Sharp GP2Y0A21YK

- Infrared distance sensor
  - You will need 5V to power IR sensor
    - Needs 10 mF or larger +5V to Gnd cap for each sensor (supply stabilization)
  - Needs analog LPF
    - Reduces noise
    - Analog input protection
  - Needs digital median filter
  - Needs calibration

See Lecture 7
Ping Distance Sensor

- Ultrasound transducers to measure distance
  - Ping)))
    - One SIG pin for both input & output
  - HCSR04
    - Two signals: Trig output and Echo input
- Need 5V to power
  - Use 5V tolerant input (not all are)

Ping))) Sensor

- Sample 10 times a second
  1) Disable interrupts
  2) Make the SIG pin an output
  3) Issue a 5μs output pulse (causing a sound pulse)
  4) Switch the SIG pin back to an input
  5) Enable interrupts
  6) Measure time until the echo is received
    - Busy-wait if foreground, interrupt if background
HCSR04 Sensor

- Sample 10 times a second
  1) Disable interrupts
  2) Issue a 10μs output pulse (causing a sound pulse)
  3) Enable interrupts
  4) Measure time until the echo is received
     - Busy-wait if foreground, interrupt if background

Input Capture

- General purpose timers
  - TM4C123: 6 GP timers (Timer 0…Timer 5)
  - CCPx pins used for input capture
    - CCP0=PD4

- Input edge time (input capture) mode
  - Detect rising/falling input edges
  - Make time measurements on input signals

See book Section 8.1
Input Capture Mode

- Generate edge based interrupts
- Count events
- Measure period
- Measure pulse width

Figure 8.2. Rising or falling edge of CCP0 causes the counter to be latched into TAR, setting CAERIS.
Event Counting

- Count wheel turns (tachometer)

```
+3.3V
100Ω
R1

5kΩ
R2

+3.3V

V1

Microcontroller
Input capture

TLC2274 or OPA2350

V2

V1
2V

3.3V

light

V2
0V

Figure 8.4. Measured V1 and V2
```

Period Measurement

- **Init**
  - Select clock period, \( \Delta t \) (measurement resolution)
  - TIMERO_TAILR_R = 0xFFFF (reload=wraparound)
  - Choose edge (rise or fall)
  - Arm interrupt on capture

- **ISR**
  - Poll to see which channel (if needed)
  - Now = captured time (TIMERO_TAR_R)
  - Period = Last – Now
  - Last = Now
  - Acknowledge interrupt
  - Save/process period
Resolution, Precision, Range

- How to choose the resolution?
  - Determine minimum & maximum robot speed
  - Convert speed to tachometer period

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<td>Speed</td>
<td>211.2676</td>
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- How to detect speed too slow (period too large)?
  - Clear a counter on each tachometer edge
  - AddPeriodicThread
    - Increment the counter on each rollover 0000 to FFFF
    - If counter >= 2, then wheel is stopped

Ping Distance Measurement

- Input pulse width
  - Time $t_{IN}$ for sound to travel back and forth
  - $t_{IN} = 2 \frac{d}{c}$ (c: speed of sound)

- Measure using input capture
  - Rising edge: record TAR
  - Falling edge: calculate distance $d = c \times \frac{t_{IN}}{2}$
Motor Interfacing

- Motor physics
- Transistor-level interface

Ya Brain, who plugged this typewriter into our TV?

Pinky, are you pondering what I'm pondering?

Motor Physics

Electromagnet

Electrical Model

Wire

Magnetic Field, B
Electrical Current, I

Lecture 9
J. Valvano, A. Gerstlauer
EE445M/EE380L.6
Digital Interfacing

\[ V_{OL} \] is defined as the voltage at maximum \( I_{OL} \)

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<th>Family</th>
<th>Example</th>
<th>( I_{OH} )</th>
<th>( I_{OL} )</th>
<th>( I_{IH} )</th>
<th>( I_{IL} )</th>
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Electrical specifications
- See Chapter 24 of TM4C123
- 5V tolerant?
- \( P_{D0}, P_{D1} \rightarrow PB7, PB6 \)

Motor Interface

- Darlington transistor
  - TIP120 (NPN)
  - \( h_{fe} = 1000 \)
  - \( I_{ce} = 3A \)

\[ I_b = \frac{I_{col}}{h_{fe}} = \frac{1A}{1000} = 1mA \]
\[ R_b \leq \frac{(V_{OH}-V_{be})}{I_b} = \frac{(3-2.5)}{1mA} = 0.5 \Omega \]
\[ V_{CE} \text{ depends on current} \]

Pulse Width Modulation (PWM)
MOSFET Interface

- $V_{GS}$ turns on
- $V_{DS}$ small
- $I_{DS}$ large

![MOSFET Interface Diagram]

H-bridge Interface

- Both directions (forward & backward)
- $V_{OH} = +V - 1.4$, $V_{OL} = 1.2$
H-bridge Interface (V1)

- PWM controls power
- Out controls direction

H-bridge Interface (V2)

- One Port is PWM controlling power
- Other port controls direction
Pulse Width Modulation (PWM)

- Generate output waveform
  - Period = High + Low
  - Duty cycle = High / Period

- PWM generators
  - TM4C123: 2 modules
    - 4 generators per module
    - 2 PWM signals per generator

PWM Module

![PWM Module Diagram]
### TM4C123 Alternate Function

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### LaunchPad Board

Notice R9 and R10
PWM Channels

- Use PWM channel
  - Choose PWM outputs
  - Runs at 16-bit precision
  - Fix the period (10 times faster than time constant)
  - Prescaled clock determines resolution
    - high+low sets the precision
    - Choose as large as possible (prescale as low as possible)

- Example
  - 2 ms period, bus clock = 80 MHz
  - Prescale divide by 2, so clocks at 40 MHz, i.e. 25ns
  - high+low = 50000
  - Precision is 50000 alternatives or 16 bits
  - Duty cycle range is 0 to 100%
  - Duty cycle resolution is 100%/50000 = 0.002%

16-Bit PWM Output

```c
// period is 16-bit number of PWM clock cycles in one period (3<=period)
// duty is number of PWM clock cycles output is high (2<=duty<=period-1)
// PWM clock rate = processor clock rate/SYSCTL_RCC_PWMDIV
// = BusClock/2 (in this example)
void PWM0_Init(uint16_t period, uint16_t duty){
    volatile uint32_t delay;
    SYSCTL_RCC_PWMDIV_R |= 0x0001;  // 1) activate PWM
    SYSCTL_RCC_GPIO_R |= 0x0020;  // 2) activate port F
    delay = SYSCTL_RCC_GPIO_R;  // allow time to finish activating
    GPIO_PORTF_AFSEL_R |= 0x01;  // enable alt func on PF0
    SYSCTL_RCC_R |= SYSCTL_RCC_USEPWMDIV;  // 3) use PWM divider
    SYSCTL_RCC_R &= ~SYSCTL_RCC_PWMDIV_M;  // clear PWM divider field
    SYSCTL_RCC_R += SYSCTL_RCC_PWMDIV_2;  // configure for /2 divider
    PWM_0_CTL_R = 0;  // 4) re-loading mode
    PWM_0_GENA_R = (PWM_X_GENA_ACTCMPAD_ONE|PWM_X_GENA_ACTLOAD_ZERO);
    PWM_0_LOAD_R = period - 1;  // 5) cycles needed to count down to 0
    PWM_0_CMPA_R = duty - 1;  // 6) count value when output rises
    PWM_0_CTL_R |= PWM_X_CTL_ENABLE;  // 7) start PWM
    PWM_ENABLE_R |= PWM_ENABLE_PWM0EN;  // enable PWM0
}
void PWM0_Duty(uint16_t duty){
    PWM_0_CMPA_R = duty - 1;  // 6) count value when output rises
}
```

Lecture 9 J. Valvano, A. Gerstlauer EE445M/EE380L.6 25

PWM_4C123.zip
PWMDual_4C123.zip
Servo Motor

- Simple digital interface (built in controller)
- Duty cycle controls angle

Servo Interface

- Needs its own +5V regulator
- Duty cycle controls angle

[Diagram of servo motor and servo interface]
Servo Software

• Duty cycle controls angle

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<td>1.5mS</td>
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<tr>
<td>Maximum</td>
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<td>2.5mS</td>
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Robot Interfacing (Lab 6)

• Power design kit
  – Protoboard
  – Connector for battery
  – 7805 regulator
  – Socket for L293
  – Eight diodes
  – Two motor connectors (0.156in header)
  – Two 4.7uF electrolytic capacitors

*My project’s ready for grading, Dr. Big Nose... Hey! ... I’m talking to you, squid brain!*
Summary

- Be careful of the currents
- Sensors are noisy
- Time lag makes it unstable
- Component testing
- Visualization and control