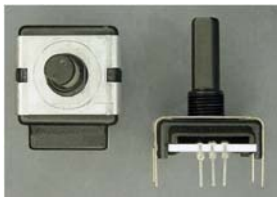
Embedded Systems

Rotary Pulse Generators & Lab 3

F-35 Lightning II Electro-optical Targeting System (EOTS)

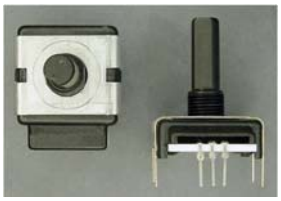
What Is An RPG?

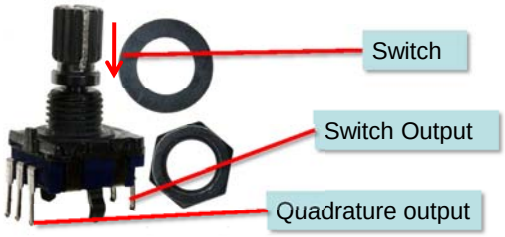
RPG = **R**ocket **P**ropelled **G**renade



RPG = **R**otary **P**ulse **G**enerator

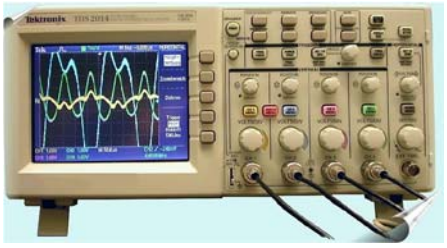
Rotary Encoders



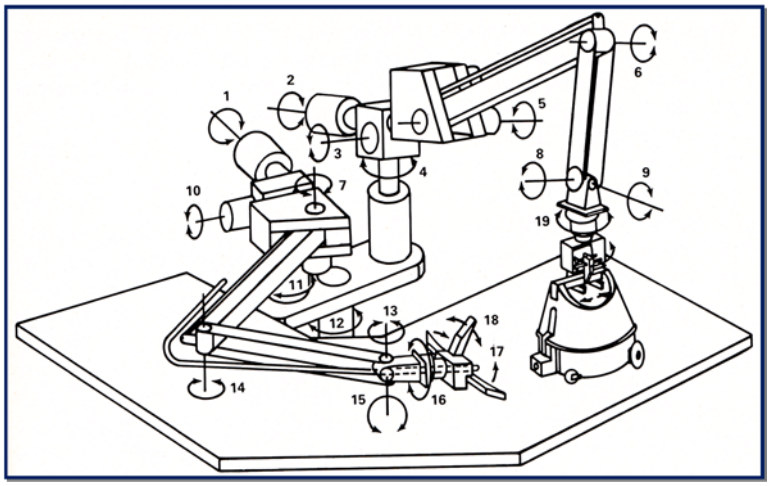


Rotary Encoder Applications

Consumer Electronics User Interfaces



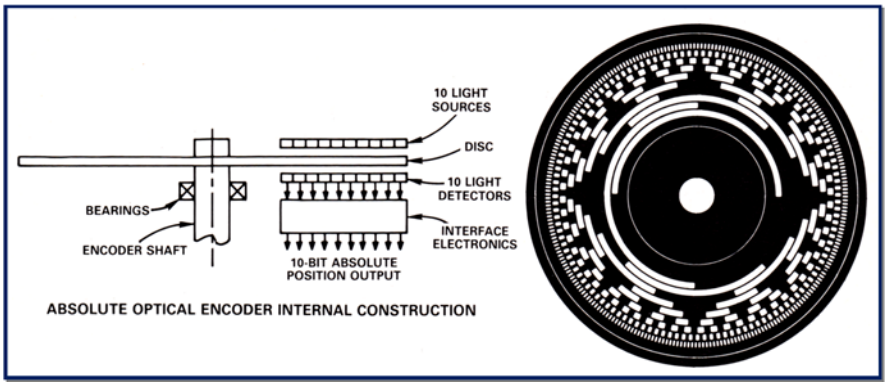
Rotary Encoder Applications



Multi-axis Robot Arms

From *Analog-Digital Conversion Handbook*, Analog Devices, 3rd Edition. Prentice Hall, 1986.

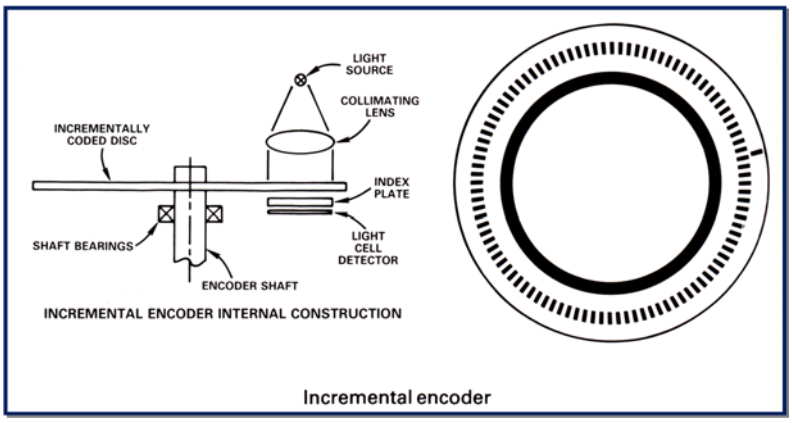
Rotary Encoders



Optical Encoders

From *Analog-Digital Conversion Handbook*, Analog Devices, 3rd Edition. Prentice Hall, 1986.

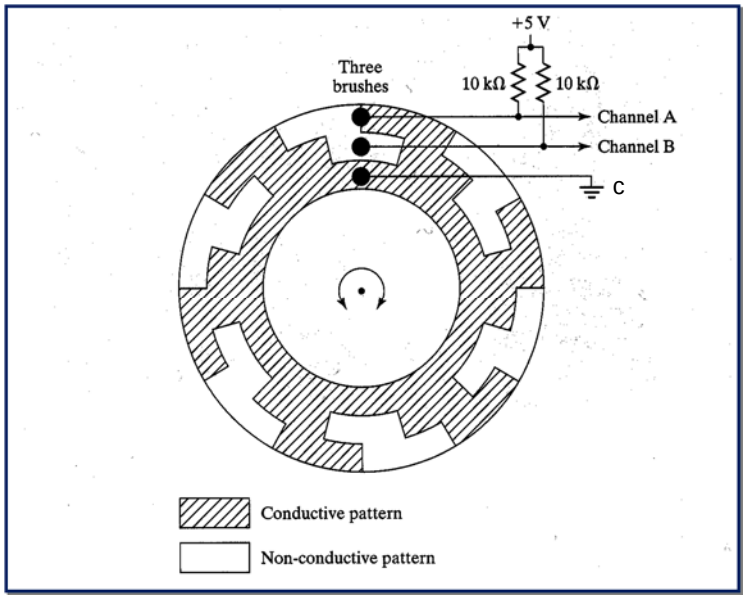
Rotary Encoders



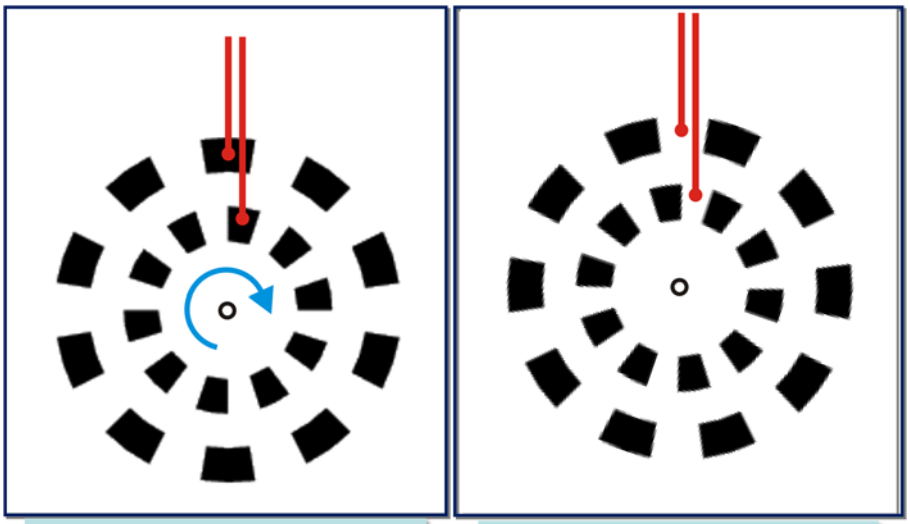
Optical Encoders

From *Analog-Digital Conversion Handbook*, Analog Devices, 3rd Edition. Prentice Hall, 1986.

Simple Rotary Encoder Internals



Simple Rotary Encoder Internals

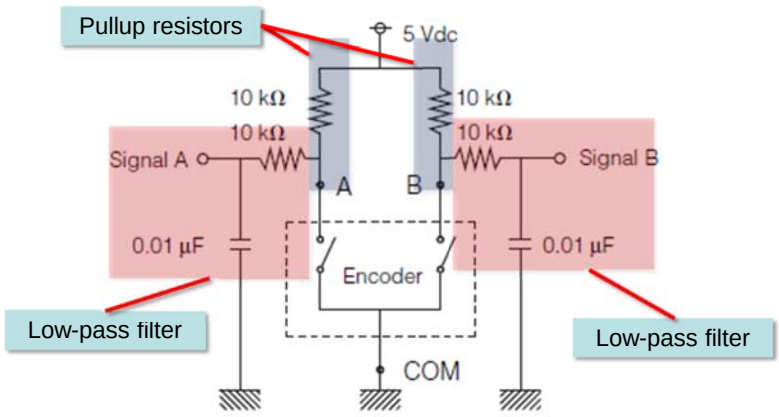


Both switches closed

Both switched open, normally at detent

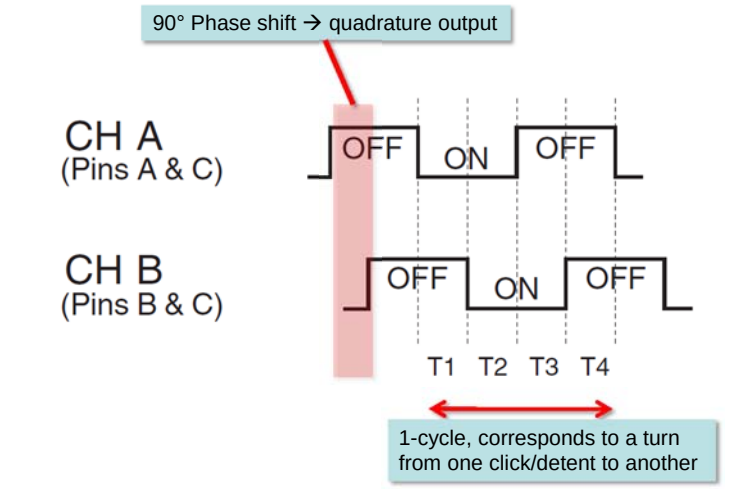
Electrical Connections

Test circuit, from the data sheet



Remember contact bounce?

Terminology



Number of pulses per revolution depends on particular device. Common numbers are 4, 6, and12, but some has as many as 6,000 ($$$)

Panasonic EVE-GA1F2012B Encoder

Cost: ~ $0.70

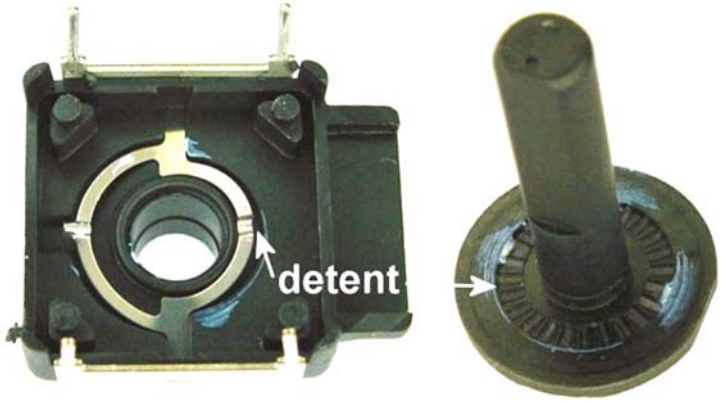
12 detents (positions)

What is a detent?

Data sheet does not explicitly specifies maximum rpm, but implies that it is 60

Quadrature output

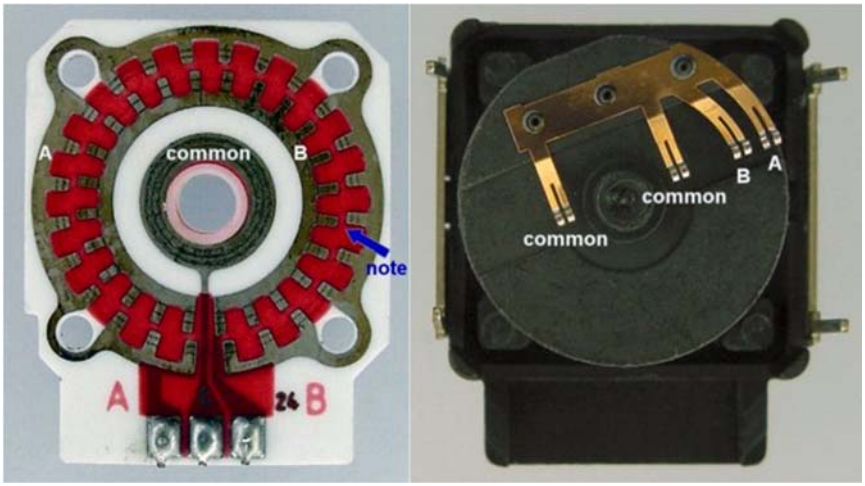
Opening Up An Encoder



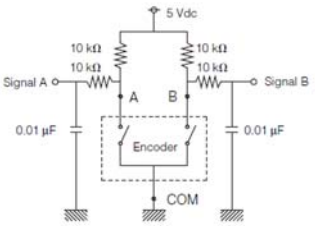
Inside the top of the rotary encoder case is a metal disc spring (also called a spring washer) with small raised areas. The disc of the encoder shaft is impressed with ridges that rub against the bumps in the spring to make clicking sounds as the shaft is turned.

Credits: www.robotroom.com

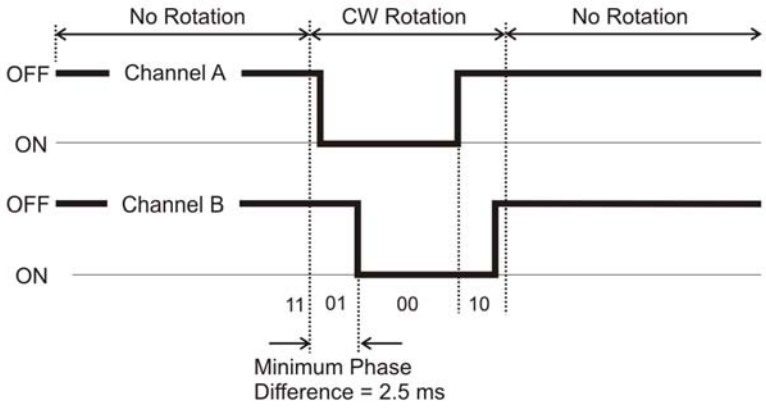
Opening Up An Encoder



Credits: www.robotroom.com

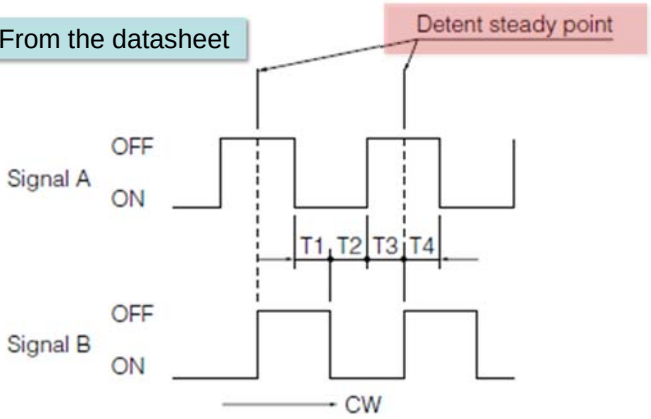


Signals with pull up resistors, and **single** detent-detent CW turn



EVE-GA1F2012B Timing Diagram

From the datasheet



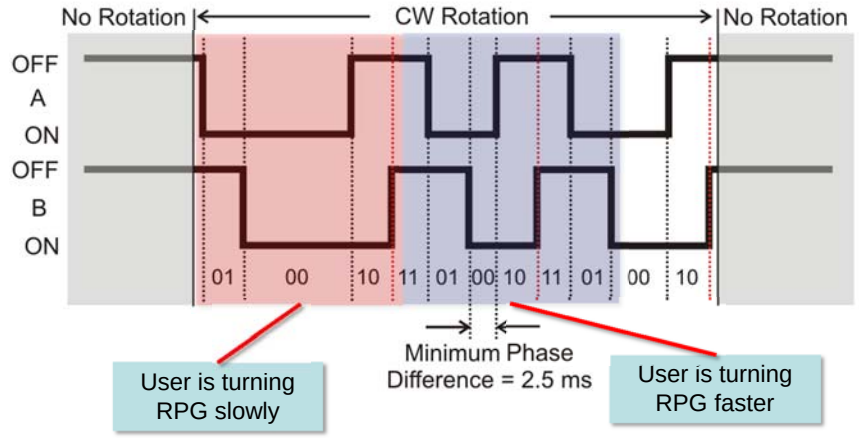
= 1 revolution/sec

Phase difference T_1, T_2, T_3, T_4
(At rotational speed 60 r/min.)

Note

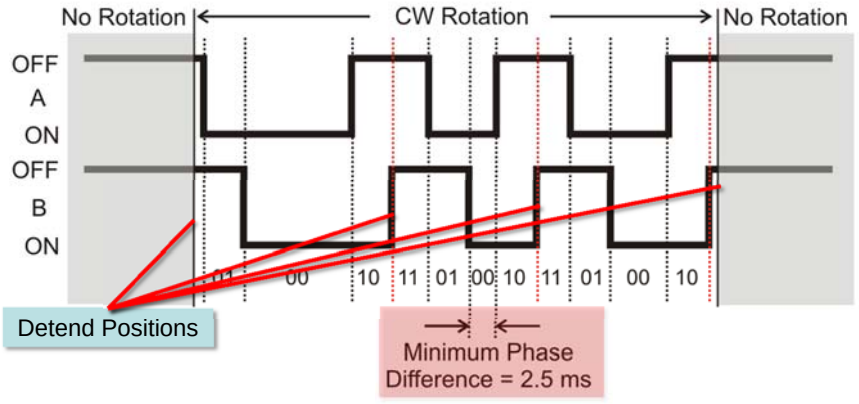
Initial·····3.5 m sec. min.
After life····· 2.5 m sec. min.

EVE-GA1F2012B Timing Diagram



EVE-GA1F2012B Timing Diagram

Note at **detent steady point, both switches are open** (and output pulled high), and the pulse width depends on how fast the RPG is turned.



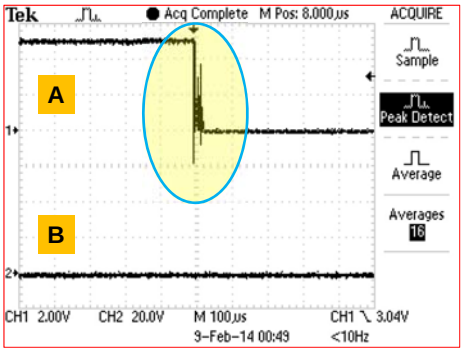
EVE-GA1F2012B Specifications

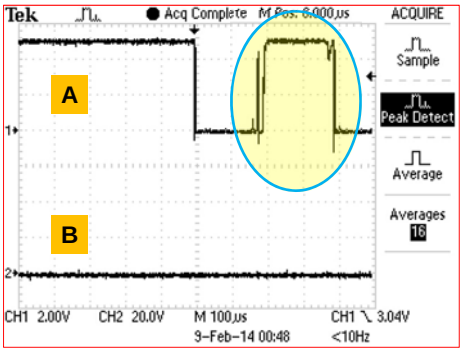
■ Specifications

Mechanical	Rotation Angle		360 ° (Endless)
	Shaft Pull/Push Strength		80 N min.
	Shaft Wobble		0.7×L/30 mm max.
	Rotation Torque	Standard Type	3 mN·m to 20 mN·m
		Heavy Rotation Torque	10 mN·m to 50 mN·m
	D		vithout detents ut detents)
Electrical	Resolution		12, 20, 24 pulses/360 °
	Rating		1 mA 5 Vdc, 1 mA 10 Vdc
	Contact Resistance		1 Ω max.
	Chattering		2 ms max.
	Insulation Resistance		10 MΩ min. (at 50 Vdc)
	Dielectric Withstanding Voltage		50 Vac for 1 minute
	Bouncing		5 ms max.
Endurance	Operating Life	Standard Type	30000 cycles min.
		Heavy Rotation Torque	15000 cycles min.
	Operating Temperature		–10 °C to +60 °C
	Storage Temperature		–40 °C to +85 °C

Contacts may “bounce” during transitions. This can cause erroneous readings

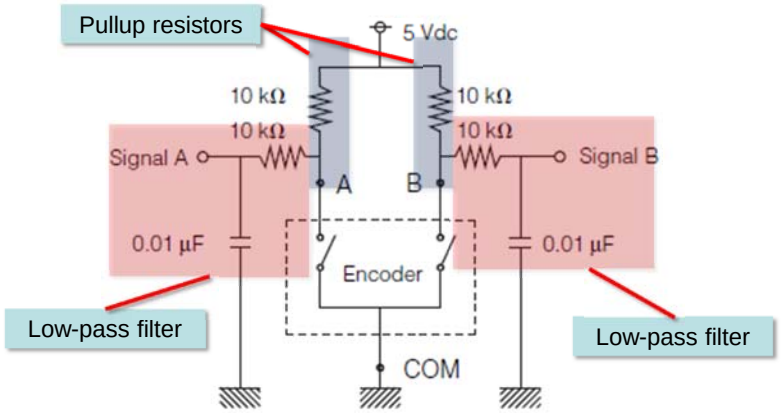
Bouncing / Chattering





Electrical Connections

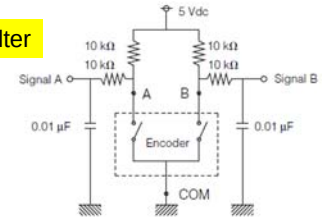
Test circuit, from the data sheet



Remember contact bounce?

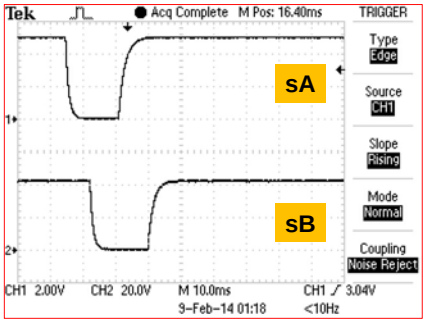
Debouncing - HW

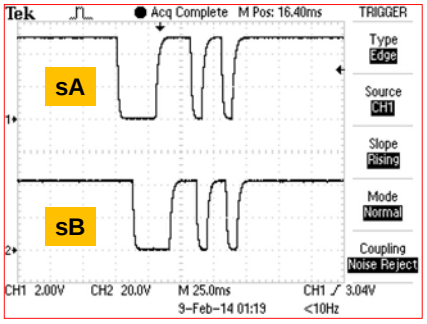
HW: LP Filter



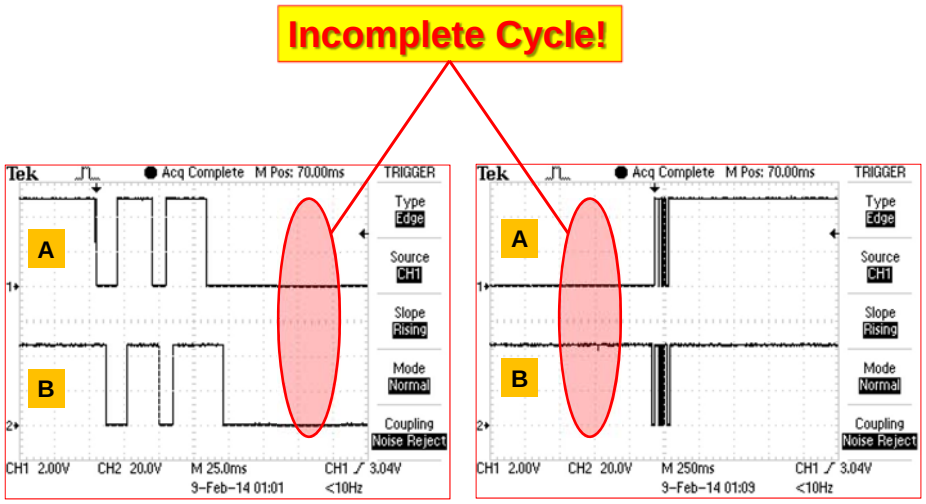
Important: RC time constant

Note: may also require an additional software approach to debouncing!





RPGs – Other Issues to Consider

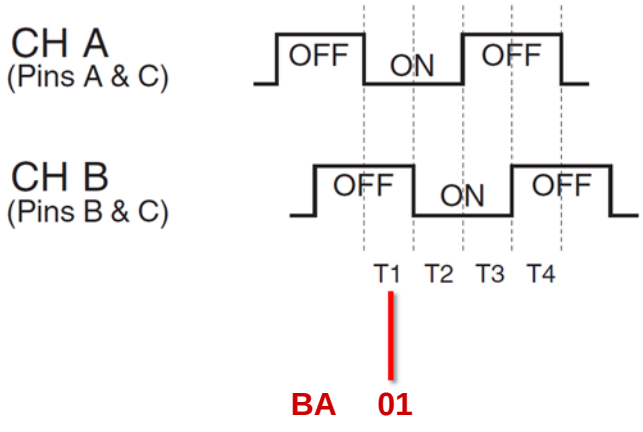


Review: Gray-Code

The **reflected binary code**, also known as **Gray code** after Frank Gray, is a binary numeral system where two successive values differ in only one bit.

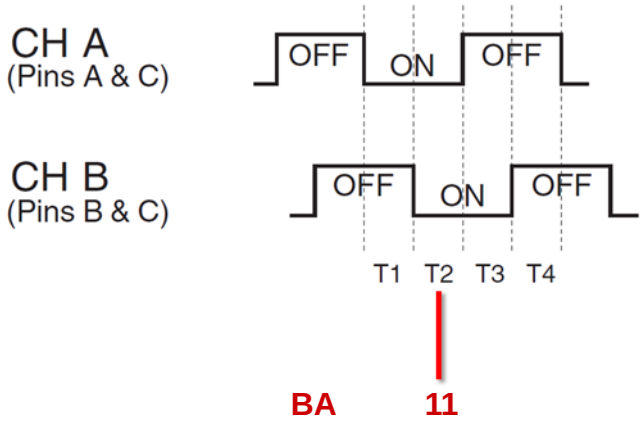
Dec	Binary	Gray
0	000	000
1	001	001
2	010	011
3	011	010
4	100	110
5	101	111
6	110	101
7	111	100

Gray-Code Output

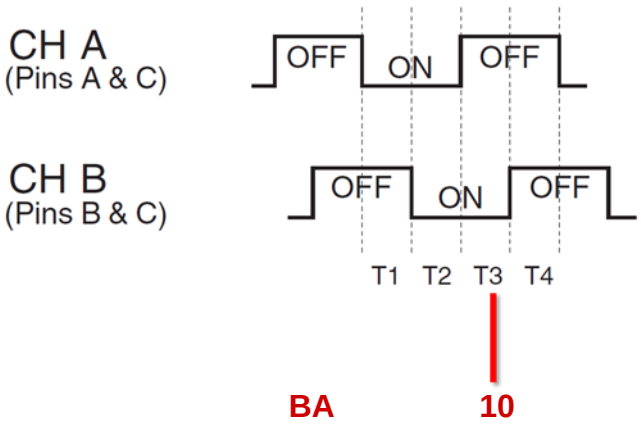


0 … Switch OFF
1 … Switch ON

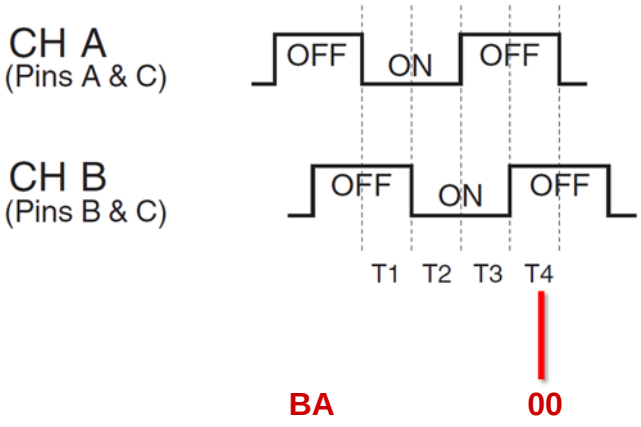
Gray-Code Output



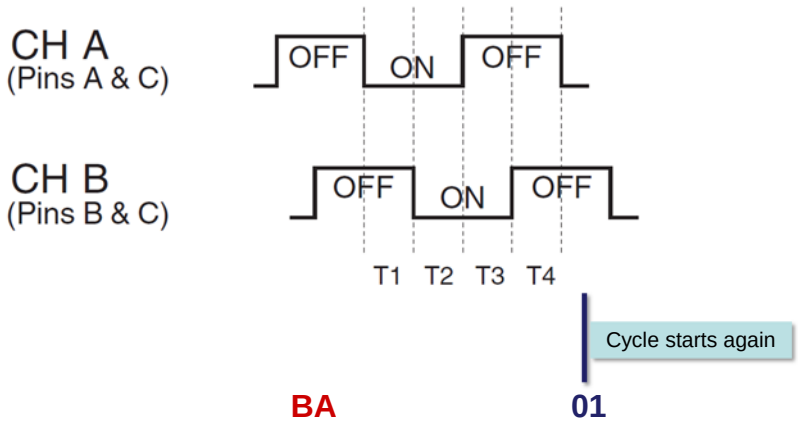
Gray-Code Output



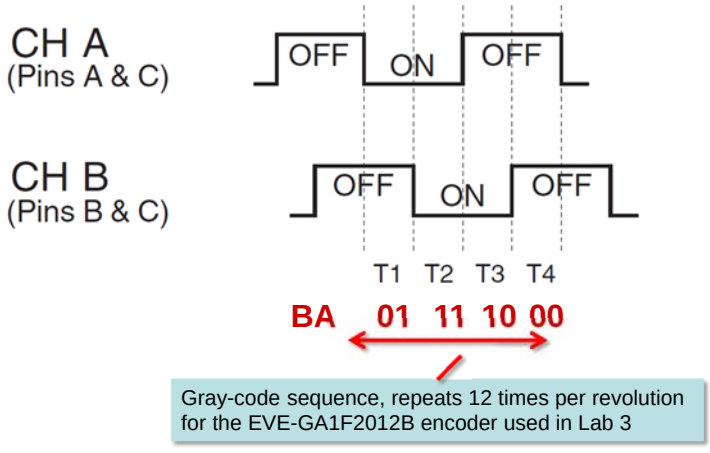
Gray-Code Output



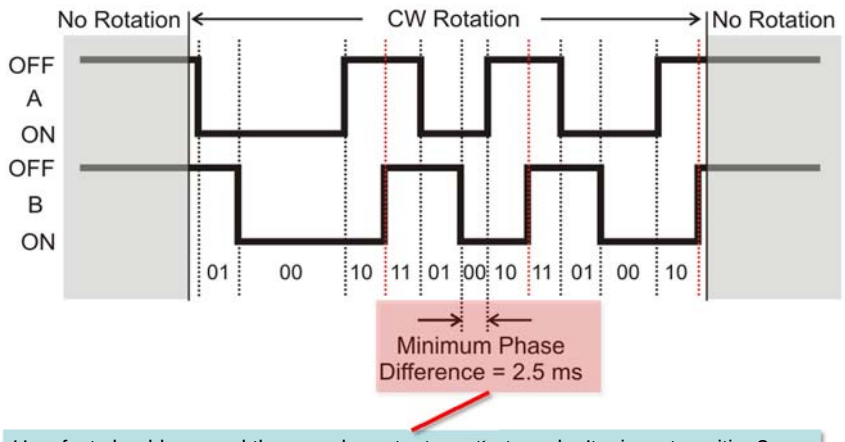
Gray-Code Output



Gray-Code Output



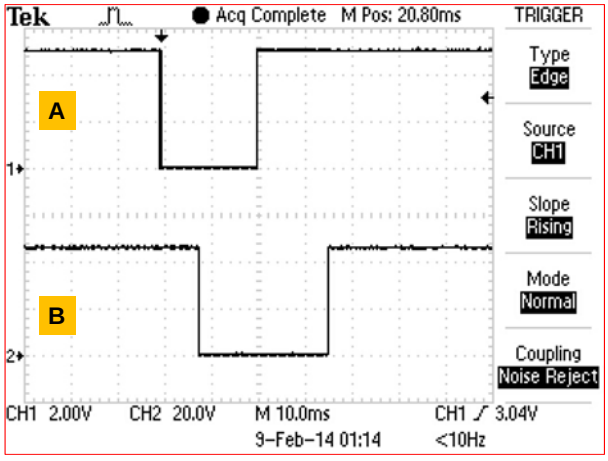
Reading Encoder Output



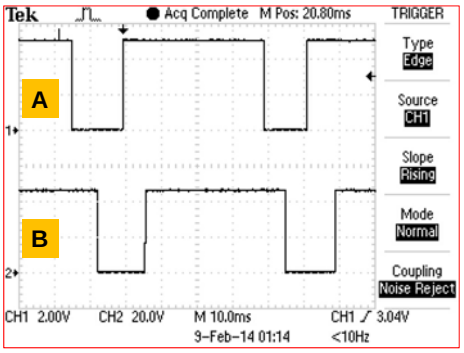
How fast should we read the encoder outputs so that we don't miss a transition?

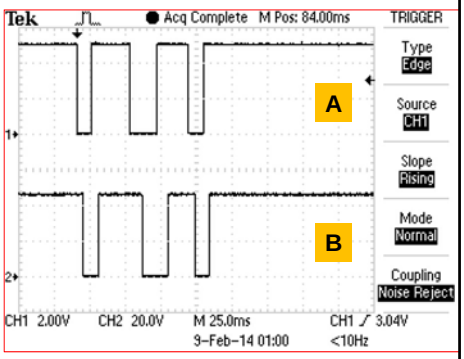
Answer: <2.5 ms (>400 Hz) – if we sample slower, we will miss a pattern

Example - CW Rotation

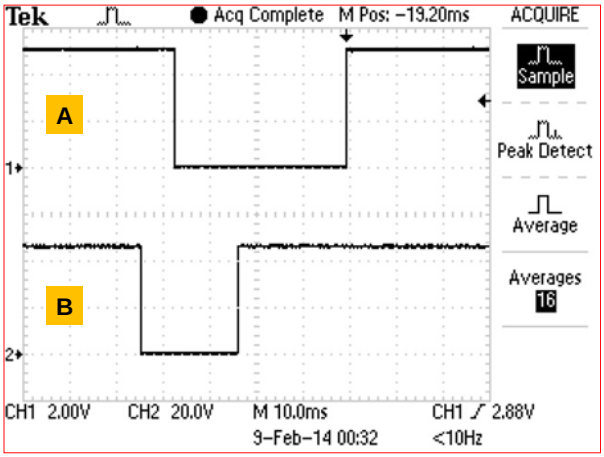


Examples - CW Rotation

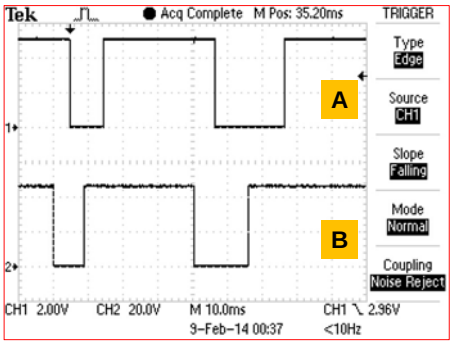


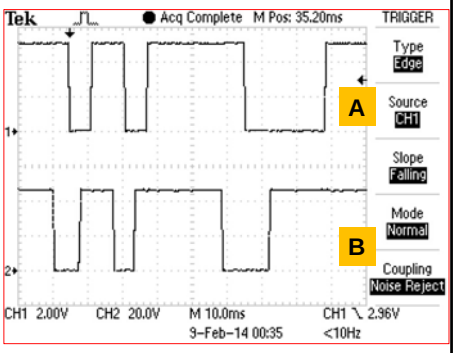


Examples - CCW Rotation

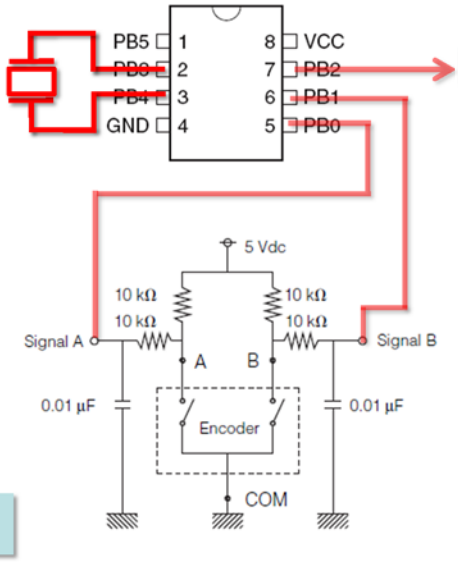


Examples - CCW Rotation





RPG Connection to ATtiny45



Output

```
...
cbi  DDRB,0
cbi  DDRB,1
...
SBIS PINB,0
...
```

This instruction tests a single bit in an I/O register and skips the next instruction if the bit is set.

For input use **PINB**, not **PORTB**!

Rotary encoder

Detecting the Direction of Rotation

Clockwise (positive) rotation pattern

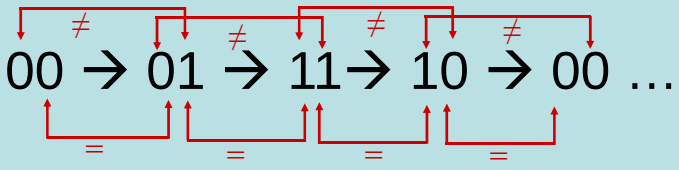
00 → 01 → 11 → 10 → 00 …

Counter-clockwise (negative) rotation pattern

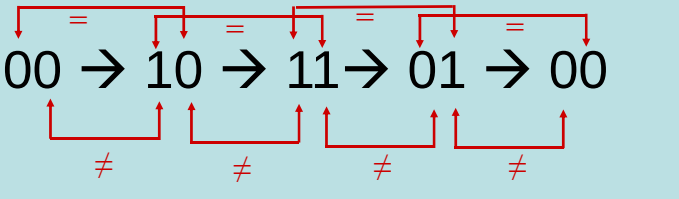
00 → 10 → 11→ 01 → 00 …

Detecting the Direction of Rotation

Clockwise (positive) rotation pattern



Counter-clockwise (negative) rotation pattern



Lab 3

So, Your Program Must:

- **Read the RPG at <2.5 ms intervals**
- **Adjust the current waveform duty cycle up or down according to detected RPG rotation**
  - **Increment or decrement the duty cycle percentage**
  - **Determine the required timer value(s) to time the waveform's on-time and off-time for this duty cycle**
  - **Reload the timer(s) to begin timing this new duty cycle**
- **Implementation approach**
  - **Write code/routine that**
    - Records and remembers the A- and B-encoder outputs every time it is called
    - Use patterns shown on previous slide to determine CW, NO, or CCW rotation
    - Return + (CW), 0 (NO) and CCW(-)
  - **Execute code/call routine at a rate >400 Hz**
  - **Recalculate and update duty cycle**

Rate-Sensitivity

Lab 3 requirements

Suppose that the RPG is used to adjust the duty cycle of a square wave over the range 30% to 70% in 1% increments without skipping increments…

Assume one RPG count gives a 0.5% duty cycle adjustment. How many revolutions of the RPG will be required to adjust across the entire duty cycle range? Recall, there are 12 detents per rotation.

```
Answer:  [(70-30)/0.5]/12 = 6.67 revolutions
```

Question: Is this an acceptable number?

Answer: Probably. But what if the requirement is a 0.1% increment?

Then 33.3 rotations are required, which may be too much. The solution is to increment/decrement in larger amounts when users turns RPG rapidly. This a *rate-sensitive* approach.

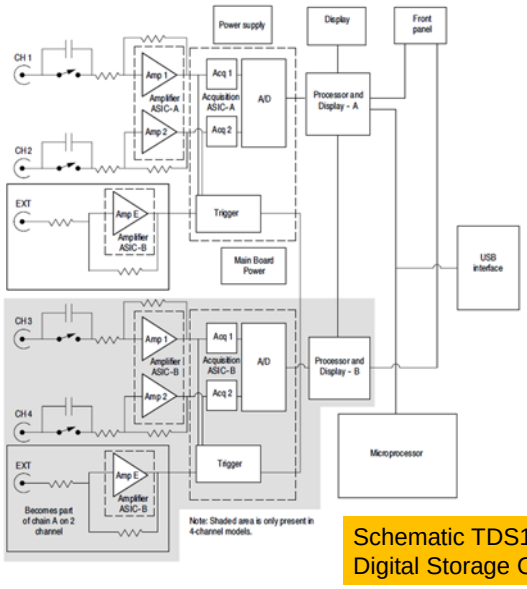
The Rate-Sensitive RPG Approach

- **For Lab 3, this is extra-credit**
- **Set a Threshold *T***
- **If changes in RPG output occur more than T×10 ms apart, use "slow change" increment/decrement by 1**
- **If changes in RPG output are less than T×10 ms apart, use "fast change" increment/decrement by 2**

Lab 3: Some Concluding Comments

- **Think carefully about the structure and design of your program before you start to write code**

The Oscilloscope …



… is an Embedded System!

You can find the manual for TDS1012B on ICON!

Schematic TDS1000B and TDS2000B Series Digital Storage Oscilloscopes

… EOL