Flowmeter Interfacing

Chapter 13

The flowmeters discussed in this chapter are a small sampling of the many types in use, but they involve a variety of interfaces, some of which have been discussed in earlier chapters.

DIFFERENTIAL-PRESSURE FLOWMETERS

This class is based on the square-root relation between the flow through a resistance (such as an orifice or a restriction in the flow path) and the pressure drop across it. Differential pressure is measured, and the square-root of the resulting signal is computed. The square root can be computed as an analog signal, for immediate use; or, in systems involving processors, the differential-pressure signal can be converted to digital, the computation performed digitally, and the data used as needed for transmission, display, or further processing.

Figure 13-1 shows a simple means of computing the square root for unidirectional flow, using an electronic analog multiplier/divider, the AD534 or the AD535. The relationship is, simply

$$E_{OUT} = \sqrt{10(Z_2 - Z_1)}$$

Note that, since the Z input is differential, the differential pressure may be established by applying the outputs of two pressure-transducer interfaces to Z_2 and Z_1; if a single DP device is used, Z_1 is simply grounded (for positive input at Z_2). If the net input is negative, the roles of Z_2 and Z_1 should be interchanged. If it is desired to compute the negative of the output, reverse the external

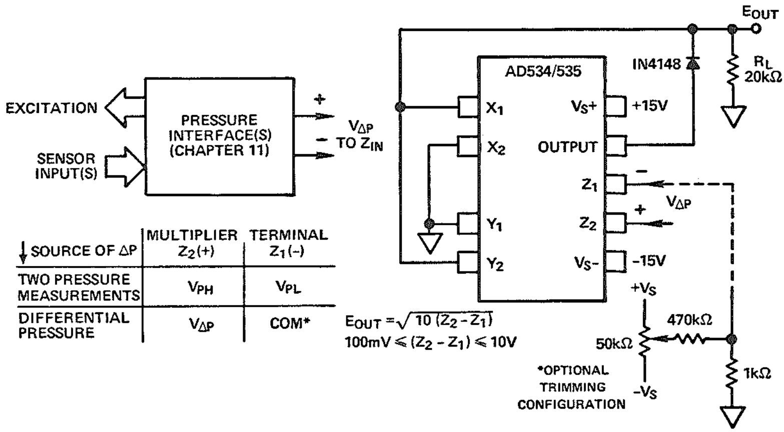

Figure 13-1. Square-root circuit for flow computation

diode connection and the X input polarity.

This circuit is normalized to 10V full scale. That is, for 10V in, representing ΔP_{max}, the output will be 10V. If the ratio of full scale to the lowest pressure is large, the optional trimming circuit shown should be applied to the normally grounded Z_2 input; alternatively, a pressure interface's *offset trim* can be used instead. The trim is adjusted for zero output as the differential input approaches zero.

FREQUENCY-OUTPUT FLOWMETERS

An important advantage of a flowmeter having a frequency output is that the signal can be transmitted with considerable noise immunity, despite little (if any) processing at the front end; also, the signal can be readily isolated and eventually transformed into either analog or digital information.

Figure 13-2 shows a circuit that has been used for instrumenting a turbine-type self-generating flowmeter. The 10mV output pulses are preamplified, using an op amp connected for gain of 1000, in an essentially ac-coupled circuit, to avoid amplifying offsets. The pulse frequency is converted to voltage in an f/V converter. The FVC is followed by a voltage-controlled low-pass filter, which further cleans up the waveform. The filter can also be adjusted to damp out the effects of periodic surges in flow, due to pumping, or to follow rapid slewing of the flow rate, depending on the control voltage applied. A follower-connected op amp buffers the output of the filter.

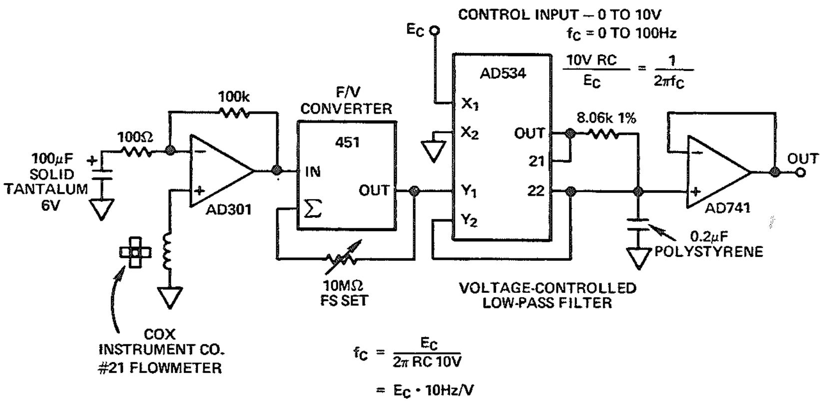

Figure 13-2. Flowmeter-to-analog interface

Figure 13-3, somewhat similar to Figure 13-2, shows an interface for a paddle-wheel-type flowmeter. A short pulse is produced each time a wheel arm passes the sensing point. The AD311 comparator senses the small pulses and provides logic pulses, which may be used to generate analog or digital information. For small signals, some gain (as shown) may be desirable, to allow the comparator to discriminate more easily.

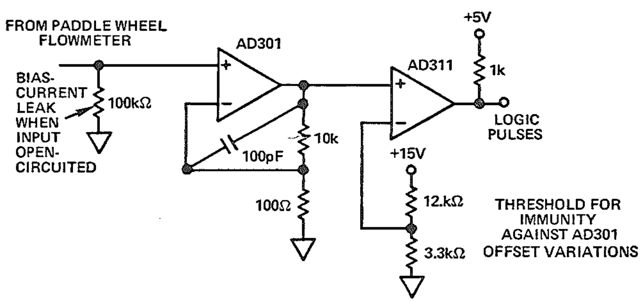

Figure 13-3. Interface for paddle-wheel-type flowmeter

ANEMOMETERS

The anemometer (*wind-meter*) is a common form of flow meter. In its most commonly seen form, the cup (or propeller) type, the output is a frequency, produced by actuating a reed switch magnetically for each revolution. This is a reliable scheme, with potentially long equipment life. However, if the readout is to be analog, the slow rate of rotation at low wind speeds poses the dilemma that if the filter time-constant is long enough to smooth the output of a frequency-to-voltage converter sufficiently to make the reading appear steady, it will respond rather slugglishly to puffs or gusts. The circuit of Figure 13-4 provides one solution to this dilemma.

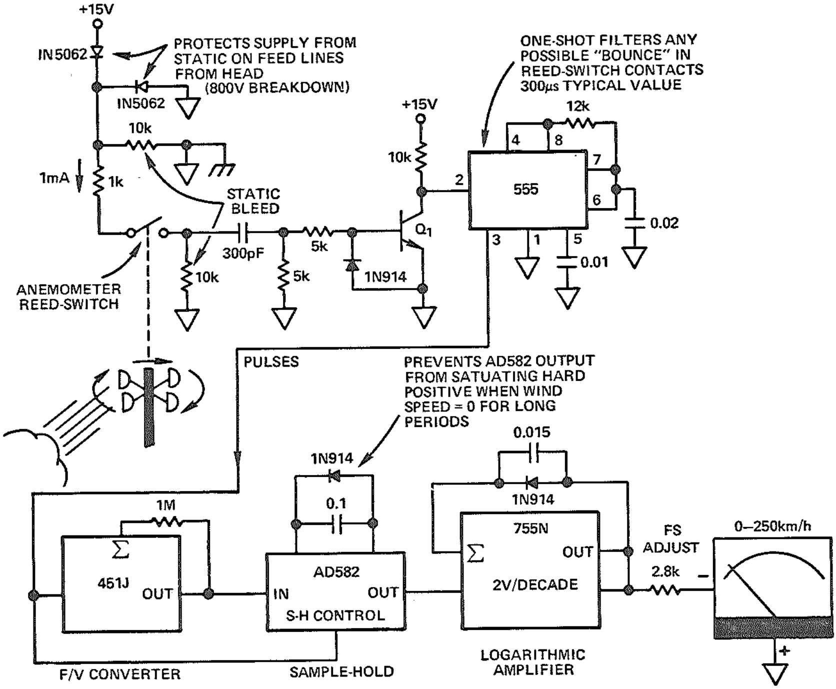

Figure 13-4. Anemometer circuit

In the system shown, the reed-switch closing drives Q1 into conduction, which triggers the 555 one-shot. The 300μs output pulse from the 555 is the input signal to the Model 451 f→ V converter, with a 1MΩ feedback resistor for full-scale output at 100Hz. At high wind speed, the percentage of ripple in the output of the f/V converter is small, yet response is fast. At low wind speeds, the readings will have large, slow, unstable-appearing variations, unless heavy low-pass filtering is used.

The solution, in this system, is to use an AD582 sample-hold, which acts as a synchronous filter to sample the output of the 451J in synchronism with the input, then hold it until the next pulse. The output of the sample-hold is at a properly proportioned dc level, regardless of how low the repetition rate of the input signal is.

Better definition at low speeds is obtained by displaying wind speed logarithmically, using the 755N log/antilog amplifier and a meter with a log calibration.

The *hot-wire* anemometer measures speed of a medium by the cooling effect of the flow upon an electrically heated platinum filament (i.e., an RTD in the self-heating region). Figure 13-5 shows a typical voltage-current characteristic at two values of air speed.

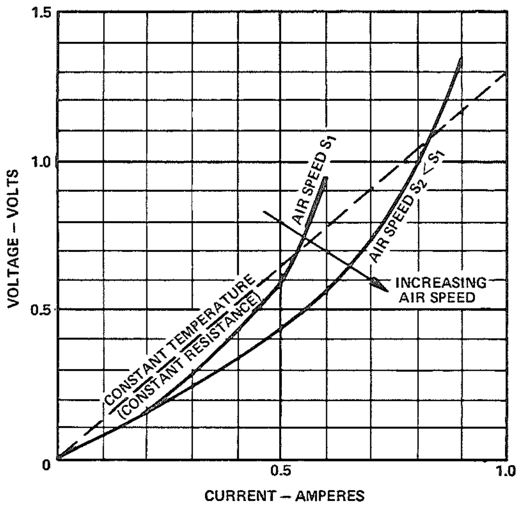

Figure 13-5. Volt-ampere characteristics of 7/16"L X 0.002"D straight filament of pure platinum in the presence of moving air, for two values of air speed.

When operated at constant current, the device is quite sensitive, but could self-destruct at very low airspeeds; when operated at constant voltage, the device is stable but less sensitive. In either case, a change in temperature is associated with the change in airspeed, hence a delay in measurement, which could be unstabilizing if the anemometer were part of a control loop.

Therefore, it is useful to operate the device at constant resistance (i.e., constant temperature), by adjusting the drive voltage (Figure 13-6)[1]. From the curves, one can see that, if the resistance were maintained at 1.3Ω, as indicated by the dashed line, one could obtain a current change of 0.3A and a voltage change of 0.4V, for the speed change shown, with no danger of overheating in

[1] Miyara, J., "Measuring Air Flow Using a Self-Balancing Bridge," *Analog Dialogue*, Volume 5, Number 1, 1971

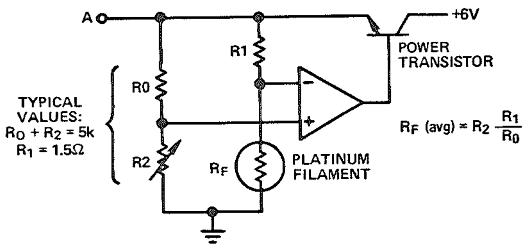

Figure 13-6. Basic circuit of the temperature-controlled bridge

normal operation. Response would be speedy, since temperature changes are transient and small.

In the circuit of Figure 13-6, the op amp continuously adjusts the flow of current to maintain the two inputs equal. This can be accomplished only by keeping the voltage across the filament equal to that across R2, and the filament current equal to the current through R1. However, since the current through R1 is proportional to the current through R0 (which has the same voltage drop as R1) and the current through R0 is determined by the voltage drop across R2, it can be seen that the resistance of the filament, R_F, must be equal to that of R2, multiplied by the ratio R_1/R_0.

Suppose that, starting from a given equilibrium point, the air flow increases. This will take heat away from R_F, causing its voltage to tend to drop. The amplifier's output voltage increases, which increases the current through the power transistor, and thus makes more power available for the filament to dissipate to maintain its temperature (and hence its resistance) constant.

The output voltage is measured at terminal *A*, which provides an amplified version of the filament voltage, at an impedance low enough to operate even the crudest of meter movements. The zero-speed voltage is biased off by an auxiliary constant voltage, and the readings can be displayed with a moving-coil meter. The scale is a nonlinear (calibratable) function of airspeed, actually expanding toward the lowest values. Thus, low air speeds can be read with high sensitivity; in fact, the device can virtually detect a whisper several feet away.

For practical realization, the following points should be considered:

1. A small keep-alive current must be introduced to insure that the output goes positive on turnon.

2. The power transistor must have ample current-handling capacity; the filament requires substantial fractions of 1 ampere.

3. Stability is dependent on the physical layout, especially if the filament is at the end of a twisted pair. The circuit should be checked with an oscilloscope, and appropriate measures taken to insure stability (capacitance from base to collector of the power transistor, small resistance in series with the base, compensating inductance in series with R1, etc.)

4. R0 and R2 form a trim potentiometer to set the operating temperature (e.g., resistance) of the filament. If R2 is a variable resistance, start with $R_2 = 0$, and increase it until the filament just starts to glow, then back down a little. This will give optimal sensitivity, as well as independence of ambient temperature.

Applications: The device has been used commercially to trip out equipment when the air speed in a forced-draft duct falls below a preset value, but the approach is highly suggestive of other applications in instrumentation.

HINGED-VANE FLOWMETER

The hinged vane (Figure 1-15b) can be linked to a potentiometer; the fractional rotation is a function of flow. In Figure 13-7, the pot is energized by an AD580 voltage reference, and the output is shown optionally feeding an AD2026 3-digit panel meter, a simple follower (and subsequent system instrumentation), and an instrumentation amplifier (where grounds are noisy).

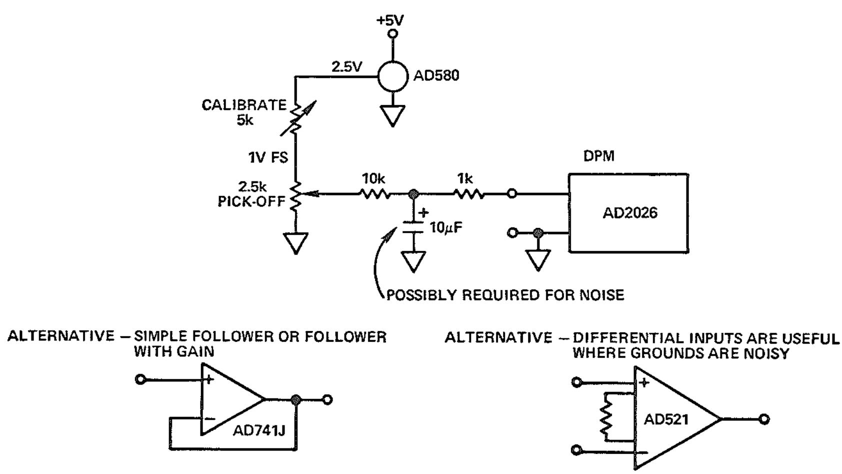

Figure 13-7. Interfacing a hinged-vane flowmeter

The calibration rheostat is adjusted for 1V full-scale across the potentiometer, or for a reading of 999 on the digital panel meter at (99.9% of) full-scale flow.

THERMAL FLOWMETER

If a heat source is thermally centered between two sensors, the difference between the temperatures they measure is a function of the flowrate (Figure 13-8a). Figure 13-8b is a simplified diagram of a patented flowmeter built upon this principle. The temperature sensors are AD590 semiconductor devices, and the difference between the voltages they develop across 1kΩ resistors is read out by an AD521 instrumentation amplifier. Heat is supplied by a controlled heating element (in this case, a vitreous resistor).

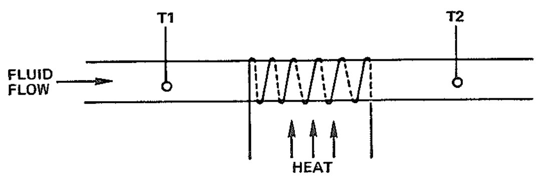

Figure 13-8a. Flowmeter principle

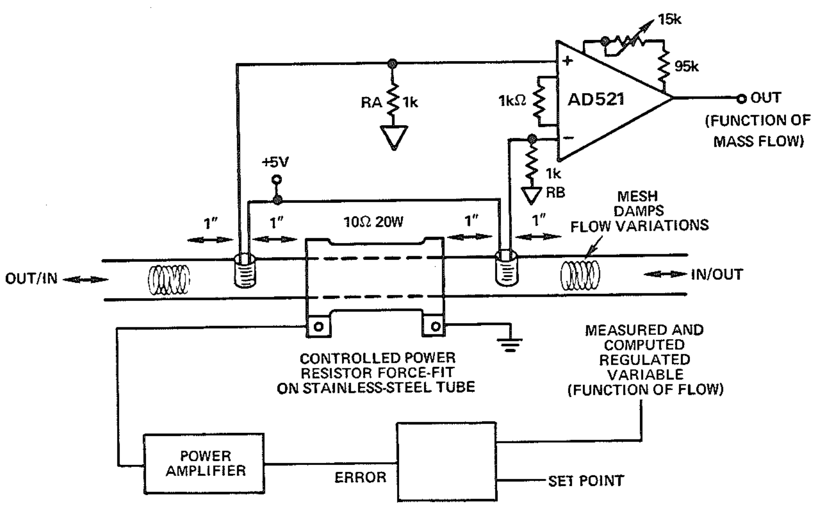

Figure 13-8b. Flowmeter circuit

TRANSMISSION, ISOLATION, AND READOUT

As earlier chapters have noted, the outputs of interface circuits can be easily translated to 4-to-20mA signals for analog transmission in industrial-process environments, with either common system wiring or isolation. Also, isolators and isolated op amps are available for two- or three-port voltage-to-voltage isolation. Frequency-output devices are easily isolated, optically or electromagnetically. Where a number of channels are to be read, the AD2037 6-channel scanning digital voltmeter provides a sensitive front end, 3 1/2-digit readout, and flexible digital control options.