

## The Incredible Shrinking Encoder

### Introduction

Encoders are integral parts of motor control systems that sense mechanical motion, then generate digital signals in response to that motion. Whether the system is an automated pick and place (x-y positioning), an automobile (assisted lane detection), or a robotic arm, the position feedback information is an integral part of the motor-control system (Figure 1).

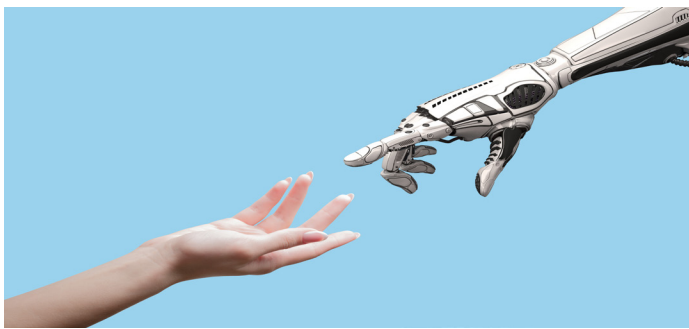


Figure 1. Human vs. Robotic Arm, Where Encoders Abound

The trend today is to create smaller mechanical and electronic devices. The motor as well as its encoder is part of this trend in applications such as robotics, drones, medical equipment, and hand-held devices. The major challenge that designers face is trying to fit the necessary number of devices into the encoder's shrinking allotted space. This design solution reviews the typical approach to motor encoder system design and proposes a solution that reduces the encoder's electronics real estate.

### Encoder Applications

Encoders provide incremental or absolute positions in motion applications. The system translates motion such as speed, direction, and shaft angle into electrical signals. When an application needs a relative motor position, an incremental encoder is useful. One uses these types of encoders with AC induction motors. In contrast, pairing the absolute encoder with permanent-magnet brushless motors assists in servo applications. The encoder feedback ensures synchronization of the motor stator by providing rotor direction, speed, and position.

Embedded in an encoder is a motor position-sensing device and several analog-to-digital converters (ADCs). These circuits provide motor direction, speed, and position information to the system microcontroller or processor (Figure 2).

In Figure 2, the optical wheel connects to a motor stator. The system's microcontroller controls the speed of the stator and thereby the speed of the rotation of the motor and optical wheel.

The illumination from the LED is constant as the optical wheel turns. The LED light shines through each wheel window, one at a time. As the LED light shines through a window, the photodiode at the input of the transimpedance amplifier (TIA) converts the impinging light into a current ( $I_{PD}$ ). The  $I_{PD}$  current flows through the feedback resistor,  $R_F$ , to create a voltage greater than  $V_{REF}$  at the output of the TIA.

The signal travels through a gain block and then the ADC-driving amplifier, the [MAX44242](#). The MAX44242 is a 180MHz, low-noise fully differential successive-approximation-register (SAR) ADC driver. Next to it is the [MAX11192](#) ADC, which continually samples the output of the MAX44242 to construct a square wave over time.

The appropriate ADC encoder topology includes a dual, simultaneous SAR ADC, which is available with a 12-, 14-, or 16-bit resolution. The higher resolution ADCs provide extra sensitivity and positioning accuracy.

For the encoder, a dual, simultaneous sampling SAR ADC takes consistent snapshots, providing an instantaneous picture of the encoder's motor direction, speed, and position. The MAX11192 is a 12-bit, 2Msps, dual simultaneous sampling SAR ADC with internal reference.

### Encoding Action

The diagram in Figure 2 illustrates one channel of an optical encoder. Encoders have at least two identical signal channels, each focusing on different windows. Figure 3 shows an example of the output of a two-channel encoder.

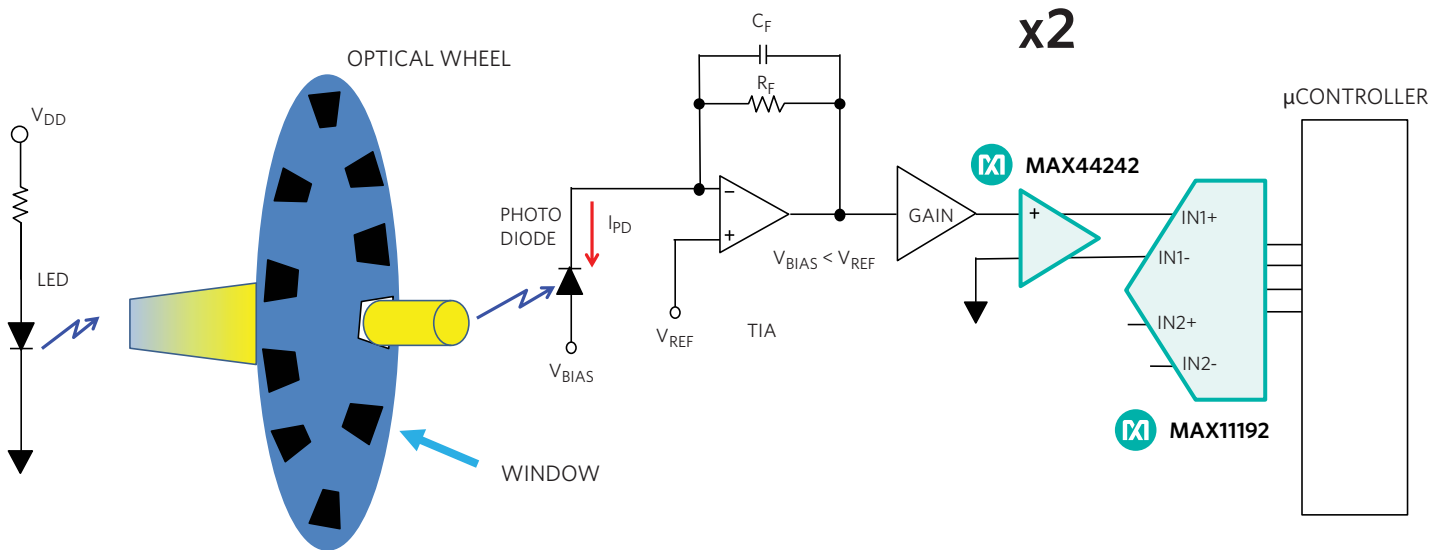


Figure 2. Basic Sensing Circuit for an Optical Encoder

Encoders produce pulses, which indicate movement over short distances. There are two counting methods applied to the encoder's output.

- A count of pulses indicates movement and speed over time.
- The channel order of the  $\text{ØA}$  compared to  $\text{ØB}$  indicates the direction.

Encoders have their electronics inside the housing or donut. Having the PCB inside the encoder minimizes interconnections, but as the encoder cubic area lessens, the PCB square area also reduces in size. The design challenge becomes the process of populating the smaller PCB with smaller devices.

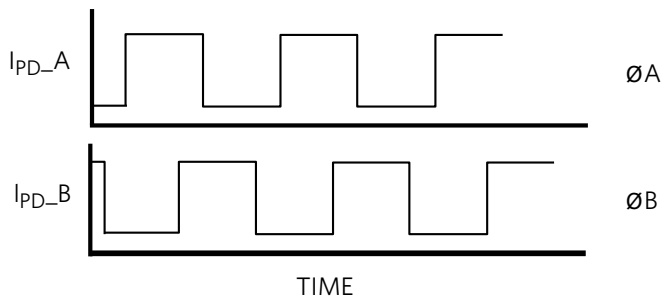


Figure 3. The Encoder Continues to Shrink in Size

### The Shrinking Encoder

With the space inside optical encoders continuing to tighten, it's become even more critical to verify device layout in the development phase. Small motor encoders can have a diameter as small as 25mm with a shaft diameter of 4mm.

The components depicted in Figure 2, plus various capacitors, must all fit on the PCB of an encoder (Figure 4). The MAX11192 family of 12-, 14- and 16-bit converters help meet tight space restrictions with a TFDN plastic package option, which is the smallest in the industry with 3mm x 2mm dimensions and a 0.75mm clearance.

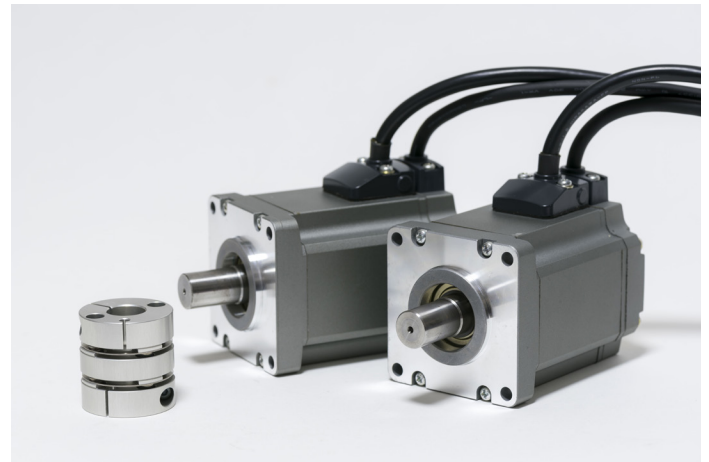


Figure 4. The Encoder Continues to Shrink in Size

### Other Uses for This ADC Family

Other appropriate applications for the MAX11192/MAX11195/MAX11198 ADCs are for resolvers and linear variable differential transformers (LVDTs), specifically for position sensing. The MAX1119x devices also have a good affinity for the resolver SIN+COS analog interface, nonisolated current sense in servo drives, fish finders or ultrasound doppler devices.

## Conclusion

The world's electronics are becoming smaller and smaller. The housing of these electronics is within smaller and smaller dimensions. With the shrinking donut shape and internal PCB size of motor encoders, the ultra-small MAX11192/MAX11195/MAX11198 SAR ADC family allows technology to get a good hold of the future.

## Glossary

**Encoder:** A device that senses mechanical motion. It translates motion such as speed, direction, and shaft angle into electrical signals.

**Stator:** The stationary portion of an AC motor

**Shaft:** A mechanical component for transmitting torque and rotation

**TIA:** Transimpedance amplifier

**LED:** Light-emitting diode

**SAR ADC:** Successive-approximation-register analog-to-digital converter

## Learn more:

[MAX11192 12-bit, 2Msps, Dual Simultaneous Sampling SAR ADC with Internal Reference](#)

[MAX11195 14-Bit, 2Msps, Dual Simultaneous Sampling SAR ADC with Internal Reference](#)

[MAX11198 16-Bit, 2Msps, Dual Simultaneous Sampling SAR ADC with Internal Reference](#)

[MAX44242 180MHz, Low-Noise Fully Differential SAR ADC Driver](#)

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