Duty Cycling and Multiplexing Magnetic Field Sensors

NVE magnetic field sensors are uniquely suited to duty cycling and multiplexing. Multiplexing sensors reduces I/O and power requirements.

Magnetic Field Switches

Unlike most magnetic switches, NVE AD-Series sensors can easily be multiplexed because the unique bipolar outputs are inactive when the devices are unpowered. Most magnetic switch outputs short to ground when they are unpowered, making them unsuitable for multiplexing. Open-collector outputs allow AD-Series sensors to be wire-ORed together. The sensors' high speed and non-duty-cycled operation allows fast polling rates.

Additionally, unlike other types of sensors, the switching hysteresis is provided by the GMR magnetic sensor element, not a comparator, so the proper hysteresis state is retained when the part is duty-cycled.

Figure 1 shows an eight-by-eight multiplexed sensor array for a chessboard with no additional components:

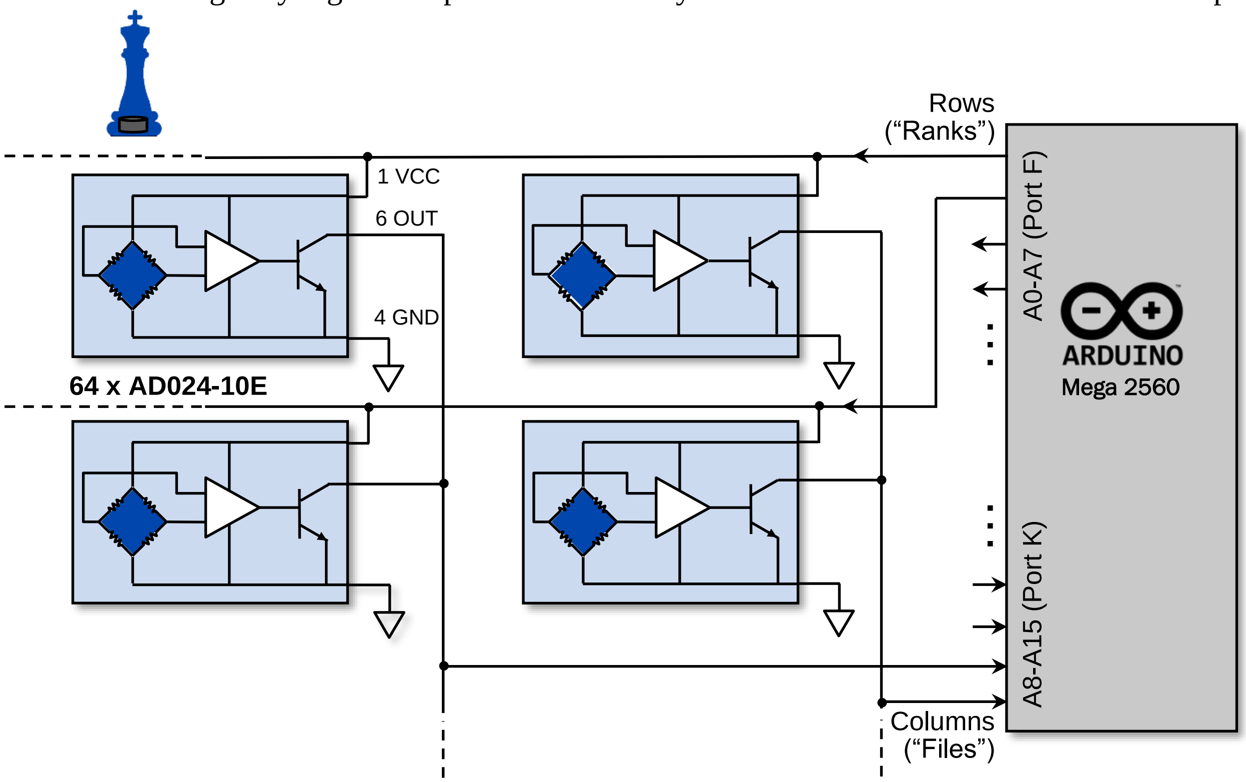

Figure 1. Eight-by-eight magnetic switch array. AD024-10E open collector outputs are connected together in each column (wire-OR style).

In this example, Port F of an Arduino Mega 2560 powers one row of sensors at a time, and the sensor columns are read on Port K. It's possible to multiplex 64 individual AD024-10E sensors into only eight input pins because the AD024-10E outputs are inactive when the VCC isn't powered; only the AD024-10E sensor *in a powered row can sink current*, so the other AD024-10E sensors don't interfere with each other in the *wire-OR configuration*.

Although the AD024-10E sensors are not especially low power compared to other NVE sensors, the supply current is low enough that most typical microprocessor outputs can power eight sensors.

Multiplexing reduces the I/O pins required from 64 to 16 and reduces the power consumption by a factor of eight. A program to poll and read the sensors is as follows:

```
//A Mega 2560 reads an 8x8 array of AD024 magnetic switches for a chessboard.
byte fileMask[9], rank;
void setup() {
DDRK = 0; //Set Port K as inputs for sensors
PORTK = 0xFF; } //Enable Port K input pullups
void loop() {
for(rank=1; rank < 9; rank++) { //Scan through sensor ranks (rows)
DDRF = 1<<(rank-1); //Turn on selected sensor row via Port F
PORTF = 1<<(rank-1);
delayMicroseconds(100); //Allow sensors to stabilize before reading outputs
fileMask[rank] = ~PINK; //Read sensor files (columns)
```

The program scans eight rows of sensors ("ranks" in chess parlance) and reads eight columns ("files") as a byte of data. The sensors' open-collector outputs are LOW when actuated, represented by a "0" bit.

As shown in Figure 2, there is a protection diode from the output to VCC, so that if VCC is grounded the sensor output will be low (approximately 0.6 volts), and the pullup resistor will draw current:

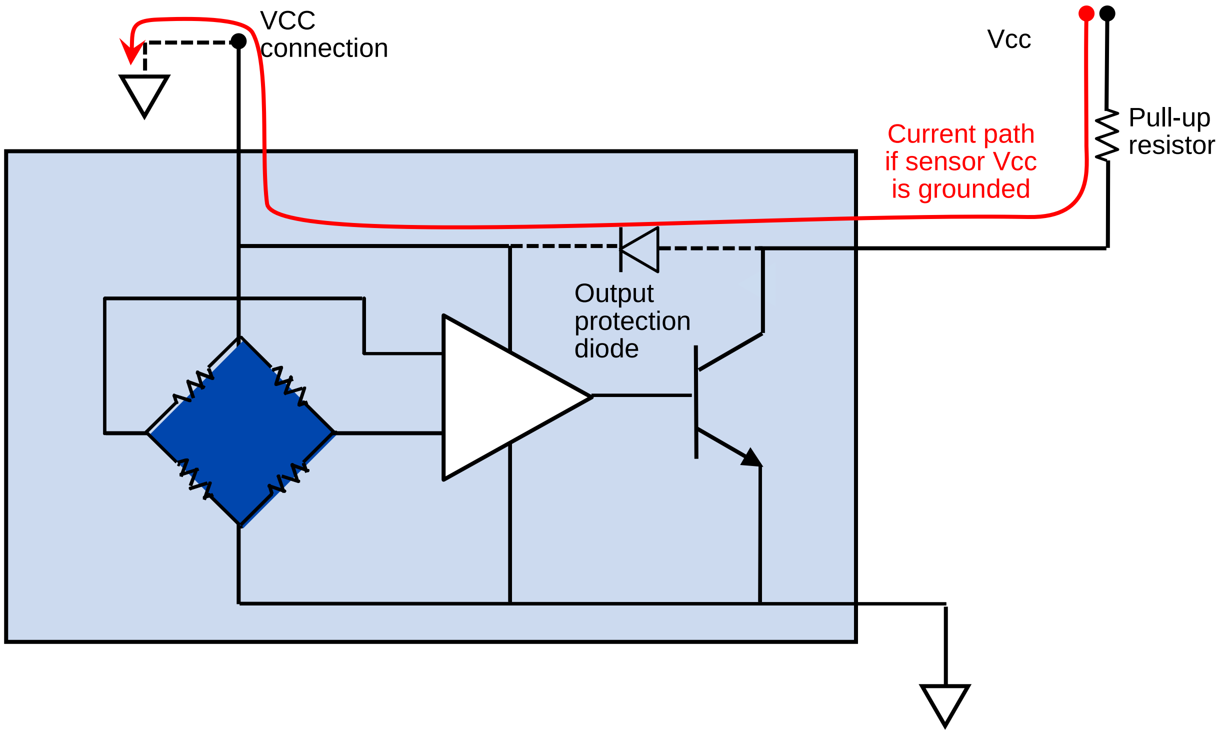

Figure 2. AD-Series / ADL9-Series sensor equivalent circuit.
VCC should not be grounded when a pull-up resistor is wired into the circuit.

Therefore, it is more efficient to tri-state VCC to deactivate the part, rather than simply grounding VCC.
Click Here to to watch: Chessboard Demonstration MUX 64 GMR Sensors With Only 16 I/O Pins

A variety of AD-Series sensors suitable for multiplexing applications are available, as summarized in the following table:

Available Part Number	Operate Point (typ.)	Release Point (typ.)	Magnetic Orientation	Supply Voltage	Package
AD004-00E	2 mT	1 mT	Standard	4.5 to 30 V	MSOP8
AD005-00E	4 mT	2.5 mT			
AD006-00E	8 mT	5 mT			
AD021-00E	2 mT	1 mT	Cross-axis		
AD022-00E	4 mT	2.5 mT			
AD024-00E	2.8 mT	1.4 mT			
AD024-10E	2.8 mT	1.4 mT			DFN6
AD023-00E	8 mT	5 mT			MSOP8
AD084-00E	2.8 mT	1.4 mT		3 to 6 V	

Duty Cycling CMOS Magnetic Switches
CMOS magnetic switches sensors generally can not be multiplexed in the same way as bipolar logic switches shown in the previous section; CMOS outputs short to ground when they are unpowered. They can be *duty-cycled*, however, to reduce average power requirements. NVE offers internally duty cycled magnetic switches for both lithium- and single-cell battery operation.

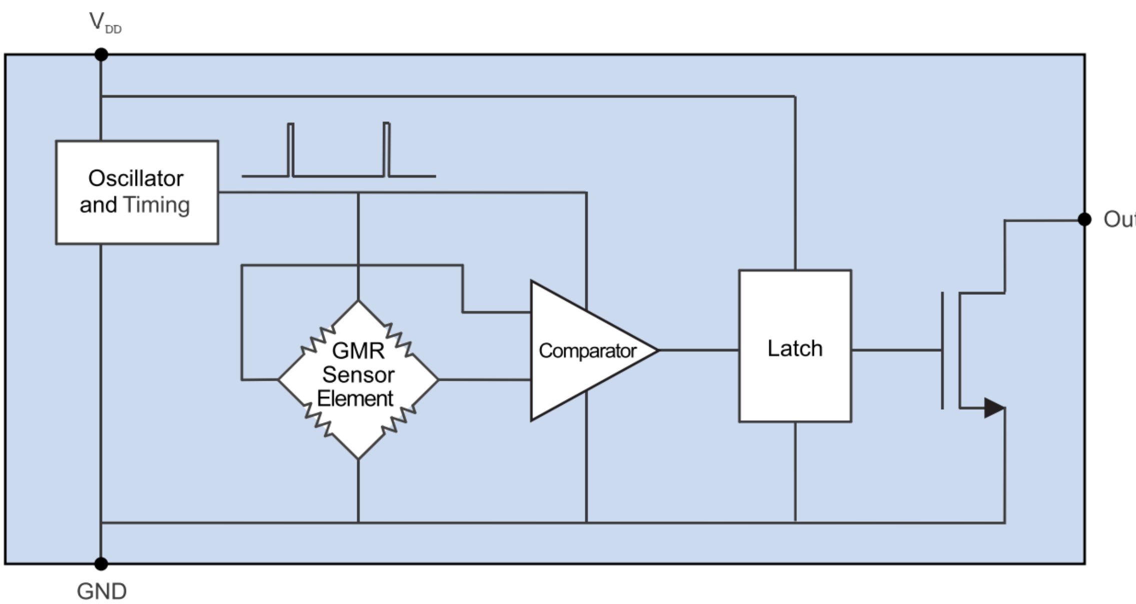

Figure 3. NVE's Nanopower GMR Switch Block Diagram

The power requirements for NVE's nanopower GMR Switch products are summarized below:

Product family	Supply Voltage	Internal Duty-Cycle Frequency	ON State Current	RMS Current Draw
AHL02x	0.9 – 2.4 V	40 Hz	15 µA	**32 nA**
ADL02x	2.4 – 4.2 V	55 Hz	35 µA	**50 nA**
ADL12x	2.4 – 4.2 V	30 Hz	35 µA	**35 nA**

Table 1. NVE's Nanopower GMR Switches

NVE also offers *high-speed* GMR and TMR switch sensors operating at *continuous duty*. Unlike slow, power-hungry hall switches, NVE's magnetic field switches are manufactured with state-of-the-art, high-resistance GMR and TMR for ultralow power without duty cycling. This enables NVE's sensors to switch at frequencies up to 100 kHz.

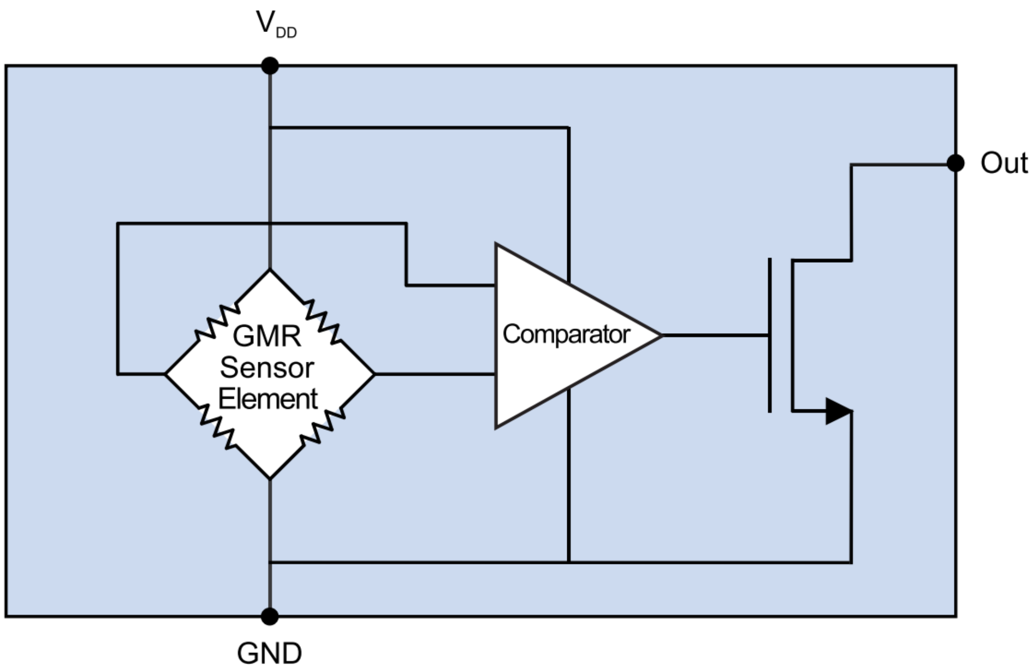

Figure 3. NVE's Continuous-Duty GMR Switch Block Diagram

Because of their short power-on settling time, these sensors can also be duty cycled externally by microcontroller pins or logic gates. This enables end-users to optimize power budgets on their own schedule:

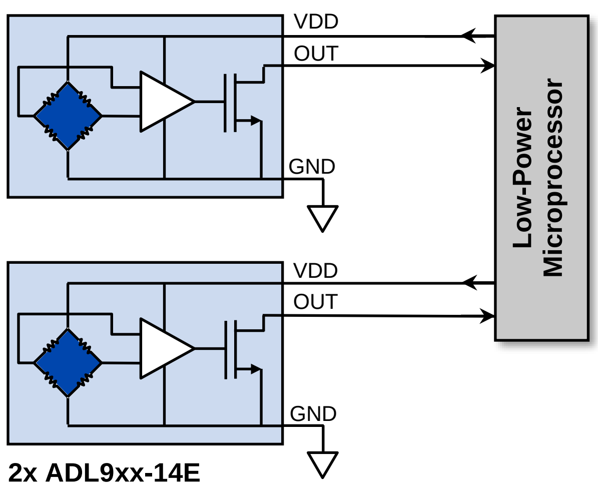

Figure 4. Duty-cycling ADL9- and ADT9-Series CMOS magnetic switches.

After applying power to the sensor, the microcontroller should allow for the sensor's maximum *power-on settling time* before sampling the sensor's output. The power-on settling time is the time required for the sensor's output state to be accurate, and it is caused by the large resistance of the sensor element bridge. Continuous-duty sensors do not have an internal latch circuit, so the microcontroller must read the sensor output when power is applied. The sampling time should also allow the pull-up resistors to charge the microprocessor's input capacitance and stray capacitance when the sensor output is high. We summarize power budgets and recommended duty-cycle ON times in Table 2 below.

Product family	Continuous-duty maximum switching speed	Continuous-duty current draw	Power-on settling time	Typical current draw at 10 Hz duty-cycle
AHT92x	3 kHz	0.35 µA	200 µs	**2.7 nA$_{RMS}$**
ADT92x	20 kHz	1 µA	4 µs	**2 nA$_{RMS}$**
AHL92x	100 kHz	15 µA	< 1 µs	**8 nA$_{RMS}$**
ADL92x	100 kHz	35 µA	< 1 µs	**10 nA$_{RMS}$**

Table 2. Externally Duty-Cycling NVE's Continuous-Duty Switches

NVE's CMOS switch sensors have an internal protection diode from the output to VDD, so VDD should not be grounded while a pullup resistor is connected, as is the case with external pullup resistors. Instead, VDD should be tri-stated to cycle the power.

However, if a microcontroller's internal pullup resistor is used, it can be disabled before driving VDD LOW. This is another power-efficient method for duty-cycling NVE sensors.

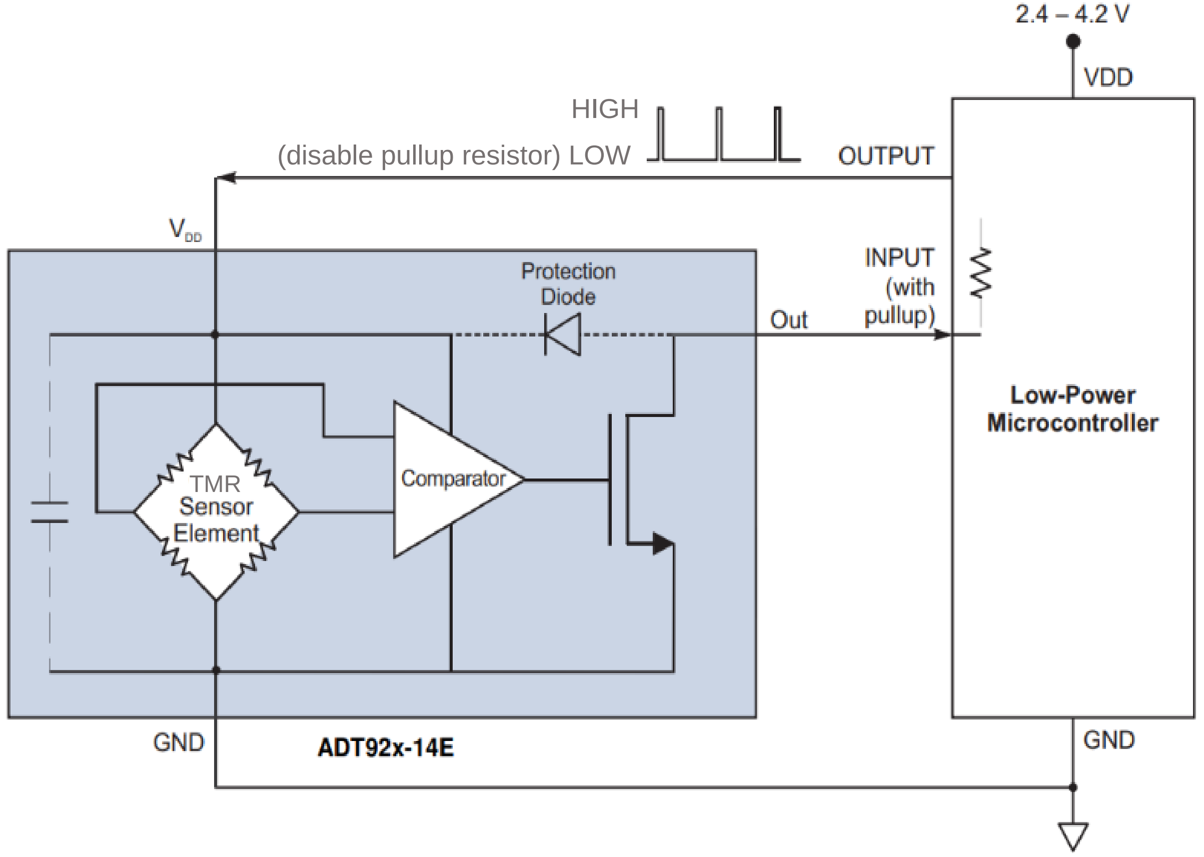

Figure 5: Example circuit for duty-cycling ADT92x-Series sensors.
The INPUT pullup resistor should be disabled when V_{dd} is driven LOW.

Multiplexing Analog Magnetic Sensors
Wheatstone bridge sensor outputs can be switched with an inexpensive analog switch such as an 74HC4051 to reduce ADC or microprocessor input requirements. Power can be duty-cycled to reduce average power requirements:

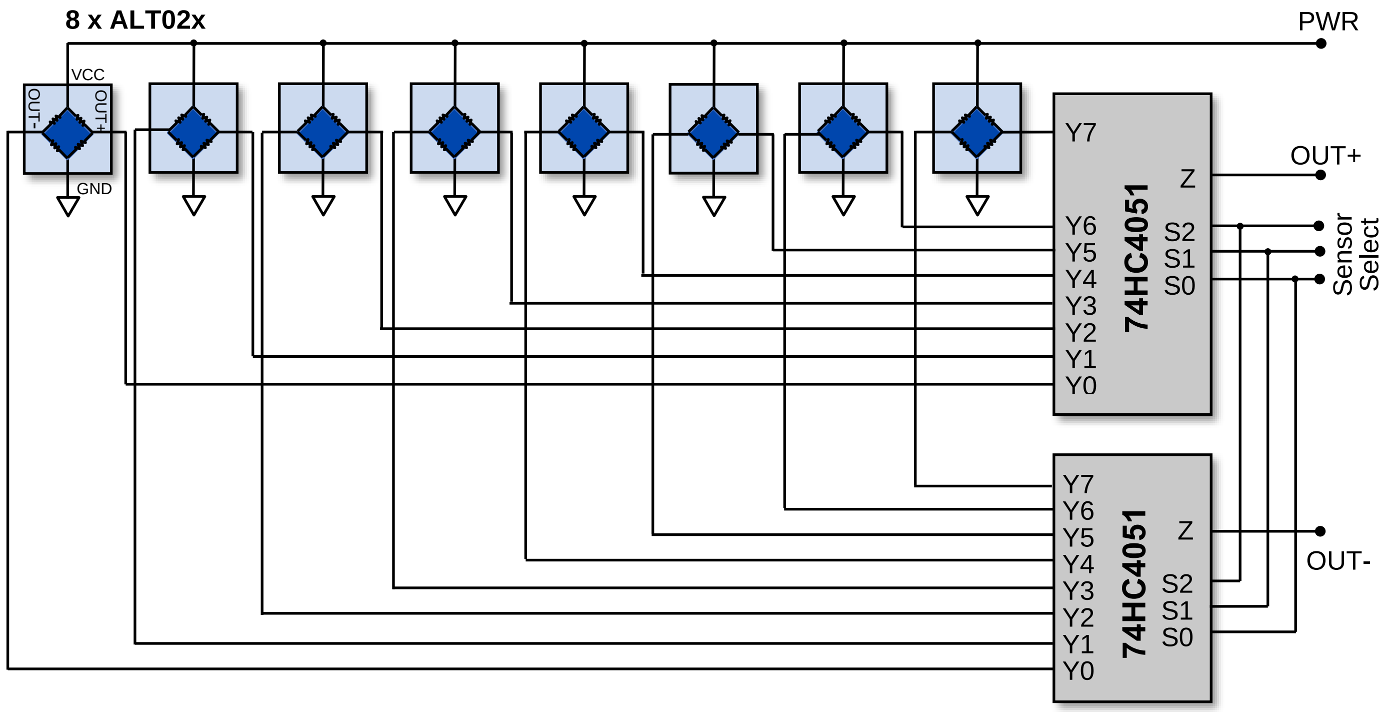

Figure 6. Multiplexed ALT-Series analog TMR magnetic sensors.

This configuration requires only three microprocessor outputs to select the sensor and two microprocessor analog inputs to read the sensors.

ALT-Series TMR sensors have a typical bridge resistance of 20 kΩ, so each output has an output resistance of 10 kΩ. The sensor output capacitance is negligible, so sampling speed is limited by the input capacitance of the amplifier or the sample-and-hold capacitor of the ADC. Assuming a sample-and-hold capacitance of 14 pF, a 1 µs sampling time is adequate.

For even higher speed, AA-Series GMR sensors such as the AAH002-02 and AAH004-00 have output resistances of just 1 kΩ.

Contact
We will respond to your questions within 24 hours by email. No matter where you are in the world, we have representatives to support you, and we look forward to helping with your next great design.

- nve.com
- sensor-apps@nve.com
- https://www.youtube.com/@NveCorporation
- +1 952 829 9217