Useful Pressure Transducer Performance Outside Normal Operating Range

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In some applications, there is a requirement to detect pressures above or below the normal operating range of the pressure sensor. One example is if the system requires alarms at points outside the normal operating range. In this situation, it may be undesirable to use a sensor with a range encompassing the alarm points since this will reduce the resolution in the normal operating range in order to accommodate infrequent excursions to the alarm pressures. This application note describes how far outside the normal operating range the pressure transducer will function and its performance in these regions.

Device Operating Regions

A typical pressure transducer output versus pressure is shown in Figure 1. The shaded region of the curve between $P_{LoScale}$ and $P_{HiScale}$ is specified in the standard pressure transducer documentation. Typical values for the parameters which define this region might be (for a 100 psig device with V_{DD}=5V) $P_{LoScale}$ = 0 psig, $P_{HiScale}$ = 100 psig, $Out_{LoScale}$ = 0.5 V and $Out_{HiScale}$ = 4.5 V. Other parameters such as the linearity are also specified. Below $P_{LoScale}$ and above $P_{HiScale}$ the pressure transducer continues to produce an output proportional to pressure until either P_{Min}, P_{Max}, Out_{LoSat} or Out_{HiSat} is reached. What factors influence the values of P_{Min}, P_{Max}, Out_{Min} and Out_{Max}?

Values of P_{Min}, Out_{Min}

The location of the minimum pressure point depends on the type of device (absolute, sealed or gage), normal device range, output impedance of the transducer and the external load which the transducer is driving.

The position of the lower breakpoint may be constrained either by the attainable input pressure or by the transducer output at low saturation. More specifically, the lowest possible output is the greater of 1) the output corresponding to an input pressure of 0 psia or 2) the lowest achievable output voltage based on

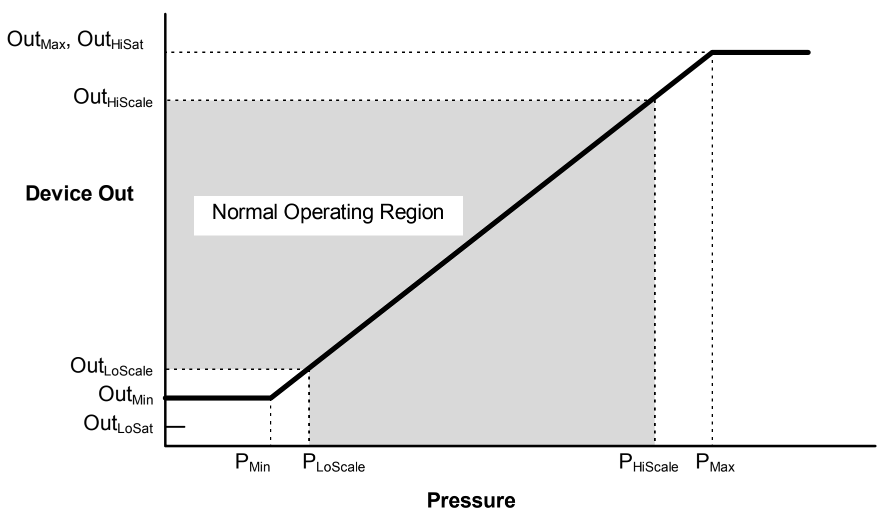

Figure 1. Typical Device Output vs. Pressure

transducer impedance and load.

The output corresponding to a 0 psia input pressure is found using the equation for the normal operating region line in Figure 1. This value is:

$$Out_{Min1} = m \times \left(P_{Min} - P_{LoScale}\right) + Out_{LoScale} \quad [1]$$

where:

$$m = \left(\frac{Out_{HiScale} - Out_{LowScale}}{P_{HiScale} - P_{LoScale}}\right)$$

P_{Min} = 0 psia
0 psis (calibrated as absolute)
~ -15 psig

As an example, consider a 0-100 psig device with supply voltage of 5V and with a normal output range between 0.5V and 4.5V. Then

m = (4.5 - 0.5)/100 = 0.04 V/psig.

and

Out_{Min1} = 0.04 * (-15 - 0) + 0.5 = -0.1 V

Since this transducer cannot generate an output below 0 V, the minimum output voltage will be limited by the electrical constraints on the output and not by the input pressure.

The lowest achievable output voltage depends on the load and on transducer output impedance. The worst case output impedance is 140Ω. The minimum output voltage is found by assuming that the external load is a pull up (to V_{DD}) and calculating the output of the voltage divider formed by the output impedance and the load:

$$Out_{Min2} = V_{DD} \times \frac{R_{out}}{R_{out} + R_{load}}$$

The following table shows the value of the minimum output voltage with three different loads.

R_{load} (Ω)	Out_{Min2} (V)
2,000	0.065 V_{DD}
5,000	0.027 V_{DD}
10,000	0.014 V_{DD}

Table 1. Minimum output vs load

If it is found that the lowest output voltage is limited by the output impedance, the input pressure corresponding to this output may be found by solving equation [1] for P_{Min}:

$$P_{Min} = \frac{1}{m}\left(Out_{Min} - Out_{LoScale} + m \cdot P_{LoScale}\right) \quad [2]$$

If we continue with the example above, with a 10KΩ output load, Table 1 shows that the minimum output voltage is 0.07V. Using equation [2], we can find the pressure to which this output corresponds:

P_{min} = (1/0.04) * (0.07 - 0.5 + 0.04 * 0)
= -10.8 psig

Values of P_{Max}, Out_{HiSat}

Since exceeding the full scale pressure by less than 15% will not cause the plates of the capacitive sensing element to make contact, the location of the maximum pressure point depends only on the output impedance of the transducer and the external load.

The worst case output impedance of the transducer is 140Ω. If there is an external load connected to ground, the maximum output value is:

$$Out_{Max} = V_{DD} \times \frac{R_{load}}{R_{out} + R_{load}}$$

The following table shows the value of the maximum output voltage with three different loads.

R_{load} (Ω)	Out_{Max} (V)
2,000	0.93 V_{DD}
5,000	0.97 V_{DD}
10,000	0.99 V_{DD}

Table 2. Maximum output vs. load

Continuing with the example above, with a 10K output load, Table 2 shows that the maximum output voltage is 4.93V. Using equation [2], with Out_{Max} in place of Out_{Min}, we can find the pressure to which this output corresponds:

P_{Max} = (1/0.04) * (4.93 - 0.5 + 0.04 * 0)
= 110.8 psig.

So this device will produce an output proportional to pressure input from about -10% to 110% of its rated pressure range.

Caveats

It is important to be aware that device operation below the normal operating region causes the diaphragm of the sensing element to move into a geometry for which it was not specifically designed. At these pressures the diaphragm will assume a curvature opposite the curvature in its normal operating region. Due to the small deflections involved, the transducer is able to operate in this region, but it has neither been characterized nor has long term reliability been established in this region.

Device parameters such as linearity, repeatability and hysteresis which are specified in the normal operating range are not specified for excursions outside this range.