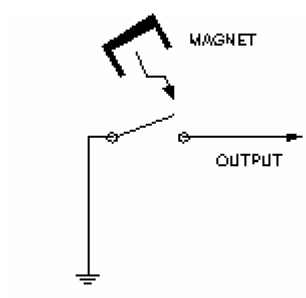
PHOENIX AMERICA INC.
4717 CLUBVIEW DRIVE
FORT WAYNE, IN 46804

Phoenix America Application Note 07-001

INTERFACING WITH PHOENIX AMERICA NPN OPEN COLLECTOR SENSORS

The majority of Phoenix America's sensors are constructed with an NPN open collector (or N Channel open drain) output stage. This configuration is versatile and allows for easy connection to a wide variety circuit configurations. The two main constraints to be kept in mind when implementing a connection with an open collector output are output voltage and output current. Fortunately, these limitations are easy to understand and are described herein..

Conceptually, the NPN output stage can be thought of as a switch, with one terminal of the switch connected to ground (see Fig.1). The activation of this switch is controlled by a magnetically sensitive element front end stage (and it's associated circuitry). Under the control of the front end stage, the output stage will turn off and on according to the applied magnetic field. When the output device is ON, current flows between the GROUND lead and the OUTPUT lead. When the device is OFF, no current flows, except for a tiny leakage current, between GROUND and OUTPUT.



Typically, there are three leads coming out of the sensor, the GROUND, the OUTPUT and the SUPPLY lead. The SUPPLY lead furnishes the operating power to the front end stage. The SUPPLY lead is connected to a source of DC power as shown in Figure 2. Note that the GROUND lead is common to both the input and output of the sensor and it's associated circuitry. The voltage on the SUPPLY lead must be of the correct polarity, that is, POSITIVE, with respect to GROUND and must be above the minimum required operating voltage and below the absolute maximum voltage. These limits can be found on the data sheet for the particular sensor.

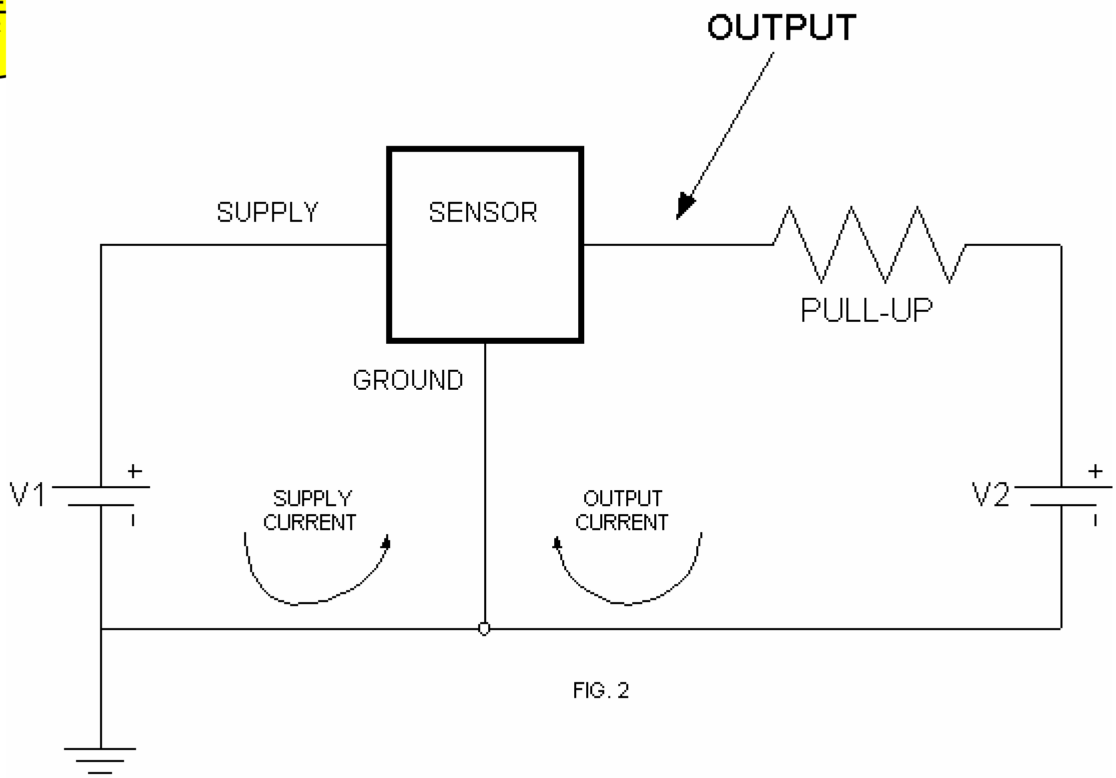


FIG. 2

The OUTPUT lead requires a voltage source of it's own to establish the voltage that will appear on the OUTPUT lead when the output stage is OFF. A resistor, the PULL-UP RESISTOR provides the connection between the OUTPUT lead and the output supply and establishes the OUTPUT CURRENT level when the OUTPUT stage is on. The limitations on the OUTPUT voltage are that it must be of the proper polarity, i.e. it must be positive with respect to GROUND and it must be less than the absolute maximum allowable output voltage. The OUTPUT CURRENT must be less than the absolute maximum allowable current. Again, refer to the sensor data sheet for these values. While it is technically possible to operate the sensor at the absolute maximum limit values, Phoenix America does NOT recommend such operation. Note that the PULL-UP resistor also limits the current which flows to an external device which may be connected to the sensor output when the sensor output is in the OFF state. If an external device which can supply current to the output is connected to the sensor output in addition to the pull-up resistor, this additional current must be accounted for and the value of the pull-up resistor increased accordingly.

One of the advantages of an open collector output structure is that it allows the sensor and the output stage to operate at different voltages (see Fig. 3). That is, the operating supply for the sensor and the output stage may or may not be the same supply, as required by the application. In either case, however, the limitations on voltage and current still apply. The calculations necessary are shown in the figures referenced above. The resultant numbers may have to be modified in accordance with the requirements of the circuit to which the sensor is connected, but the absolute maximum limits are still the governing limits.

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The calculations are given by Ohm's Law. For the pull-up resistor, the minimum allowable value is calculated so that the output current does not exceed the value given on the sensor data sheet. Keep in mind that the minimum resistance yields the maximum current, and that within practical limits, it is best to keep the output current at the lowest value consistent with the requirements of the application.
The minimum value for the pull-up is: $Rmin \geq V2/Imax$

For example, assuming a value of 24 volts for V2 and an absolute maximum value of 20 milliamperes (obtained from the sensor data sheet), the from the above equation, the lowest value for the resistor would be 1.2K Ohms. In actual practice, a value higher than this is desirable, consistent with the requirements of the application.

In theory, the upper limit for the value of the pull-up resistor can be very high, in practical terms, there is an upper limit, although this is generally of little concern in most applications and can be ignored. In the OFF state, the OUTPUT SUPPLY (V2) voltage, the pull-up resistor and the OFF STATE LEAKAGE CURRENT will determine the voltage of the sensor output in the OFF state.

For the sake of illustration, assuming an output supply voltage V2 of 9 volts, the minimum value for the pull-up resistor as given by the above equation is 450 Ohms. This is not a standard value for 5% tolerance resistors, so the next higher standard value of 470 Ohms is the minimum allowable value for the pull up resistor. Further assuming that the sensor is connected to an external circuit that must see a minimum voltage of 6 volts to recognize an output high state. This gives a maximum allowable drop in the OFF state of 3 volts (V2 = 9 V – 6V = 3V). Taking the OUTPUT LEAKAGE CURRENT from the sensor data sheet (for this example, 10 microamperes), Ohm's law is used to calculate the maximum value for the pull-up resistor as 300 K Ohms. Thus, the PULL-UP can range between 470 Ohms and 300 K Ohms. In practice, a resistor giving an output current of 5 to 10 milliamperes would be a good practical choice.

In applications with only one supply voltage source, i.e. the output supply and the sensor supply are the same, the equations still apply as given above. The value of supply V1 is substituted for the value of V2 and the supply side of the pull-up is connected to V1 as shown on the sensor data sheet.

Should further assistance be required, please contact PAI engineering by email, telephone or facsimile. To enable PAI to assist you as quickly as possible, please have the pertinent information (voltages, information on the equipment, module or device to which you are attempting to connect the sensor, schematics, etc.) at hand.

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