

Rotary Encoder Debounce Circuit

Description

The ELM401 is an 8 pin integrated circuit that is used to 'debounce' the signals from a mechanical rotary (quadrature) encoder. The low power CMOS technology used ensures that only a very small current is required over the entire 2.0 to 5.5 volt operating range.

There is no need for external filtering or debounce circuits with the ELM401, as this is all performed within the integrated circuit. The 'A' and 'B' motion sensing encoder signals are both passed through a filter then a comparator circuit, and finally a timer circuit to remove noise and contact bounce, while the switch input receives standard debounce processing. The result are three virtually noise-free signals that are suitable for direct use by an electronic circuit.

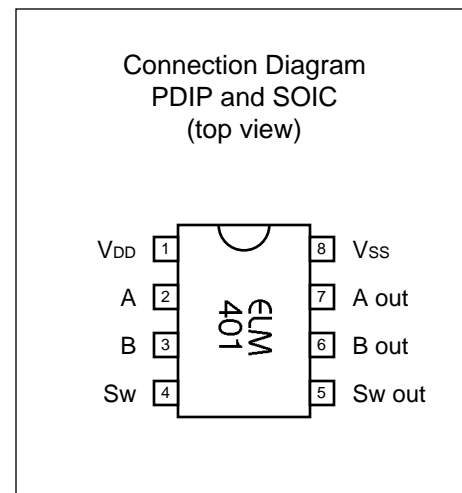
Note that no inversion or manipulation of any kind is performed on the input signals, other than the debouncing. If your applications requires decoding of the signals, you may wish to look at our ELM402 to ELM408 family of products.

Applications

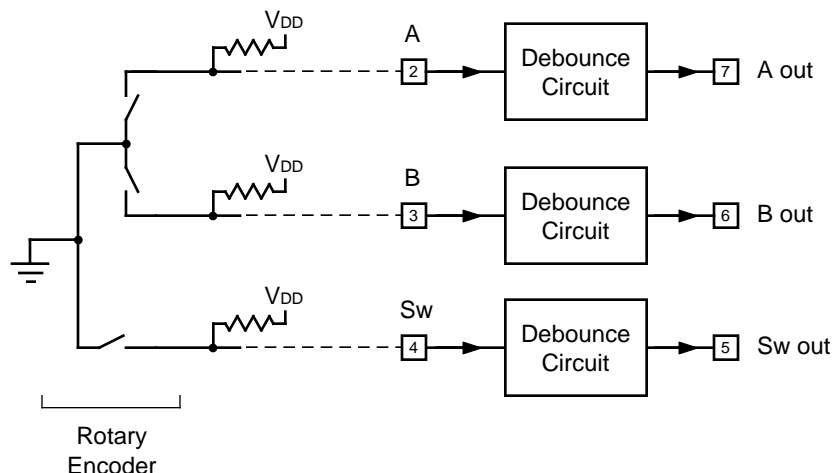
- Microcontroller Interfaces
- Monitoring of Encoder Signals
- General Switch Debouncing

Features

- Low power CMOS design
- Wide supply range – 2.0 to 5.5 volts
- Complete debouncing of the encoder signals
- No external filtering needed
- Includes switch debouncing circuit
- Startup delay timer
- High current drive outputs



Block Diagram





Pin Descriptions

V_{DD} (pin 1)

This pin is the positive supply pin, and should always be the most positive point in the circuit. Internal circuitry connected to this pin is used to provide power on reset of the internal logic, so an external reset signal is not required. Refer to the Electrical Characteristics section for more information.

A (pin 2)

This input is usually connected to what is normally known as the 'A' signal from a rotary (quadrature) encoder. An external pullup resistor is required for the encoder (a typical value is 10 K), but no external capacitors are needed (as the internal debounce circuitry provides the filtering).

B (pin 3)

This input is usually connected to what is normally known as the 'B' signal from a rotary (quadrature) encoder. An external pullup resistor is required for the encoder (a typical value is 10 K), but no external capacitors are needed (as the internal debounce circuitry provides the filtering).

Sw (pin 4)

This input may be used to debounce any standard mechanical contact (from a switch or relay). The circuitry uses simple set/reset logic to control a timer, so is not suitable for use with the A or B signal from a rotary encoder (as those signals continue to generate sliding noise while the contact is closed).

Sw out (pin 5)

This output is the debounced representation of the signal that is at pin 4.

B out (pin 6)

This output is the debounced representation of the signal that is at pin 3.

A out (pin 7)

This output is the debounced representation of the signal that is at pin 2.

V_{SS} (pin 8)

Circuit common is connected to this pin. This is the most negative point in the circuit.

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Ordering Information

These integrated circuits are only available in either a 300 mil plastic DIP format, or in a 150 mil SOIC surface mount type of package. To order, add the appropriate suffix to the part number:

300 mil Plastic DIP..... ELM401P

150 mil SOIC..... ELM401SM

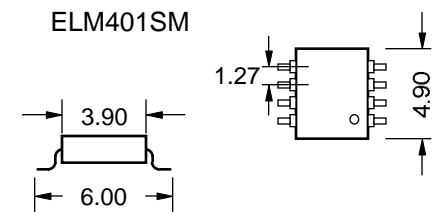
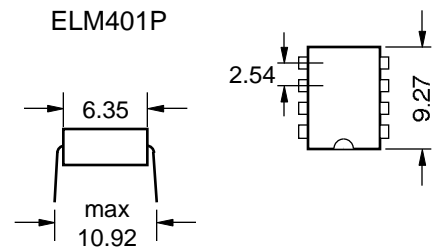
Outline Diagrams

The diagrams at the right show the two package styles that the ELM401 is available in. The first shows our ELM401P product, which is an ELM401 in a 300 mil DIP package. This is a standard through hole type dual inline package. The ELM401SM is our surface mount version of the ELM401. The device package has a 3.90 mm wide body, and is commonly called a 150 mil SOIC package.

The drawings shown here provide the basic dimensions for these ICs only. Please refer to the following Microchip Technology Inc. documentation for more detailed information:

- *Microchip Packaging Specification*, document name en012702.pdf (7.5MB). At the www.microchip.com home page, click on Packaging Specifications, or go to www.microchip.com/packaging

- *PIC12F508/509/16F505 Data Sheet*, document 41236E.pdf (1.5 MB). At the www.microchip.com home page, click on Data Sheets, then search for 12F508.



Note: all dimensions shown are in mm.



Absolute Maximum Ratings

Storage Temperature..... -65°C to +150°C
 Ambient Temperature with
 Voltage Applied.....-40°C to +85°C
 Voltage on V_{DD} with respect to V_{SS}..... 0 to +6.5V
 Voltage on any other pin with
 respect to V_{SS}..... -0.3V to (V_{DD} + 0.3V)

Note:
 Stresses beyond those listed here will likely damage this device. These values are given as a design guideline only. The ability to operate to these levels is neither inferred nor recommended.

Electrical Characteristics

All values are for operation at 25°C and a 5V supply, unless otherwise noted. For further information, refer to note 1 below.

Characteristic	Minimum	Typical	Maximum	Units	Conditions
Supply voltage, V _{DD}	2.0	5.0	5.5	V	
V _{DD} rate of rise	0.05			V/msec	see note 2
Power on reset time	9	18	30	msec	see note 3
Average supply current, I _{DD}		0.6	1.1	mA	V _{DD} = 5.0V
		0.2	0.3	mA	V _{DD} = 2.0V
Output low current (sink) V _{DD} = 5.0V V _{DD} = 3.0V		10		mA	V _{OL} = 0.25V
		5.0		mA	V _{OL} = 0.25V
Output high current (source) V _{DD} = 5.0V V _{DD} = 3.0V		2.5		mA	V _{OH} = 4.75V
		1.7		mA	V _{OH} = 2.75V
A & B debounce period		5.5		msec	see note 4
Startup time delay		50		msec	
Internal timing variation		1	4	%	see note 5

Notes:

1. This integrated circuit is based on a Microchip Technology Inc. PIC12F5XX device. For more detailed specifications, please refer to the Microchip documentation (www.microchip.com).
2. This spec must be met in order to ensure that a correct power on reset occurs. It is quite easily achieved using most common types of supplies, but may be violated if one uses a slowly varying supply voltage, as may be obtained through direct connection to solar cells, or some charge pump circuits.
3. The internal reset circuitry stops the ELM401 from doing anything during this period, so that the power supplies and oscillators have time to stabilize. During this time, all pins behave like inputs.
4. Typical only - the actual period varies with the amount of noise present in the input signal.
5. All filtering, delay, and output timing is based on an internal master oscillator. The frequency of this oscillator will vary with voltage and temperature. Values shown are typical maximums for 2.0V V_{DD} 5.5V, and temperatures of -40°C to +85°C

Rotary Encoders

A rotary encoder (sometimes referred to as a quadrature encoder) is a device that produces digital (on/off) outputs in response to rotary, or circular, motion. It is often constructed such that it looks very much like a potentiometer, or audio volume control (see the picture of a typical device, at the right).



A typical rotary encoder

As the encoder shaft is turned, internal contacts open and close, creating two waveforms that are ideally separated in phase by 90 degrees (ie 'in quadrature'). Actually, you need to provide external 'pullup' resistors and a power supply to create these waveforms, as the contacts themselves can not do this. An ideal waveform from a rotary encoder would look like this:

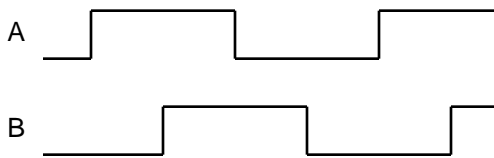


Figure 1. Quadrature Waveforms

Due to the 90 degree phase difference, when one waveform changes, the other is always stable. By noting the direction of the change and the level of the other input at that time, you can determine the direction of motion of the shaft.

Rotary encoders are not ideal, however. Due to their construction, and variations in shaft speed, the

waveforms are not perfectly square with the 50% duty cycles shown. Figure 2 shows a captured trace from a real rotary encoder that is more representative of what you will typically find. Note that the two 'scope channels (1 and 2) represent the encoder outputs A and B, respectively. The ch 1 (A) waveform leads the ch 2 (B) waveform, which usually means that the shaft is turning in a clockwise direction.

The first rising edge of the channel 2 waveform shows another problem that occurs with moving mechanical contacts - multiple pulses due to bounce. When two contacts meet, the moving one will tend to bounce, like a ball does when it is dropped on the floor. Each bounce results in an electrical connection being made, then broken, which will look like multiple inputs to a fast electronic circuit. Various mechanical means are used to reduce the amount of bounce, but it can never really be eliminated. The following section discusses how the ELM401 uses electronic means to remove the bounce.

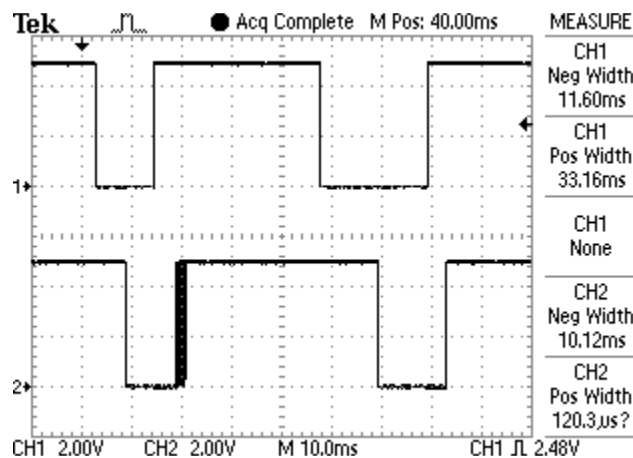


Figure 2. Actual Rotary Encoder waveform

Debouncing Circuits

Any time that two metal surfaces meet, as they do inside a rotary encoder, there will be a tendency for the moving one to bounce, which causes the electrical connection to make and break. The duration of this bouncing action may be very short, but it is usually fast enough to cause multiple counts to be recorded by connected electronic circuits. As the number of bounces can not be predicted, a means of removing them is necessary. Circuits that remove the bounce are usually called 'debouncing' circuits.

Many debouncing circuits employ a simple timer to determine if an input is stable. This generally works well if the two contacts meet and then remain still. With a rotary encoder however, one of the contacts meets the other then usually continues sliding over the surface of the stationary contact. This will produce noise while the contact is sliding, occasionally enough to make it look like there are more inputs.

The ELM401 employs a two stage system to remove the bounce and the sliding noise from the encoder signal. A block diagram of the stages are shown in figure 3. The first stage is a digital filter circuit that is used to determine the average value of the waveform over a time. If a long enough time is chosen, short duration pulses will have little effect on the overall average. If the time chosen is too long,

however, the circuit will be slow to respond, and may in fact average out some legitimate inputs. Choosing the time period (or time constant of the circuit) is thus very important in determining how effective the filtering function will be. We have found that with typical rotary encoder specifications (usually 3.0 msec of bounce or noise, maximum), the ELM401 debounce circuit works quite well.

After the signal has been filtered, it is compared to some reference levels, and the output of these comparators are used to control a simple timer. The timer is used to ensure that the output of the filter is stable, and not just a momentary transient, while the use of two comparator levels provides hysteresis, so that some variation in the filter output can be tolerated.

The Sw input uses a very simple debounce circuit that employs a timer only (and not the filter section shown in Figure 3). This is very similar to the logic used by our ELM409, ELM410, and ELM411 circuits.

Once the signals from the rotary encoder have been debounced, they may be used by your circuit to decode direction, etc.- the following sections provide some tips on this.

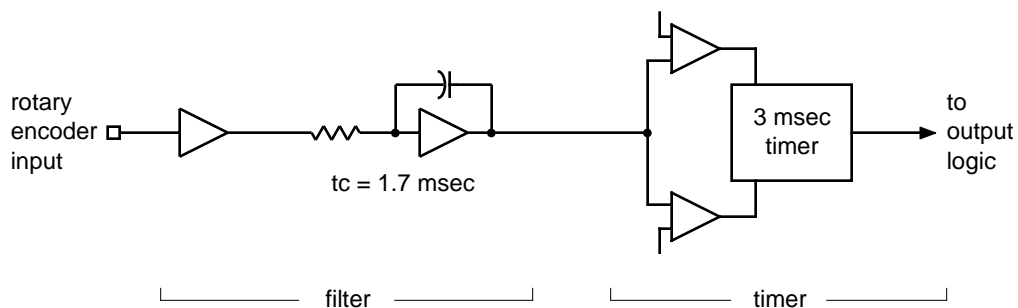


Figure 3. Internal Debouncing Logic



Design Considerations

There are a few details to consider when using the ELM401 to interface to a rotary encoder. The first is the fact that the signals available from the encoder are usually only dry contacts closing and opening. You will need to provide pullup resistors for these signals in order to use them in a circuit.

The size of the pullup resistor is chosen based on the encoder specifications. The main concern is the maximum current carrying capacity, which sets a lower limit for the pullup resistance. An upper limit for the resistance is set by the minimum current required for contact wetting. If you do not provide enough current through mechanical contacts when they are closed, they will tend to go open with time. A maximum current specification is usually in the range of 1 to 10 mA, while the minimum wetting current would be in the range of 1 mA. This means that with a 5V supply, a pullup resistor of 5 to 10 K is typically required.

The second concern is the use of capacitors on the 'A' and 'B' signal lines. Many encoder circuits show these as a way to provide some pre-filtering of the signal. That is fine, as long as you realize that the ELM401 inputs are CMOS and do not have Schmitt trigger waveshaping. This means that you should keep the rate of change of the input signal as high as possible to avoid problems (we usually try to maintain at least $1V/\mu\text{sec}$). Typically, with a 5V supply, a 10 K pullup, and TTL thresholds, this means capacitor values of no more than about 330 pF, while with a 2.0V supply, the limit would be about 100 pF.

One other issue to consider is that during the initial circuit startup, there is a period (of about 20 msec) when the ELM401 is being held in a reset state, and

the outputs are in a tristate condition. During this time, the outputs will sit at the level they were at before power up (0V) due to stray capacitance having discharged through the protection diodes. If you require that the outputs be at a high level as soon as possible after powerup, you may want to install a pullup resistor (of about 10 K) on each output to charge the capacitance quickly.

After the initial 20 msec period, the ELM401 sets all pins to their quiescent levels, but does not change any outputs for an additional 50 msec. This ensures that the external circuits have had adequate time to initialize, before being presented with signals to process.



Example Application

Figure 4 below shows how the ELM401 might be used with a microprocessor. Power for the ELM401 has been obtained from the microprocessor circuit, and a small capacitor has been added to ensure that the supply is filtered. The positive supply has been shown simply as V_{DD} , since the ELM401 will operate with any voltage from 2.0 to 5.5 volts.

The circuit uses 10 K pullup resistors with the rotary encoder signals in order to convert the signal from the dry contacts into one that swings from V_{DD} to V_{SS} . The momentary pushbutton contact from the encoder is treated no differently than the ones from the encoder wheel. Since both ICs share the same supply, they can be directly connected as shown.

That's about all there is to using the ELM401 in your circuit. Connect pullup resistors to your rotary encoder signals, connect the encoder signals to the ELM401, then connect the ELM401 to the controlled circuit. Use a common supply for all the devices, and add a small bypass capacitor across the supply line. The controlled devices can be digital pots, microprocessors, or almost any circuit that will accept CMOS signals. Enjoy!

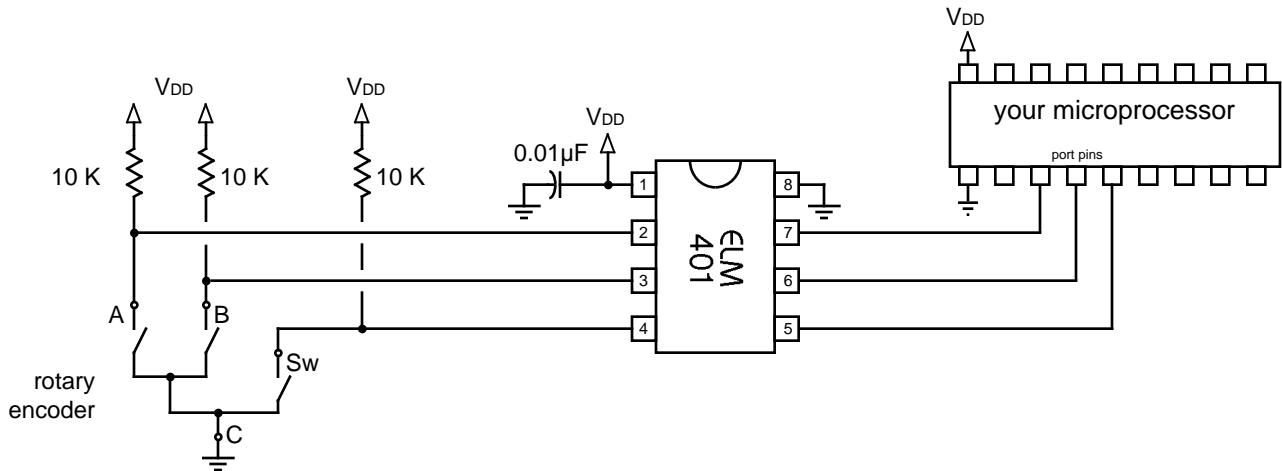


Figure 4. Connecting the ELM401 to a microprocessor