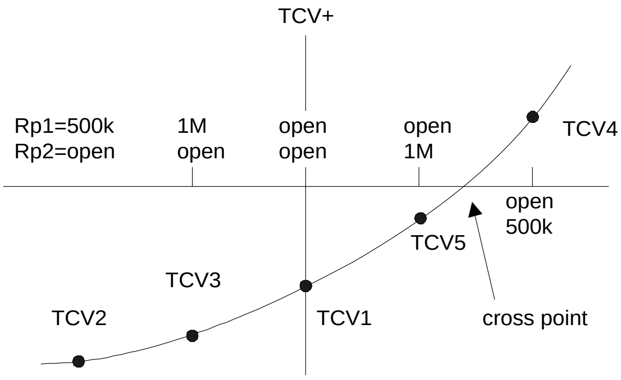


Fig. 7 Rp1, Rp2 vs. TCV

(4) The most suitable condition is the cross point of the line and X-axis. For example in Fig.7, Rp1 must be open (i.e.Rp1 is not needed) and Rp2 must be approximately 750k or so.

4-2 Temperature Coefficient of Span outpuut (TCS)

TCS is the correlation between operating temperature and bridge output voltage. It is caused by the issues as below,

(a) Impurity concentration of piezoresistors
(b) Crystal direction of piezoresistors
(c) Resistance value of external load resistor

The following describes the detail of the items (a), (c).

4-2-1 Impurity concentration of piezoresistors

TCS characteristic mainly depends on the impurity concentration of piezoresistors. Driven by a constant current source, the correlation is shown in Fig.8. There are two points of impurity concentration that can optimize the TCS.

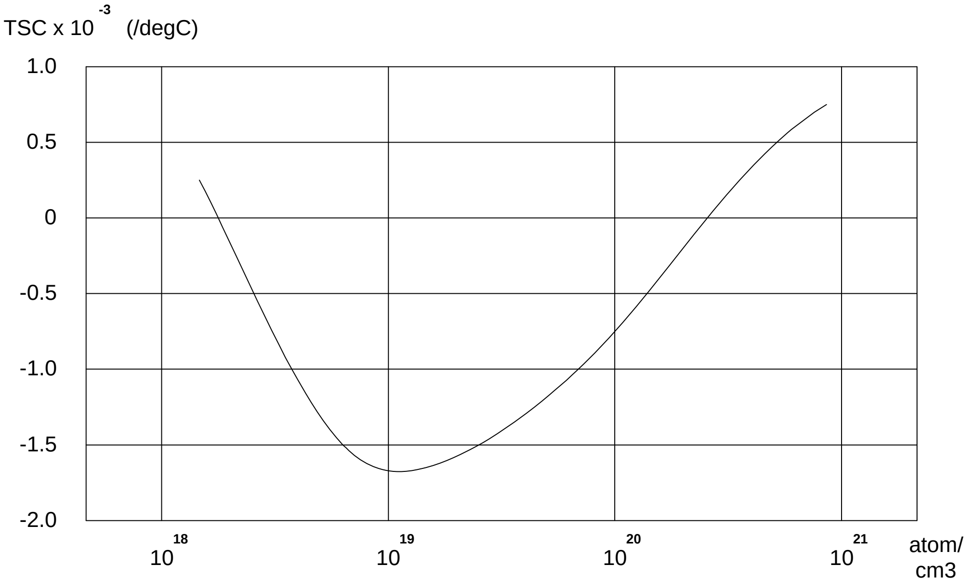


Fig. 8 Relation between temperature coefficient of the pressure sensitivity and impurity surface concentration

Fig.9 shows a temperature drift of pressure sensitivity at $2 \times 10^{20} atoms/cm^3$ of impurity concentration. It shows that constant current source can make the temperature drift better than constant voltage source. An external load resistor is useful if further compensation is required. (Please refer to 4-2-2.) In case of constant voltage source, the temperature drift shows linear characteristic, therefore, a software compensation by micro-processor is useful.

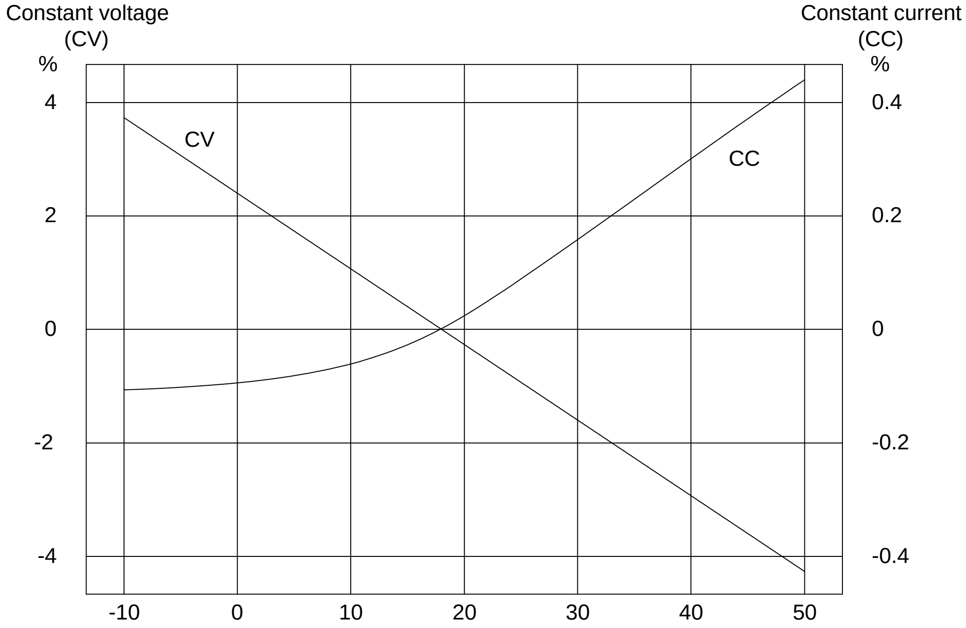


Fig. 9 Temperature drift of pressure sensitivity
for voltage and current drive

4-2-2 Compensation by an external load resistor

A circuit with external load resistor is shown in Fig.10(a). When an external signal conditioning circuit, such as an amplifier or micro-processor, is connected to the sensor's output terminals, the input impedance of the device is considered as the load resistor RL.

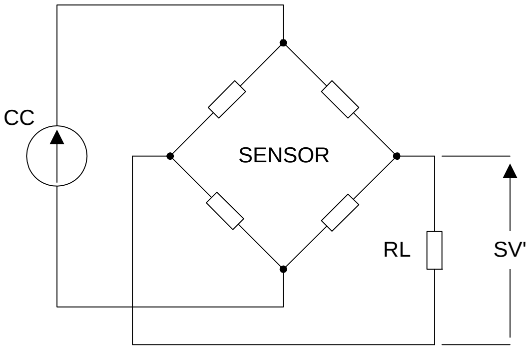


Fig. 10(a) Circuit with load resistor RL

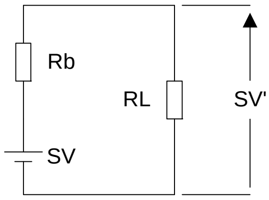


Fig. 10(b) Equivalent circuit

Showing an example of correlation between TCS and RL, Fig. 11 indicates that there is the best RL value to minimize the TCS property. However, please note that the availability of the compensation is limited by a condition that “bare” TCS property is originally positive to the temperature.

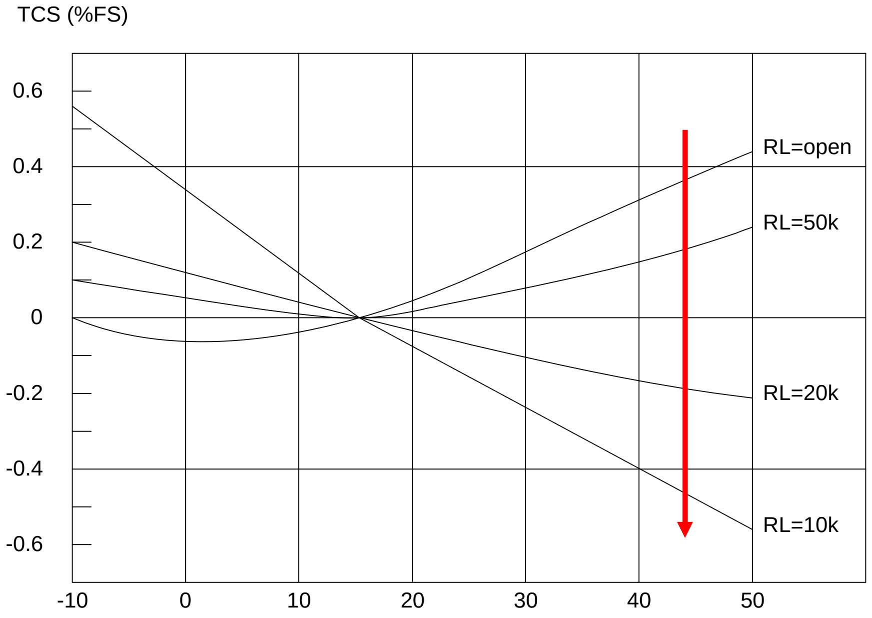


Fig. 11 Example of the relation between RL and TCS

Fig.10(b) shows the equivalent circuit of Fig.10(a), and the RL value is calculated by the following formula :

$$RL = \frac{SVc \times Rbh - SVh \times Rbc}{SVh - SVc} \qquad .....[9]$$

where SVc : Span output voltage at lower temp. of operating temp. range.
SVh : Span output voltage at higher temp. of operating temp. range.
Rbc : Bridge resistance at lower temp. of operating temp.
Rbh : Bridge resistance at higher temp. of operating temp.

Please note that the RL reduces sensor span output voltage as the following formula :

$$SV' = \frac{RL}{Rb + RL} \times SV \qquad .....[10]$$

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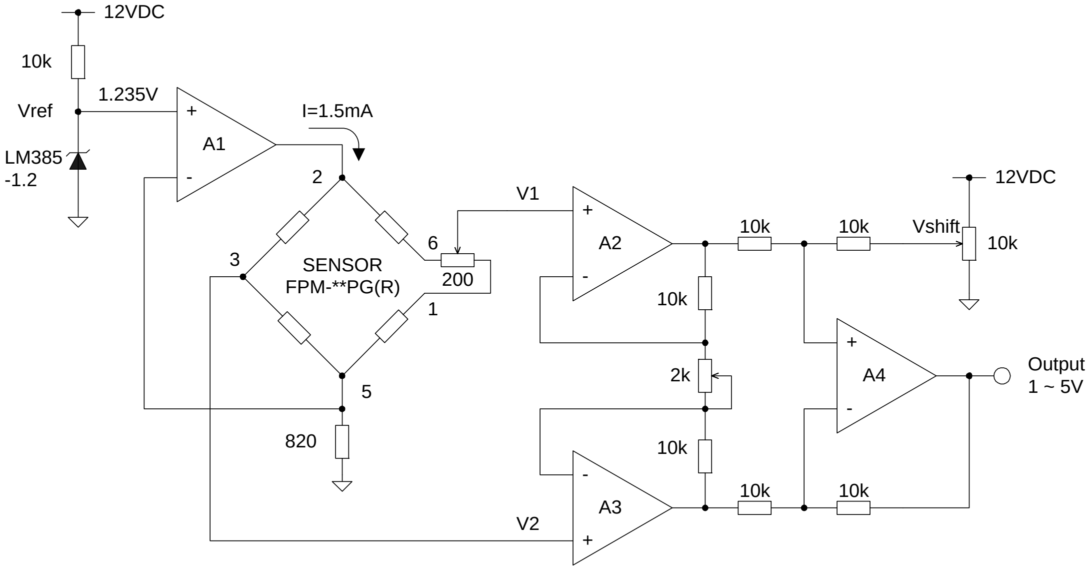
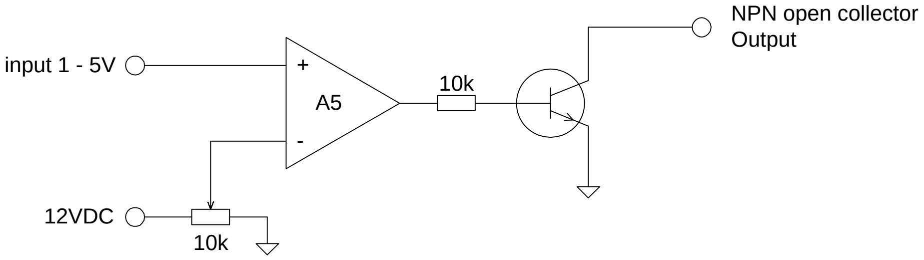
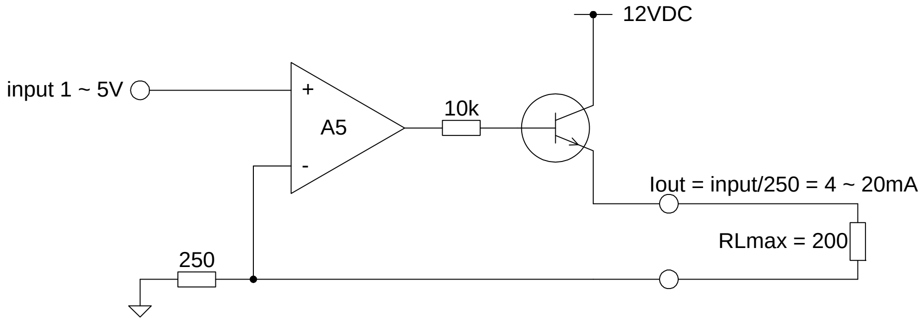
[Analog output]



[For pressure switch]



[For current output]



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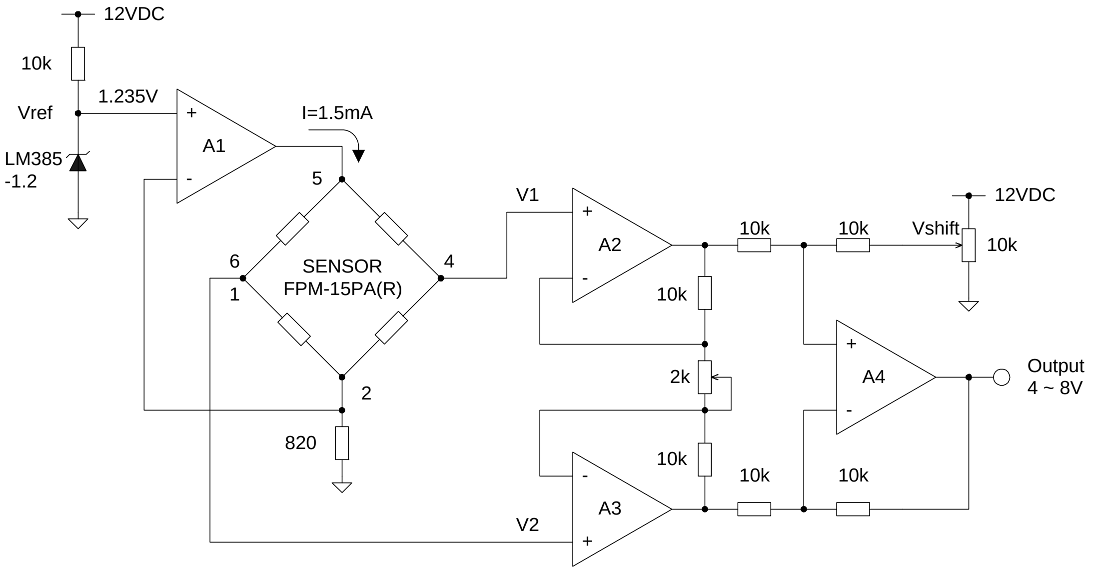
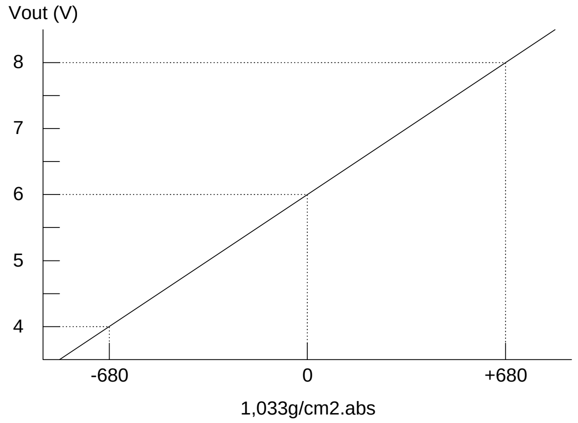
[Barometric pressure monitor]





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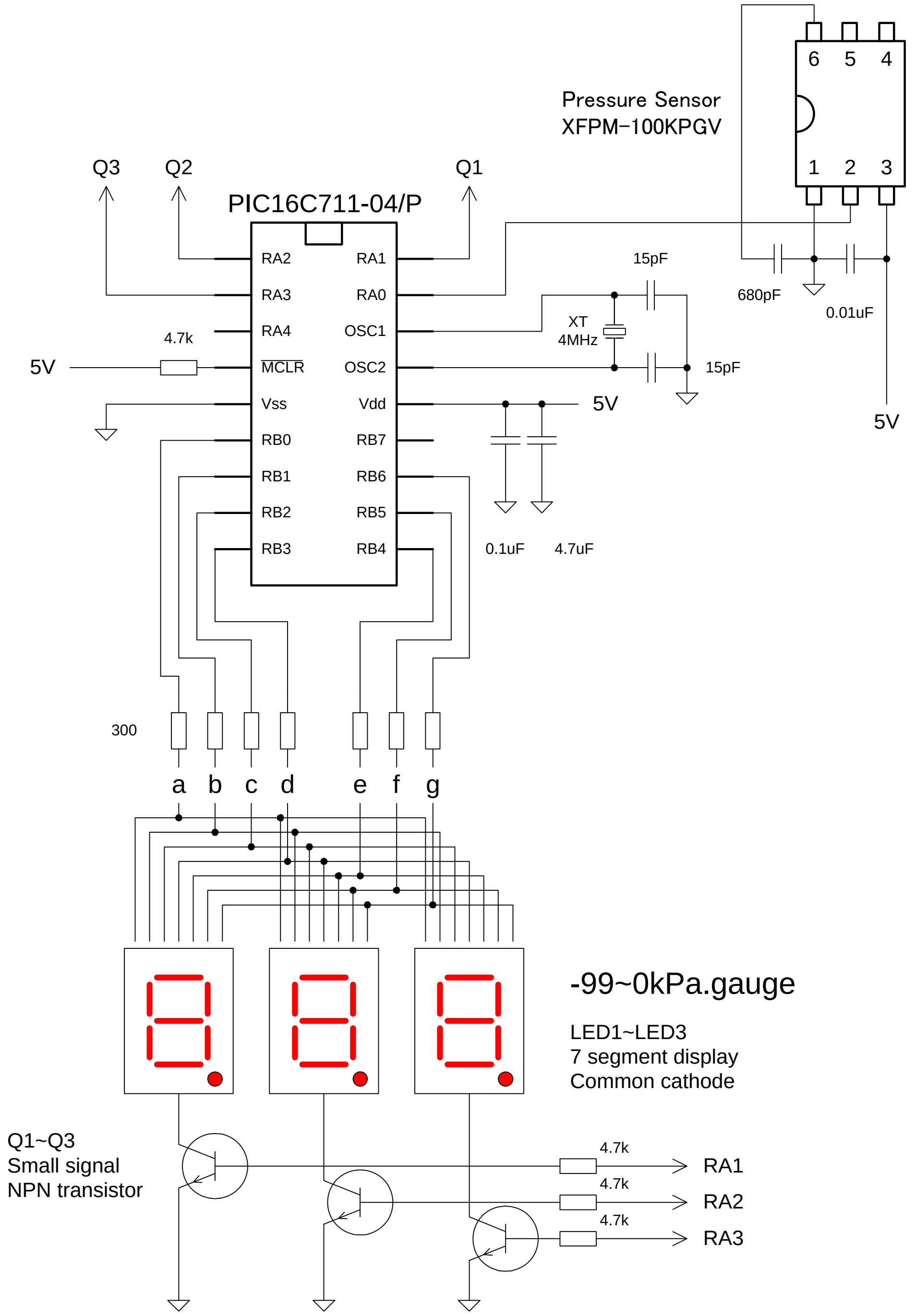
[Vacuum monitor]



-99~0kPa.gauge

LED1~LED3
7 segment display
Common cathode

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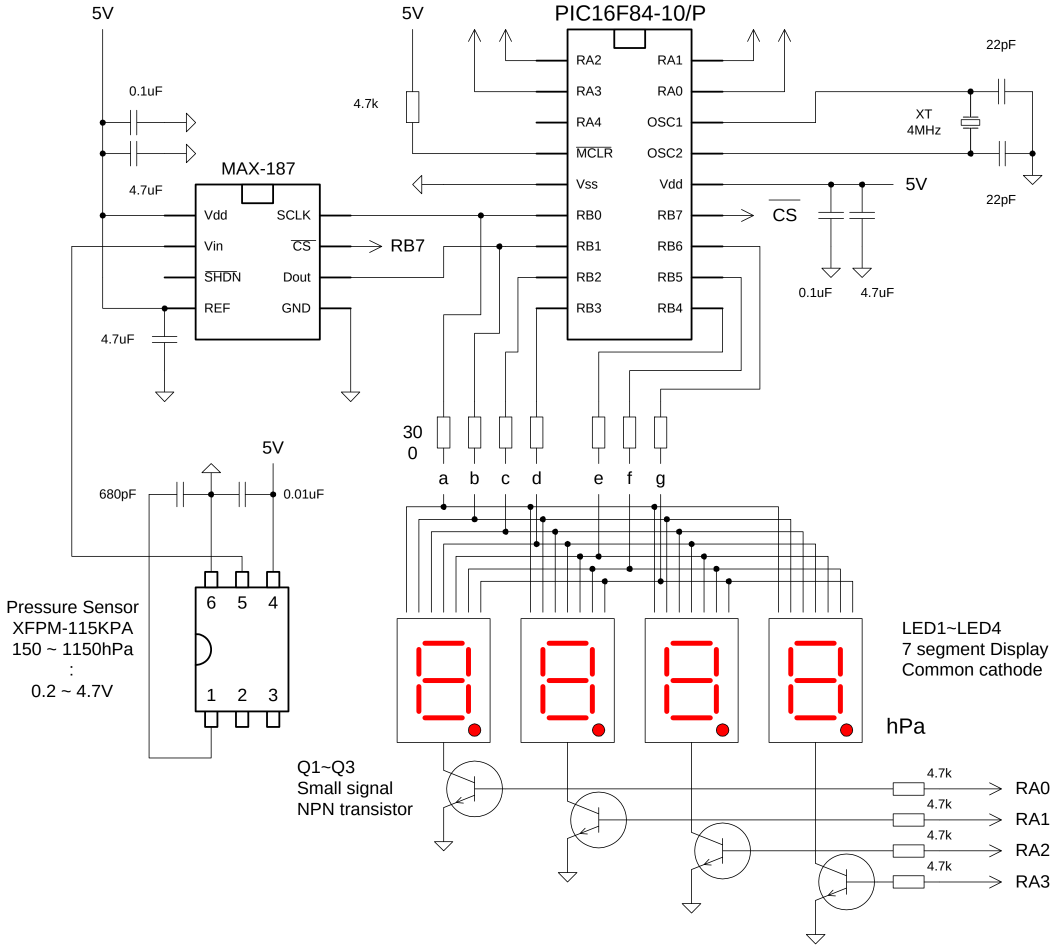
[Barometric pressure monitor]



1st October , 2011