Improving Response Time and Accuracy in Autonomous Robots With Wideband SAR-ADCs

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With a rise in adoption of autonomous robots in industry 4.0 for increasing productivity, improving quality and reducing costs, there has been a need to make robots faster and more accurate. Robots use motors for operation and an optical encoder is used for controlling the position and speed in robots.

An optical encoder is used for measurement of angular position and speed in robots. It consists of an optical disk which has two tracks engraved with sine and cosine patterns. Light is passed through these patterns and then captured by photo-diode. The photo-diode converts the light into current which is used for calculating the angular position and speed. A trans-impedance amplifier and ADC are used to covert the current output from photo-diode into digital values as shown in Figure 1.

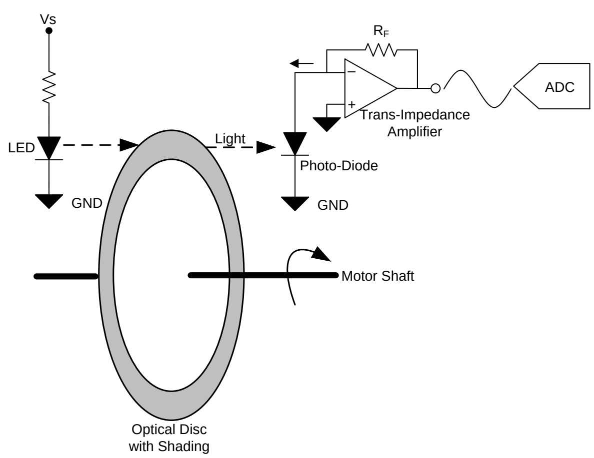

Figure 1. Optical Encoder

The overall position of the disc is a function of sector and fine angular position within the sector. To improve the accuracy of angular position, the optical disk is divided into multiple sectors. Each sector on the disk has one full cycle of sine and cosine. The number of sectors on the disk is known as linecount. Figure 2 shows a sector in an optical disk.

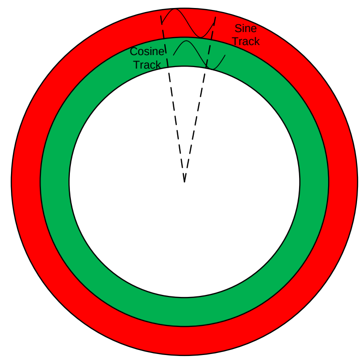

Figure 2. Sector in optical disk

As the linecount and the angular speed of motor increases, the output sine and cosine frequency from photo-diode increase and a fast ADC (> 2-MSPS) with sufficient analog bandwidth (> 500-kHz) is required for digitizing the sine and cosine signals. Equation 1 provides the relationship between signal frequency of sine and cosine outputs with motor speed. The position resolution is a function of linecount of the optical disk and the resolution of the ADC. Equation 2 provides the relationship for position resolution, linecount and resolution of the ADC.

$$\text{Signal Frequency} = \frac{k \times \text{Speed of Motor (RPM)}}{60} \tag{1}$$

$$\text{Position Resolution} = \log_2 k + N + 1$$

where

- k is the linecount
- N is the resolution the ADC (2)

A higher accuracy in position can be achieved with an ADC with higher analog bandwidth and higher resolution. Mismatch in the sampling instant of ADCs and the phase mismatch in the signal path can lead to errors in position measurement. ADS9224R device has two simultaneous-sampling matched ADCs with common start of conversion signal to eliminate the errors introduced by mismatch in the sampling instant.

A digital control loop is implemented to control the speed and position of motors in autonomous robots. The optical encoder provides the angular position and speed to the digital controller which controls the switches for regulating the speed and position. Figure 3 shows the digital control for a motor with optical encoder.

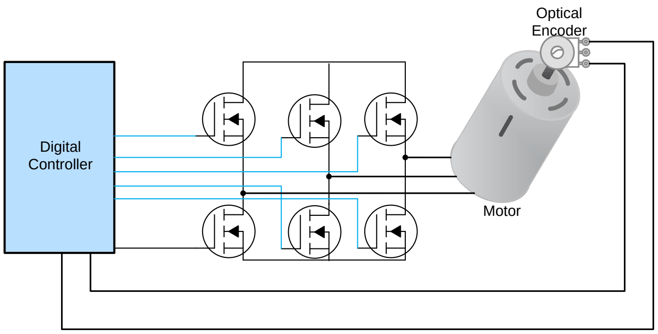

Figure 3. Digital Control loop for motor

The response time of ADC is the sum of time taken to convert the sample into digital value and the time taken by processor to read the data. Any delay caused by ADCs in acquiring the signal and providing the data, leads to degradation of phase margin and a slower transient response. Figure 4 illustrates the response time for ADC.

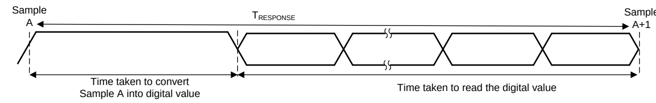

Figure 4. Response time of ADC

With ADS92x4R devices, the response time is drastically reduced. The ADS92x4R family offers a fast data conversion time (300ns) and multiple data transfer protocol for reading the data to reduce the overall response time of the system.

The ADS92x4R also provides the sufficient analog bandwidth (> 500-kHz) to capture sine and cosine signals from optical encoders. Table 1 provides the response time for ADS9224R and similar SAR-ADCs.

With its wider bandwidth, matching between ADCs and reduced read time, ADS9224R can reduce the errors in position and speed measurement in optical encoders and enhance response time in digital control of autonomous robots.

Table 1. Response time of SAR-ADCs

Device	Resolution (Bits)	Channel Configuration	Data Transfer Protocol	Conversion Time (=A) (ns)	Read Time (=B) (ns)	Response Time (=A+B) (ns)
ADS9224R	**16**	**Dual Simultaneous**	**Legacy SPI**	**300**	**277**	**577**
ADS9234R	**14**			**285**	**244**	**529**
ADS9224R	**16**	**Dual Simultaneous**	**SPI with Quad SDOs and DDR**	**300**	**155**	**455**
ADS9234R	**14**			**285**	**155**	**440**
ADS9224R	**16**	**Dual Simultaneous**	**Parallel Byte**	**300**	**97**	**397**
ADS9234R	**14**			**285**	**97**	**382**
ADS8354	16	Dual Simultaneous	Legacy SPI	700	725	1425
ADS7854	14			500	500	1000
ADS7254	12			500	500	1000
ADS7057	14	Single	Legacy SPI	400	400	800
ADS7047	12			333	333	666

References

1. ADS9224R Datasheet
2. ADS8354 Datasheet
3. ADS7854 Datasheet
4. ADS7254 Datasheet
5. ADS7057 Datasheet
6. ADS7047 Datasheet

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