

uC101: Introduction to Microcontrollers / Interfacing with the real world

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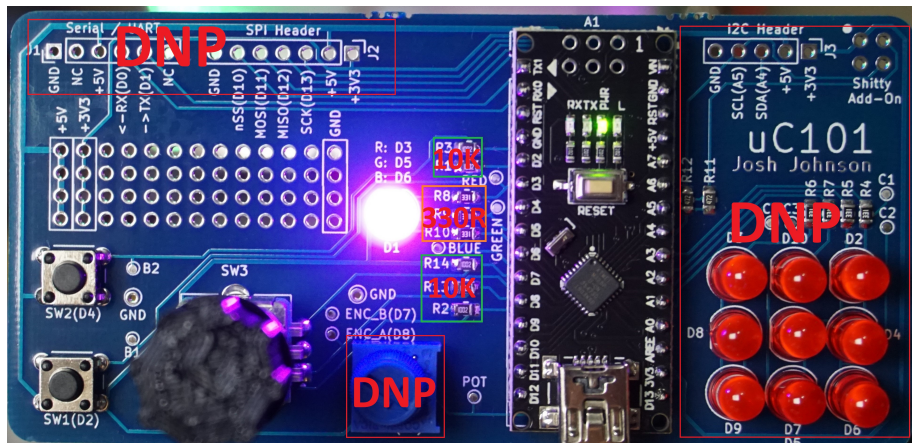
13/5/2019

Overview

- Assembly of Hardware / Installation of Software
- Microcontroller 101
- Tools
- Bit Math
- Demos
 - Blink
 - Button
 - RGB LED (PWM)
 - Rotary Encoder
 - Charlieplexing

Project Files: github.com/joshajohnson/CBRhardware

Assembly of Hardware



Software Installation!

Install Arduino IDE

Copy the uC101Library folder to /Arduino/libraries

In Arduino IDE:

File->Examples->uC101->blink

Tools->Board->Arduino Nano

Tools->Processor->ATmega328p OR

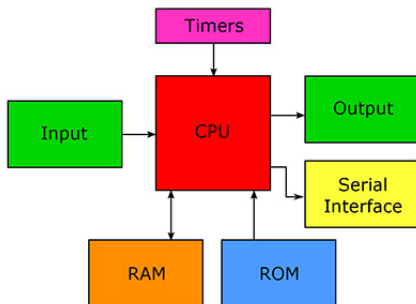
Tools->Processor->ATmega328p (Old Bootloader)

Tools->Port->\$comPort

Run blink.ino and confirm that the onboard LED is blinking

What is a microcontroller?

Microprocessor: CPU
and several supporting chips.



Microcontroller: CPU
on a single chip.

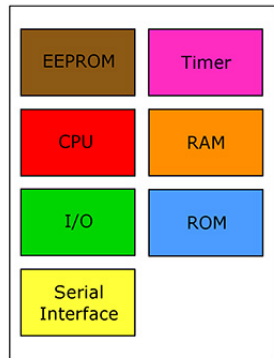


Image Credit: Kenneth C. Reese, III

Common Options

8 bit

- ATtiny
- ATmega (Atmel / Microchip)
- PIC (Microchip)

16 bit

- MSP430 (TI)

32 bit

- STM32 (ST)
- SAM (Atmel/Microchip)
- nRF5x (Nordic Semi)
- ESP8266/32 (Espressif)
- CCxxxx (TI)
- LPCxxxx (NXP)
- PIC32 (Microchip)

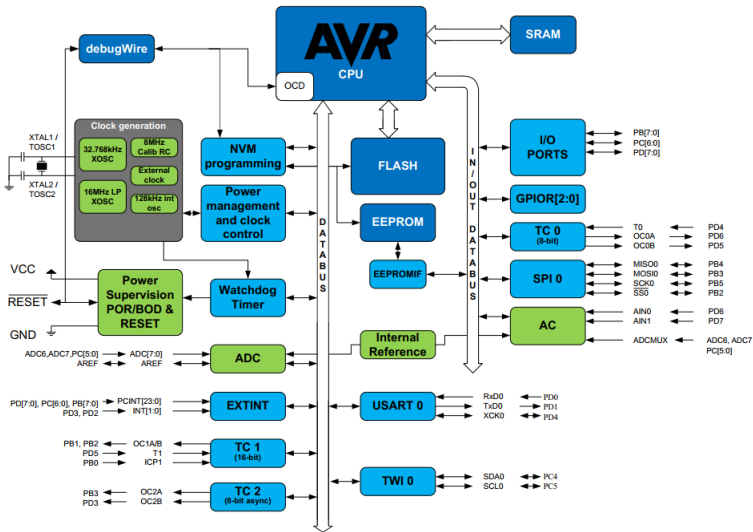
32 bit ARM cores

- Cortex-M0/M0+
- Cortex-M1 (FPGA only)
- Cortex-M3
- Cortex-M4 (M3 + DSP + FPU)
- ...

How to choose?

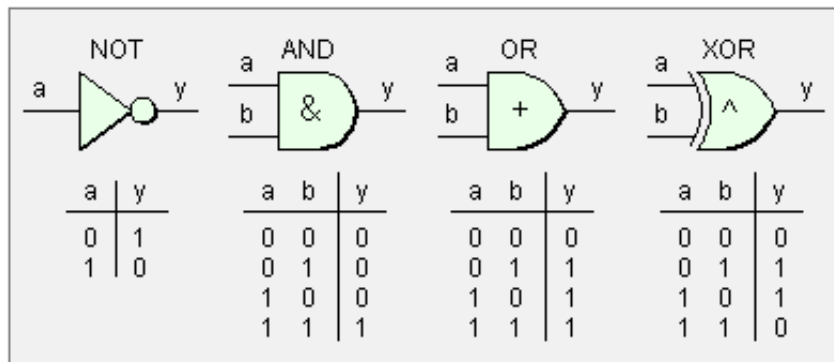
- Compute power
 - 8 bit vs 32 bit
 - DSP / FPU
- Peripherals
 - Wireless
 - WiFi
 - Bluetooth
 - LoRa
 - Cellular
 - USB
 - ADC
 - Ethernet
 - CAN
 - Number of SPI/UART/I2C/Timers

ATmega328p Architecture



- Oscilloscope
 - + High quality time domain measurements (≥ 8 bits, ≥ 1 GSPS)
 - - Expensive, short record time
- Logic Analyser
 - + Easy to use UI, long sample time / depth
 - - 1 bit*, low sample rate (25 - 100 - ≥ 500 MSPS)
 - * some logic analysers have limited analog capabilities
- Debugger
 - Program and debug device
- Multimeter
 - Voltage and resistance measurements
- Development Board
 - Whilst not a tool, extremely helpful whilst bringing up firmware
 - Helpful when developing code - the issue isn't (typically) the hardware!

Bitwise Operators



$$y = \sim a$$

$$y = a \& b$$

$$y = a | b$$

$$y = a \wedge b$$

$$\text{NOT } y = a \&\& b$$

Binary Operations

Binary Numbers

Binary: 0 1 0 0 1 0 1 1

Weight: 128 64 32 16 8 4 2 1

Base 2 (Binary): 0b01001011

Base 10 (Decimal): 75

Base 16 (Hexadecimal): 0x4B

Bit Shifting

```
a = 5;           // binary: 00000101
```

```
b = a << 3;      // binary: 00101000, 40 in decimal
```

```
c = b >> 3;      // binary: 00000101, back to 5 like we started
```

Putting it all together

```
x = 1;           // binary: 00000001
```

```
x <=< 3;         // binary: 00001000
```

```
x |= 3;          // binary: 00001011 - 3 is 11 in binary
```

```
x &= 1;          // binary: 00000001
```

Setting Registers

Setting a bit in a register

```
REG = REG | (1 << x);  
REG |= (1<<x);
```

Clearing a bit in a register

```
REG = REG & ~(1 << x);  
REG &= ~(1<<x);
```

Toggling a bit in a register

```
REG = REG ^ (1 << x);  
REG ^= (1<<x);
```

Toggling multiple bits in a register

```
REG = REG ^ ((1 << x) | (1 << y));  
REG ^= (1<<x) | (1<<y);
```

AVR specific macro to bitshift

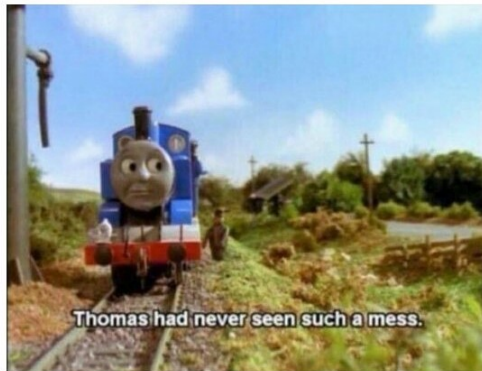
```
(1<<x) == _BV(x)  
REG = (1<<x) | (1<<y);  
REG = _BV(x) | _BV(y);
```

What is the difference between the above and the first example (other than two variables)?

Demo Time!

Me : *Explain my code to colleague*

Colleague:



- I'm a hardware person, not a software person
- Solder is my preferred programming language
- I know enough to be dangerous, nothing more
- More experienced folks, please jump in and correct me / answer questions I can't / point out bad practices
- I'm here to learn like everyone else

- Default blink
- Register level blink
- Nicer blink
- Even nicer blink
- Blink without delay
- Size comparison
- Speed comparison

button.ino

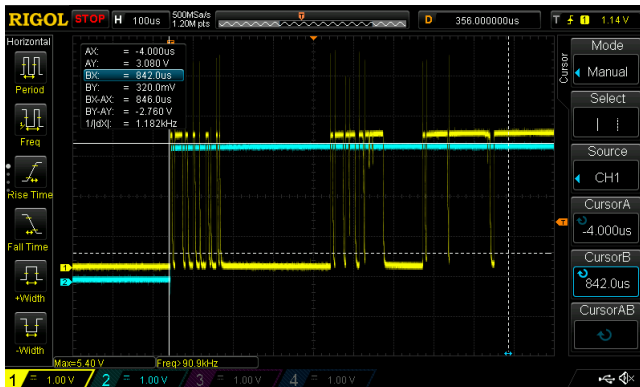
- Toggle on press
- Toggle on press with delay
- Button with interrupt
- Debounced button

Button Bounce

- What is button bounce?
- How to fix it?
 - Hardware - RC Circuit
 - Hardware - RC + Schmitt trigger
 - Software - Button polling

Button Bounce

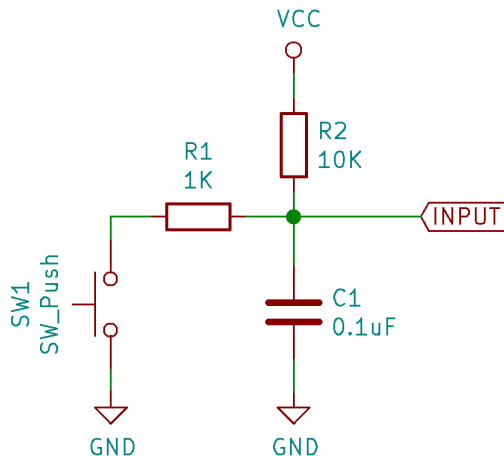
- What is button bounce?



Yellow = actual button, Blue = 'ideal button'

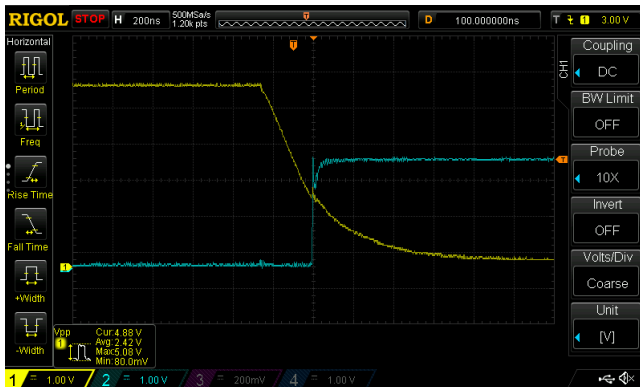
Button Bounce

- Fix 1 - RC Circuit



Button Bounce

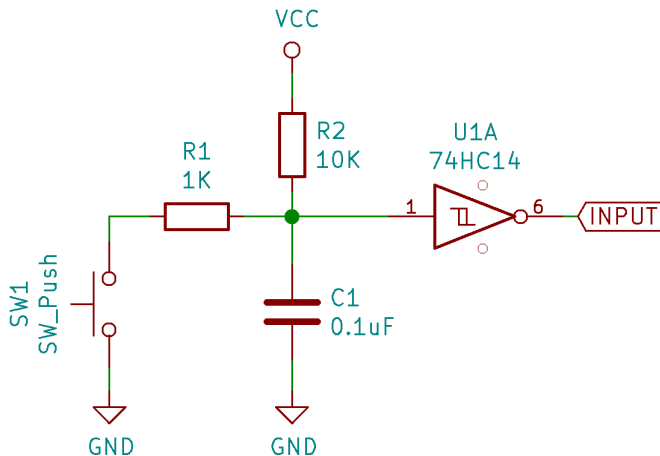
- What is button bounce?



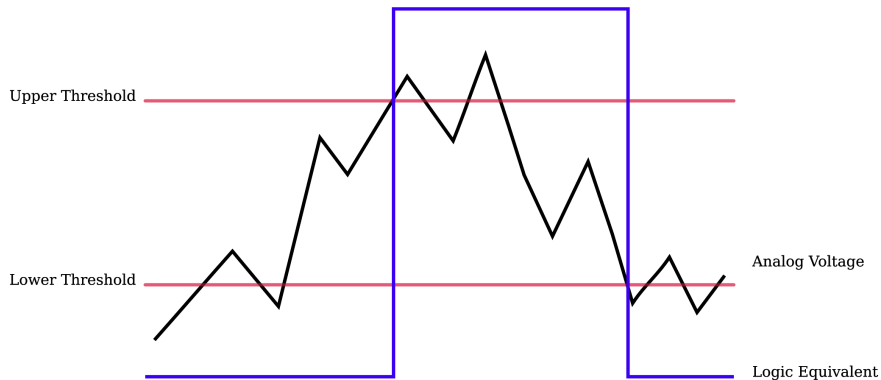
Yellow = button + RC Circuit, Blue = schmitt trigger output

Button Bounce

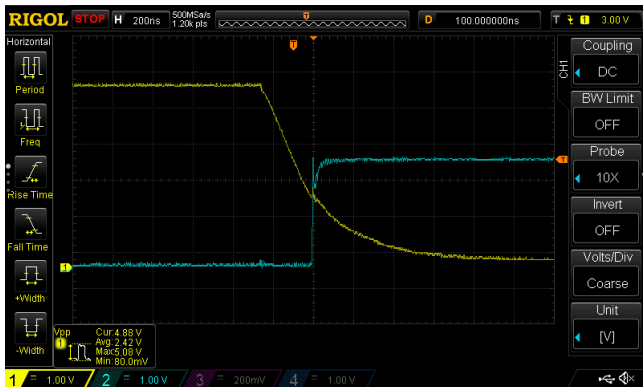
- Fix 2 - RC Circuit + Schmitt trigger



Hysteresis



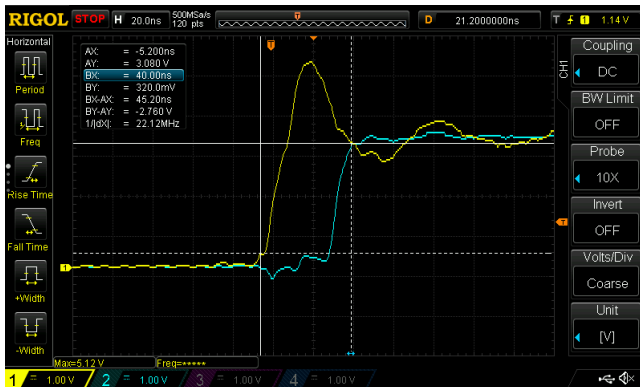
Button Bounce



RC (yellow) and schmitt output (blue)

Button Bounce

- Fix 3 - Button polling (FPGA assignment version)



Button Bounce

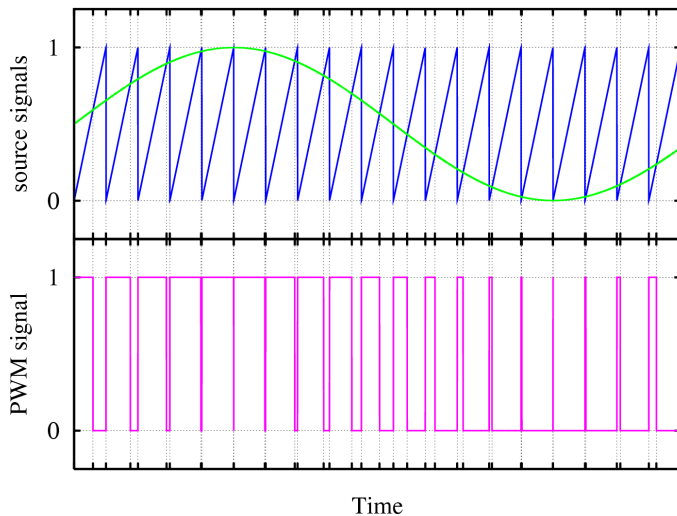
- Fix 3 - Button polling (uC101 version)

```
// Shift in a new value
history = history << 1;
history |= readPin(button);

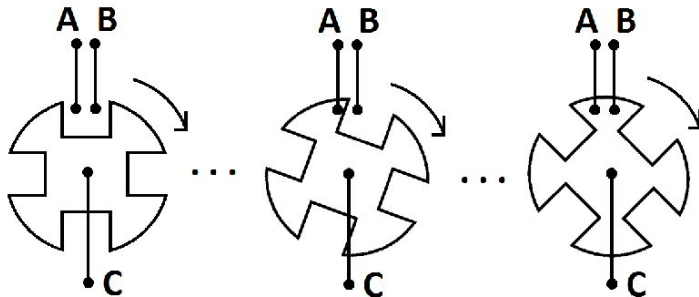
// Check for button conditions
(history == 0b11111111) ? on = 1 : on = 0;
(history == 0b00000000) ? off = 1 : off = 0;
(history == 0b01111111) ? rising = 1 : rising = 0;
(history == 0b10000000) ? falling = 1 : falling = 0;
```

Above code called every 1-5ms

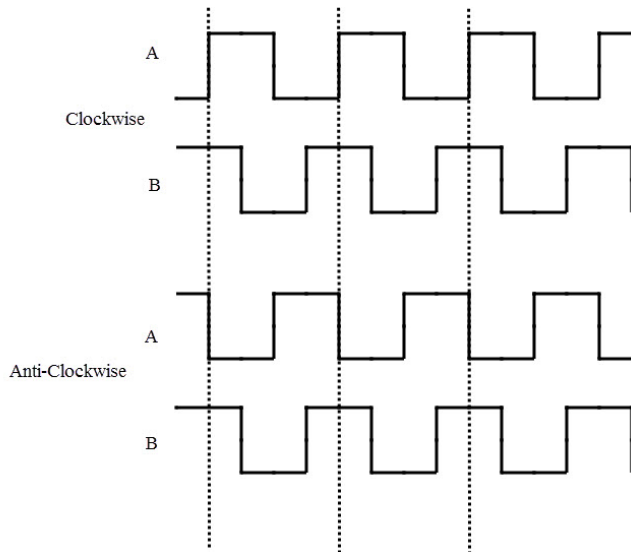
Pulse Width Modulation



Rotary Encoder Internal Operation



Rotary Encoder Output



Rotary Encoder Code

```
(onB && risingA) ? clockwise = 1 : clockwise = 0;  
(onB && fallingA) ? antiClockwise = 1 : antiClockwise = 0;
```

or

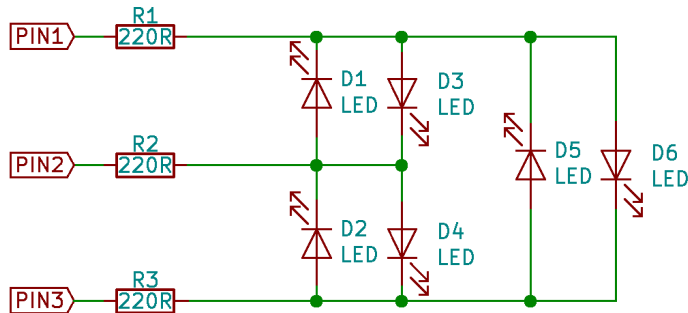
```
(onB && risingA) ? clockwise = 1 : clockwise = 0;  
(onA && risingB) ? antiClockwise = 1 : antiClockwise = 0;
```

or

```
(fallingA && onB) ? clockwise = 1 : clockwise = 0;  
(fallingA && offB) ? antiClockwise = 1 : antiClockwise = 0;
```

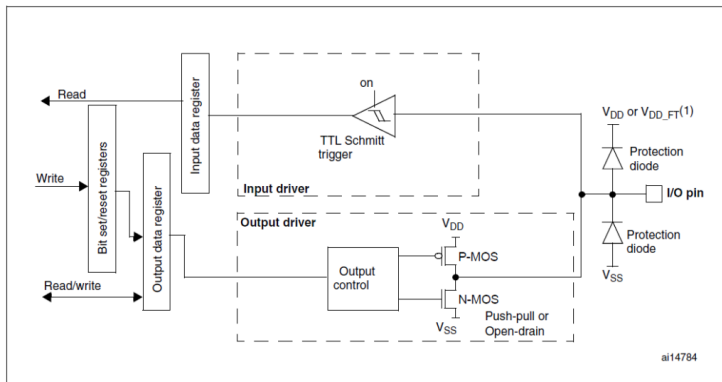
all are functionally identical, however last one can be pin interrupt driven

Charlieplexing vs Multiplexing

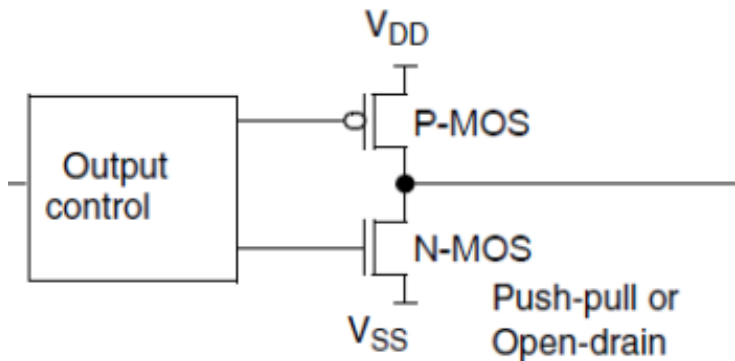


Charlieplexing: $\text{numLed} = p^2 - p$
Has to be scanned

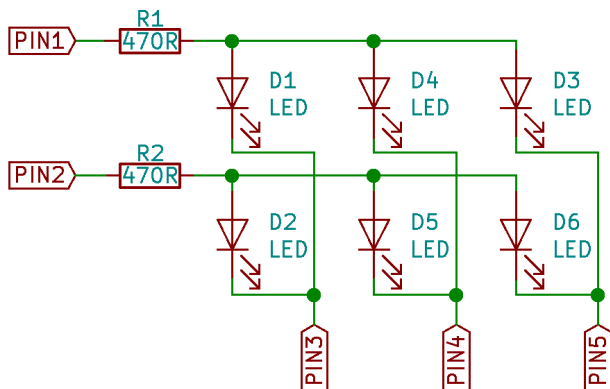
How to tristate a pin



How to tristate a pin



Charlieplexing vs Multiplexing



Multiplexing: $\text{numLed} = \left\lfloor \frac{p^2}{2} \right\rfloor$
Can be continuously driven

The End

Links to resources: [uC101/README.md](#)

Next month

- Breadboard to Printed Circuit Board
- Mechanical Design Considerations

Month after that

- You tell me!

Say Hello!

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Project Files: github.com/joshajohnson/CBRhardware