ELEC327: Lecture 5

Low Power

Today

• Power measuring
• Low power modes

Measuring current consumption

• High side vs low side
  – Common mode voltage
  – “varying ground”
  – Short circuit?

Logistics

• No lectures next week!
• Next labs:
  – Low power (due 1/31)
  – Serial communications (due 2/7)
  – Midterm projects (demo 2/19)
Low-Power Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>CPU and Clocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>CPU active. All enabled clocks active</td>
</tr>
<tr>
<td>LPM0</td>
<td>CPU, MCLK disabled. SMCLK, ACLK active</td>
</tr>
<tr>
<td>LPM1</td>
<td>CPU, MCLK disabled. DCO disabled if not used for SMCLK. ACLK active</td>
</tr>
<tr>
<td>LPM2</td>
<td>CPU, MCLK, SMCLK, DCO disabled. ACLK active</td>
</tr>
<tr>
<td>LPM3</td>
<td>CPU, MCLK, SMCLK, DCO disabled. ACLK active</td>
</tr>
<tr>
<td>LPM4</td>
<td>CPU and all clocks disabled</td>
</tr>
</tbody>
</table>

Low-Power Operation

- Power-efficient MSP430 apps:
  - Minimize instantaneous current draw
  - Maximize time spent in low power modes
- The MSP430 is inherently low-power, but your design has a big impact on power efficiency
- Proper low-power design techniques make the difference

Low-Power Operation

- Power draw increases with...
  - Vcc
  - CPU clock speed (MCLK)
  - Temperature
- Slowing MCLK reduces instantaneous power, but usually increases active duty cycle
  - Power savings can be nullified
  - The ULP ‘sweet spot’ that maximizes performance for the minimum current consumption per MIPS: 8 MHz MCLK
    - Full operating range (down to 2.2V)
    - Optimize core voltage for chosen MCLK speed

System MCLK & Vcc

- Match needed clock speed with required Vcc to achieve the lowest power
- External LDO regulator required
- Unreliable execution results if Vcc < the minimum required for the selected frequency
- All G2xxx device operate up to 16MHz
Pin Muxing

- Each pin has up to four functions
- Top selection (above) is default
- Register bits (below) select pin function

<table>
<thead>
<tr>
<th>PIN (GPIO)</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>PB2</td>
<td>EN</td>
</tr>
<tr>
<td>PB3</td>
<td>EN</td>
</tr>
<tr>
<td>PB4</td>
<td>EN</td>
</tr>
<tr>
<td>PB5</td>
<td>EN</td>
</tr>
</tbody>
</table>

Unused Pin Termination

- Digital input pins subject to shoot-through current
  - Input voltages between VIL and VIH cause shoot-through if input is allowed to “float” (left unconnected)
- Port I/Os should
  - Driven as outputs
  - Be driven to Vcc or ground by an external device
  - Have a pull-up/down resistor

Lab 4

- Workshop Lab 6 - Convert ADC sampling code to “low power”
- Measure power using DMM
- Write a 0.5 Hz LED blink function for lowest and highest power. Document your measurement technique.

Universal Serial Communication Interface

- USCI_A0 supports:
  - SPI (3 or 4 wire)
  - UART
  - IrDA
- USCI_B0 supports:
  - SPI (3 or 4 wire)
  - I2C
**USCI Serial Protocols**

- **SPI**
  - Serial Peripheral Interface
  - Single Master/Single Slave

- **I2C**
  - Inter-Integrated Circuit Interface
  - Single Master/Multiple Slaves

- **UART**
  - Universal Asynchronous Receiver/Transmitter
  - Full duplex

**Software UART Implementation**

- A simple UART implementation, using the Capture & Compare features of the Timer to emulate the UART communication
- Half-duplex and relatively low baud rate (9600 baud recommended limit), but 2400 baud in our code (1 MHz DCO and no crystal)
- Bit-time (how many clock ticks one baud is) is calculated based on the timer clock & the baud rate
- One CCR register is set up to TX in Timer Compare mode, toggling based on whether the corresponding bit is 0 or 1
- The other CCR register is set up to RX in Timer Capture mode, similar principle
- The functions are set up to TX or RX a single byte (8-bit) appended by the start bit & stop bit


**USB COM Port Communication**

- Emulation hardware implements emulation features as well as a serial communications port
- Recognized by Windows as part of composite driver
- UART Tx/Rx pins match Spy-Bi-Wire JTAG interface pins