Special Sensor Report:

US Digital's S2 Series Incremental Rotary Shaft Encoder and Interface

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Description

The US Digital S2 Series rotary shaft encoder is an optical rotary-to-digital converter. The encoder outputs a quadrature TTL level signal indicating the speed and direction of the shaft. The encoders utilize an unbreakable Mylar disk, metal shaft and bushing, LED light source, and monolithic electronics.

The encoder can be used to measure the angular position of the shaft by connecting it to a **US Digital LS7183 or LS7184 Encoder to Counter Interface Chip**. This chip is then used to drive a counter such as **Texas Instrument's SN74HC193 or CD4516B**.

Explanation

Rotary encoders are created in two forms:

1. The absolute encoder where a unique digital word corresponds to each rotational position of the shaft.
2. The incremental encoder, which produces digital pulses as the shaft rotates, allowing measurement of relative position of shaft.

Absolute encoders have the advantage of knowing the position of the shaft at all times. Incremental encoders only know the position of the shaft relative to a starting position or an index position. Incremental encoders have the advantage of a simpler construction and thus a much lower cost. This report focuses on incremental encoders; for more information on absolute encoders, check US Digital's website: http://www.usdigital.com/, or check the references at the end of this paper.

Inside of an incremental rotary encoder is a disk with a pattern around the edges. The patterns are evenly spaced around the disk. These patterns either block light from an LED light source or allow it to pass through to a photodetector.

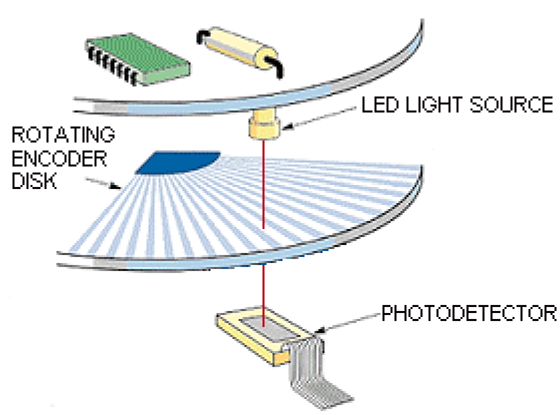

Figure 1

An incremental encoder uses two LEDs and two photodetectors to produce the quadrature output signal. The LEDs are spaced so as to produce signals that are 90 degrees out of phase with each other when the disk spins.

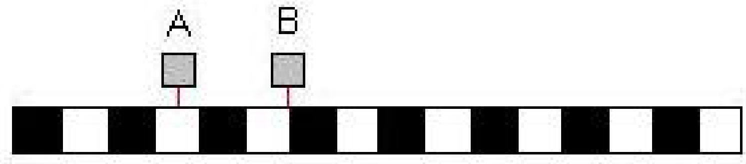

Figure 2

The angular speed of the disk can be measured by the frequency of the signals, the direction of motion can be determined by looking at which signal leads the other.

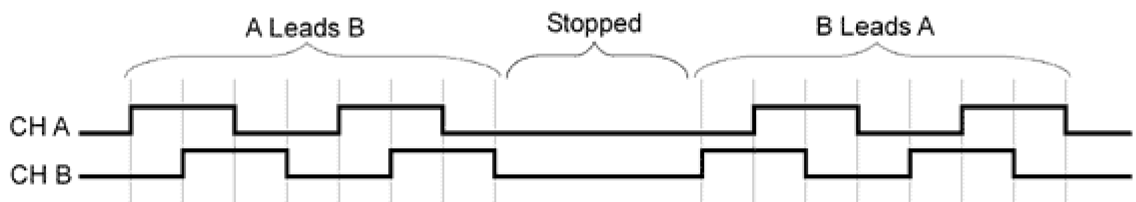

Figure 3

The encoder interface chip uses these signals to produce clock signals for a counter chip. The counter chip must be able to count up and down. Some counters have separate up and down clocks, others use a single clock and a direction input. The chip used in the circuit described below uses the latter. Be sure to get an encoder interface chip that matches your type of counter.

Most counter chips are of the 4 bit variety, but they can be connected together using their 'carry' signals to count using more bits.

Incremental encoders can also have an index channel. This signal corresponds to a single shaft position. It is active whenever the shaft is in that exact position. It can be used as a reference from which positions are obtained. In the circuit below, the index channel is used to reset the counters.

8 Bit Angular Position Circuit

The circuit on the next page was used by my robot to measure the angle of an inverted pendulum. The pendulum was attached to the shaft of the encoder. The pendulum was only allowed to swing on a small arc (about 50 degrees), so only 8 bits were needed for measurement. It uses the **US Digital S2-2048-I-B-M6**. The '2048' means the encoder has 2048 counts per revolution (the highest available). 'I' indicates that the encoder has an index channel. 'B' means the encoder uses ball bearings for low friction. 'M6' indicates a 6mm diameter shaft.

The **LS7184** chip uses a bias resistor to set the width of the clock pulse signal. Some counters require the clock to stay on longer than others. You want to set the clock signal as small as possible, however, to be able to count as fast as possible. On the datasheet for the **CD4516** counter, it states that the minimum clock pulse width is 150 ns when the supply voltage is +5 volts. From the chart on the LS7184 datasheet, this corresponds to a resistor value of 100 kOhms.

Pin 6 on the LS7184 chip is the 'mode' pin. The chip can send out clock pulses at three speeds: 1X 2X and 4X. So 4X would send out four clock pulses for every one in 1X mode. The chip in this circuit is in 1X mode. See the datasheet for more info.

The counter chips can be preset to a certain value, but that is not necessary in this circuit. All preset inputs are grounded and the Preset Enable pin is grounded as well.

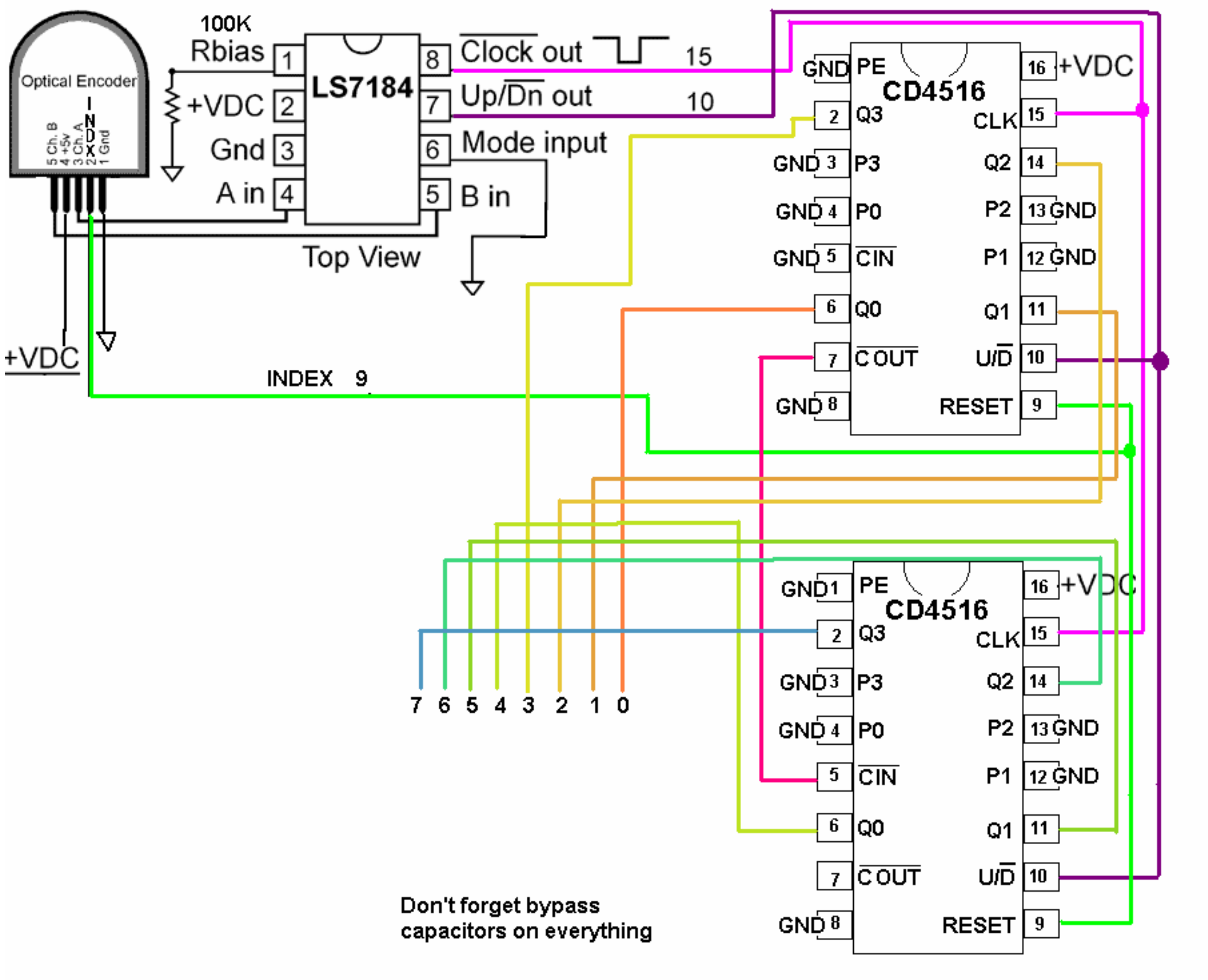

Figure 4

Advice

- Use the index channel. The encoder is pretty reliable, but it can be off sometimes. The index channel can be used to keep things in check. In my robot, I set it up so that the index is active when the pendulum is straight up. That way the index is passed as many times as possible. With this setup, the measured angle is extremely reliable.

- US digital sells another encoder interface chip, the LS7166. This chip connects to the encoder and contains a 24 bit counter. There are obvious advantages to this chip to the circuit presented above, but it requires control from a microprocessor. The 24 bit counter is accessed a few bits at a time. It would probably be good for an application with less space available that requires a high resolution counter.
- Don't forget to put bypass capacitors on all of the chips. There are a lot of pulses being sent, so you want to be sure that the chips all get power.
- Incremental encoders can be very susceptible to electrical noise. Keep the encoder and circuit away from motors and other noise producing devices. Make sure that the ground circuit is clean. Keep the wires between the encoder and the counter short.
- US Digital has a lot of information in its encoder FAQ: http://www.usdigital.com/knowledge/encoderfaq.shtml

Pricing and Availability

The S2 incremental encoder is available from US Digital at a base price of $49. Options add to the price. I used the S2 with 2048 counts per revolution, which raises the price to $58. The ball-bearing option raises the price by $8, and the 6mm shaft option is $5. I chose the 6mm shaft because I had other parts that were 6mm. US digital sells wires to connect to the encoder for $8. A compatible connector could probably be found for less money, but you might as well save yourself some time and buy this one. The total cost for the encoder and wires was $79.

The LS7184 interface chip was also from US Digital. The price for the chip is $3.05. Remember to buy the correct interface chip for your counter (7184 or 7183).

The CD4516 counters are from Texas Instruments. Texas instruments will send free samples to students. Check the website at www.ti.com and look for the 'samples' link.

Sources

US Digital website:
http://www.usdigital.com

US digital S2 encoder information page:
http://www.usdigital.com/products/s1s2/

US Digital encoder interface chip:
http://www.usdigital.com/products/ls7183-ls7184/

Texas Instruments website:
http://www.ti.com

CD4516 counter datasheet:
http://focus.ti.com/docs/prod/folders/print/cd4516b.html

LS7184 counter datasheet:
http://focus.ti.com/docs/prod/folders/print/sn74hc193.html