TWO-WIRE AND THREE-WIRE SENSOR INTERFACES

By Eric Burdette, Allegro MicroSystems

Introduction

Electrical interfaces for active sensor integrated circuits (ICs) include both two-wire and three-wire interfaces. These two technology styles are named for the number of required connections needed to communicate the sensor output. This application note discusses use and tradeoffs of both interface styles.

Three-Wire

A three-wire configuration requires the user to have three discrete electrical connections to the IC. The naming convention derives from use of wires in a wiring harness.

First, consider a simple sensor which conveys a digital output. One would need two dedicated lines to supply power and ground to the IC (labeled as VCC and GND in Figure 1). A third line can be dedicated to the digital signal; this digital level can be conveyed via open-drain or open-collector transistor, as shown in Figure 1.

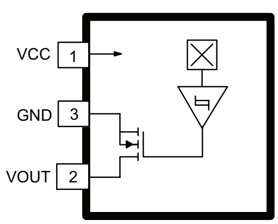

Figure 1: Example three-wire IC pinout

The interface circuit to attain digital voltage levels is simple, given that the FET state is either on or off. Figure 2 shows a single pull-up resistor; the output will then be either a low voltage (FET on) or a voltage approximately V_{PULLUP} (FET off).

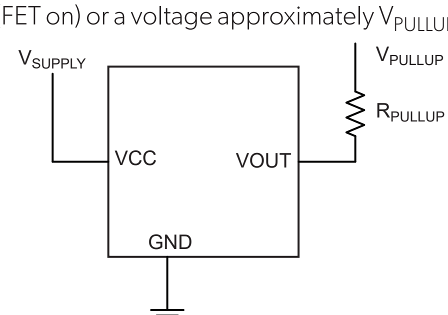

Figure 2: Three-wire interface circuit

In Figure 2, V_{SUPPLY} and V_{PULLUP} are separately noted for sake of clarity; the two can be the same source. One then only needs to note that datasheets refer to I_{CC} as current into the supply pin; current flowing through R_{PULLUP} should be accounted for separately.

Two-Wire

A two-wire sensor only requires two electrical connections. Power supply and ground contacts are still required, and so the digital output is conveyed using multiple current levels.

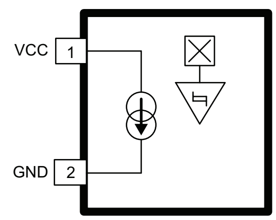

Figure 3: Example two-wire IC pinout

As sensor output is communicated along the supply lines, this saves the user the cost of a third line, as only two wires in the harness are necessary for operation.

Figure 4 illustrates two-state (digital) output levels of an example two-wire IC. Valid output levels are $I_{CC(LOW)}$ and $I_{CC(HIGH)}$; any other current level indicates a fault. As such, two-wire interfaces have inherent diagnostic ability. Note the fault conditions shown in Figure 4 are not actively determined by the IC but would occur due to errors in the circuit.

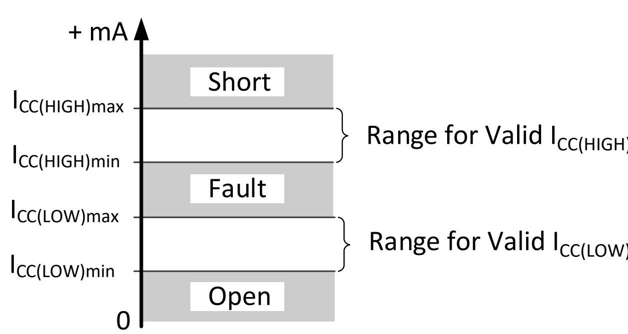

Figure 4: Two wire digital levels

Two-Wire Interface Circuits

Electrical interface for a two-wire IC is slightly more complicated than for a three-wire, the latter being directly compatible with many logic systems. One common interface for a two-wire IC is to use an inline sense resistor, as shown in Figure 5. The voltage across the sense resistor is routed to a comparator to create a digital output voltage.

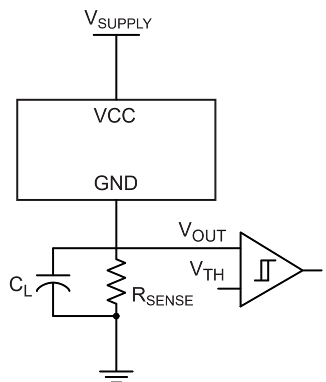

Figure 5: Two-wire interface circuit

The nominal comparator reference voltage (trip point) can be calculated as:

$$V_{TH} = R_{SENSE} \times [(I_{CC(HIGH)(min)} + I_{CC(LOW)(max)}) / 2]$$
$$V_{TH} = R_{SENSE} \times [(I_{CC(HIGH)} + I_{CC(LOW)}) / 2]$$

Additional comparators can be implemented to detect fault conditions shown in Figure 4. Alternately, the V_{OUT} signal can be used with an analog-to-digital converter to detect desired signals and fault conditions.

The sense resistor (R_{SENSE}) location in Figure 5 is referred to as 'low-side.' This arrangement has the benefit that V_{TH} is referenced to system ground. Figure 6 shows the sense resistor in both a low-side and high-side location. The signal amplitude on the resistor is the same, but absolute $V_{OUT(H)}$ is dependent on V_{SUPPLY}. Figure 6 shows that the relative polarity of the voltage signal changes between high-side and low-side sensing.

In a low-side configuration, note that IC GND is not the same as system ground. To reduce potential confusion, sometimes the GND connection from the IC is referred to as the RETURN line.

A sense resistor is not required for IC operation. As such, the user could implement other methods of sensing the output current. For example, the Allegro A6850 interface IC uses a current mirror.

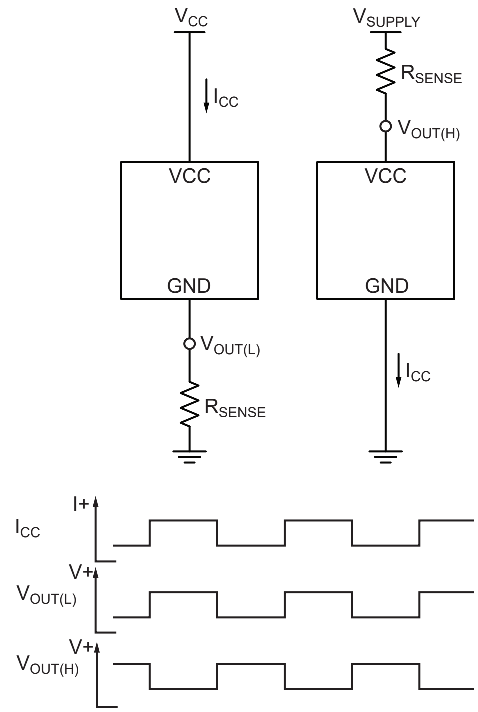

Figure 6: High and low side sensing

Two-Wire Supply Voltage

It is critical for supply voltage to be compatible with the selected sense resistor value. A datasheet $V_{CC(min)}$ does not account for I-R drop on the sense resistor. Accounting for voltage across R_{SENSE}:

$$V_{SUPPLY} \geq V_{CC(min)} + I_{CC(HIGH)(max)} \times R_{SENSE}$$

A very common mistake is to use a V_{SUPPLY} = 5 V with a 100 Ω resistor on an IC with 4 V minimum operating voltage. Applying the equation above, one quickly sees that with a 16 mA current, the voltage across the IC pins would only be 3.4 V.

Rise and Fall Times

In a three-wire IC, the output is actively driven to the low state. Thus, the fall time and low voltage level are dominated by IC function. The rise time and high voltage value are controlled entirely by the passive components in the circuit.

In a two-wire IC, output rise and fall times are governed by the IC's current drive and the interfacing load circuit. The value of capacitor C_L (in Figure 5) and one connected between VCC and GND (not shown) have a direct impact on the rise and fall time measured on R_{SENSE}.

A change in the output rise and fall times are a consideration if additional passives are paired with an IC to improve electromagnetic immunity. For example, with a three-wire IC, a capacitor can be added to the supply line without changing output. This is not true for a two-wire IC.

Multi-Level Outputs

Examples up to this point consider ICs with two-level outputs, but it is possible for both two-wire and three-wire ICs to have additional output states. For example, some two-wire ICs use an output protocol with three operating I_{CC} states: low, middle, and high. Or an additional diagnostic state of I_{FAULT} may be used to indicate the IC failed a self-diagnostic.

Similarly, a three-wire output can be configured to operate in two normal states and have two additional states that convey open or short electrical conditions and/or failure of a self diagnostic.

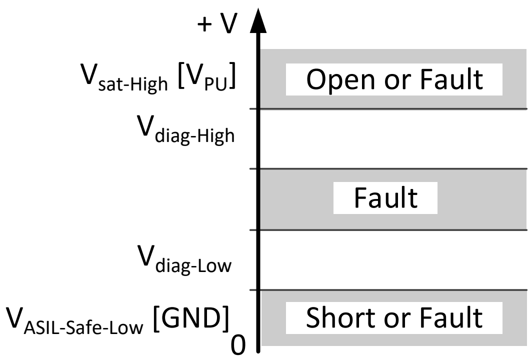

Figure 7: Three-wire output states including diagnostic

Additional Thoughts

It is possible to convert a three-wire device into a two-wire sensor, as is shown in Figure 8, with proper selection of R_{PULLUP} and supply voltage. The user must make close note of I_{CC} specifications, particularly across temperatures, as a three-wire IC generally has looser design requirements. Two-wire ICs are carefully designed to attain constant I_{CC} values across temperature and voltage and are thus far preferable for a two-wire sensor.

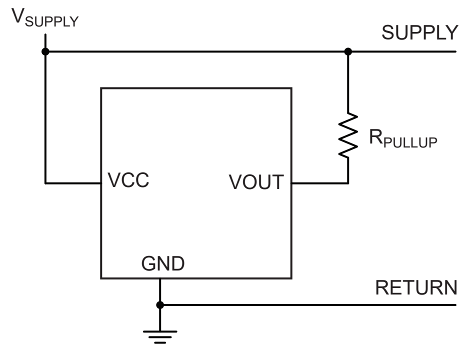

Figure 8: Conversion of three-wire to two-wire

Multiple two-wire ICs may also be operated from a single supply line, as shown in Figure 9. This can further reduce wiring needs if the ICs are located in close proximity. The designer should consider system failure modes, as breakage of this supply wire would then disable two sensor ICs.

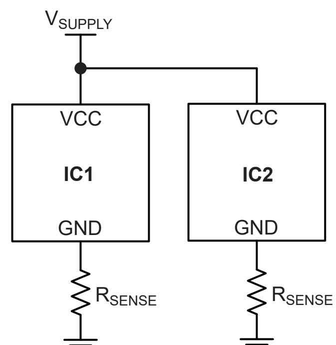

Figure 9: Two two-wire ICs on shared supply

Revision History

Number	Date	Description	Responsibility
–	June 8, 2021	Initial release	E. Burdette

955 PERIMETER ROAD • MANCHESTER, NH 03103 • USA
+1-603-626-2300 • FAX: +1-603-641-5336 • ALLEGROMICRO.COM