The Datasheet and Interfacing

EE3376
MSP430 Datasheet

MIXED SIGNAL MICROCONTROLLER

FEATURES
- Low Supply-Voltage Range: 1.8 V to 3.6 V
- Ultra-Low Power Consumption
  - Active Mode: 230 μA at 1 MHz, 2.2 V
  - Standby Mode: 0.5 μA
  - Off Mode (RAM Retention): 0.1 μA
- Five Power-Saving Modes
- Ultra-Fast Wake-Up From Standby Mode in Less Than 1 μs
- 16-Bit RISC Architecture, 62.5-ns Instruction Cycle Time
- Basic Clock Module Configurations
  - Internal Frequencies up to 16 MHz With Four Calibrated Frequency
  - Internal Very-Low-Power Low-Frequency (LF) Oscillator
  - 32-kHz Crystal
  - External Digital Clock Source
- Two 16-Bit Timer_A With Three Capture/Compare Registers
- Up to 24 Touch-Sense-Enabled I/O Pins
- Universal Serial Communication Interface (USCI)
  - Enhanced UART Supporting Auto Baudrate Detection (LIN)
  - IrDA Encoder and Decoder
  - Synchronous SPI
  - i²C™
- On-Chip Comparator for Analog Signal Compare Function or Slope Analog-to-Digital (A/D) Conversion
- 10-Bit 200-ksp Anlog-to-Digital (A/D) Converter With Internal Reference, Sample-and-Hold, and Autoscant (See Table 1)
- Brownout Detector
- Serial Onboard Programming, No External Programming Voltage Needed, Programmable Code Protection by Security Fuse
- On-Chip Emulation Logic With Spy-Bi-Wire Interface
- Family Members are Summarized in Table 1
- Package Options
  - TSSOP: 20 Pin, 28 Pin
  - PDIP: 20 Pin
  - QFN: 32 Pin
- For Complete Module Descriptions, See the MSP430x2xx Family User’s Guide (SLAU144)
## Modes of the MSP430

<table>
<thead>
<tr>
<th>Mode</th>
<th>SCG1</th>
<th>SCG0</th>
<th>OSC</th>
<th>CPU</th>
<th>GIE</th>
<th>Power Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Active Mode (this class)</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>250μA</td>
</tr>
<tr>
<td><strong>LPM0 (CPU asleep)</strong></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>35 μA</td>
</tr>
<tr>
<td><strong>LPM3 (only ACLK on)</strong></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1 μA</td>
</tr>
<tr>
<td><strong>LPM4 (sleep mode)</strong></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.1 μA</td>
</tr>
</tbody>
</table>
Clocks of the MSP430

- Oscillators
  - VLO
  - LFXT1
  - XT2 (if present)
  - DCO

- Selectors
  - LFXT1Sx
  - SELS

- Dividers
  - /1/2/4/8
  - DIVAx
  - DIVSx
  - DIVMx

- Clocks
  - ACLK (auxiliary clock)
  - SMCLK (sub-system master clock)
  - MCLK (master clock)

Peripheral connections:
- CPU and a few peripherals
- Other peripherals
# DC Power Specs of the MSP430

## Low-Power Mode Supply Currents (Into $V_{CC}$) Excluding External Current

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>$T_A$ (°C)</th>
<th>$V_{CC}$ (V)</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_{LPM0,1MHz}$</td>
<td>$f_{MCLK} = 0$ MHz, $f_{SMCLK} = f_{DCO} = 1$ MHz, $f_{ACLK} = 32768$ Hz, $BSCCTL1 = CALBC1_1MHZ$, $DCOCTL = CALDCO_1MHZ$, $CPUOFF = 1$, $SCG0 = 0$, $SCG1 = 0$, $OSCOFF = 0$</td>
<td>25°C</td>
<td>2.2 V</td>
<td>56</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{LPM2}$</td>
<td>$f_{MCLK} = f_{SMCLK} = 0$ MHz, $f_{DCO} = 1$ MHz, $f_{ACLK} = 32768$ Hz, $BSCCTL1 = CALBC1_1MHZ$, $DCOCTL = CALDCO_1MHZ$, $CPUOFF = 1$, $SCG0 = 0$, $SCG1 = 1$, $OSCOFF = 0$</td>
<td>25°C</td>
<td>2.2 V</td>
<td>22</td>
<td></td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{LPM3,LFXT1}$</td>
<td>$f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz, $f_{ACLK} = 32768$ Hz, $CPUOFF = 1$, $SCG0 = 1$, $SCG1 = 1$, $OSCOFF = 0$</td>
<td>25°C</td>
<td>2.2 V</td>
<td>0.7</td>
<td>1.5</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{LPM3,VLO}$</td>
<td>$f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz, $f_{ACLK}$ from internal LF oscillator (VLO), $CPUOFF = 1$, $SCG0 = 1$, $SCG1 = 1$, $OSCOFF = 0$</td>
<td>25°C</td>
<td>2.2 V</td>
<td>0.5</td>
<td>0.7</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>$I_{LPM4}$</td>
<td>$f_{DCO} = f_{MCLK} = f_{SMCLK} = 0$ MHz, $f_{ACLK} = 0$ Hz, $CPUOFF = 1$, $SCG0 = 1$, $SCG1 = 1$, $OSCOFF = 1$</td>
<td>25°C</td>
<td>2.2 V</td>
<td>0.1</td>
<td>0.5</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>85°C</td>
<td>2.2 V</td>
<td>0.8</td>
<td>1.7</td>
<td></td>
<td>µA</td>
</tr>
</tbody>
</table>

(1) All inputs are tied to 0 V or to $V_{SS}$. Outputs do not source or sink any current.
## Absolute Maximum Ratings

<table>
<thead>
<tr>
<th>Spec</th>
<th>MIN (°C)</th>
<th>NOM (°C)</th>
<th>MAX (°C)</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage applied at $V_{CC}$ to $V_{SS}$</td>
<td>-0.3</td>
<td>4.1</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Voltage applied to any pin</td>
<td>-0.3</td>
<td>$V_{CC}$ + 0.3</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Diode current at any device pin</td>
<td>±2 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storage temperature range, $T_{stg}$</td>
<td>-55</td>
<td></td>
<td>150</td>
<td>°C</td>
</tr>
<tr>
<td>Unprogrammed device</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programmed device</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

(2) All voltages referenced to $V_{SS}$. The JTAG fuse-blow voltage, $V_{FB}$, is allowed to exceed the absolute maximum rating. The voltage is applied to the TEST pin when blowing the JTAG fuse.

(3) Higher temperature may be applied during board soldering according to the current JEDEC J-STD-020 specification with peak reflow temperatures not higher than classified on the device label on the shipping boxes or reels.

## Recommended Operating Conditions

<table>
<thead>
<tr>
<th>Spec</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$: Supply voltage</td>
<td>1.8</td>
<td>3.6</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>During program execution</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>During flash programming/erase</td>
<td>2.2</td>
<td>3.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{SS}$: Supply voltage</td>
<td>0</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$T_{A}$: Operating free-air temperature</td>
<td></td>
<td></td>
<td></td>
<td>°C</td>
</tr>
<tr>
<td>Processor frequency (maximum MCLK frequency using the USART module)</td>
<td></td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>$V_{CC} = 1.8$ V, Duty cycle = 50% ± 10%</td>
<td>dc</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CC} = 2.7$ V, Duty cycle = 50% ± 10%</td>
<td>dc</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{CC} = 3.3$ V, Duty cycle = 50% ± 10%</td>
<td>dc</td>
<td>16</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Input DC Specs of the MSP430

## Schmitt-Trigger Inputs, Ports Px

Over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted).

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( V_{CC} )</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{IT+} )</td>
<td>Positive-going input threshold voltage</td>
<td>( 0.45 , V_{CC} )</td>
<td>( 0.75 , V_{CC} )</td>
<td>( 3 , V )</td>
<td>( 1.35 )</td>
<td>( 2.25 )</td>
</tr>
<tr>
<td>( V_{IT-} )</td>
<td>Negative-going input threshold voltage</td>
<td>( 0.25 , V_{CC} )</td>
<td>( 0.55 , V_{CC} )</td>
<td>( 3 , V )</td>
<td>( 0.75 )</td>
<td>( 1.65 )</td>
</tr>
<tr>
<td>( V_{hys} )</td>
<td>Input voltage hysteresis ( (V_{IT+} - V_{IT-}) )</td>
<td>( 3 , V )</td>
<td>( 0.3 )</td>
<td>( 1 )</td>
<td>( V )</td>
<td></td>
</tr>
<tr>
<td>( R_{Pull} )</td>
<td>Pullup/pulldown resistor ( (V_{IN} = V_{SS} ) )</td>
<td>( 3 , V )</td>
<td>( 20 )</td>
<td>( 35 )</td>
<td>( 50 )</td>
<td>k( \Omega )</td>
</tr>
<tr>
<td>( C_{I} )</td>
<td>Input capacitance</td>
<td>( V_{IN} = V_{SS} ) or ( V_{CC} )</td>
<td>( 5 )</td>
<td>p( \Omega )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Input Signal**

**Output Signal**

- **VT + max**
- **VT + min**
- **VT - max**
- **VT - min**

- **Switches High Here**
- **Vih**
- **Vil**

- **Switches Low Here**

---
Output DC Specs of the MSP430

**Outputs, Ports Px**

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( V_{CC} )</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{OH} ) High-level output voltage</td>
<td>( I_{OH_{\text{max}}} = -6 \text{ mA} ) (^{(1)})</td>
<td>3 V</td>
<td>( V_{CC} - 0.3 )</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( V_{OL} ) Low-level output voltage</td>
<td>( I_{OL_{\text{max}}} = 6 \text{ mA} ) (^{(1)})</td>
<td>3 V</td>
<td>( V_{SS} + 0.3 )</td>
<td>V</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^{(1)}\) The maximum total current, \( I_{OH_{\text{max}}} \) and \( I_{OL_{\text{max}}} \), for all outputs combined should not exceed \( \pm 48 \text{ mA} \) to hold the maximum voltage drop specified.

**Output Frequency, Ports Px**

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( V_{CC} )</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_{Px,y} ) Port output frequency (with load)</td>
<td>( Px,y ), ( C_L = 20 \text{ pF}, R_L = 1 \text{ k}\Omega ) (^{(1)}) (^{(2)})</td>
<td>3 V</td>
<td>12</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
<tr>
<td>( f_{\text{Port_CLK}} ) Clock output frequency</td>
<td>( Px,y ), ( C_L = 20 \text{ pF} ) (^{(2)})</td>
<td>3 V</td>
<td>16</td>
<td></td>
<td></td>
<td>MHz</td>
</tr>
</tbody>
</table>

\(^{(1)}\) A resistive divider with two 0.5-\( \text{k}\Omega \) resistors between \( V_{CC} \) and \( V_{SS} \) is used as load. The output is connected to the center tap of the divider.

\(^{(2)}\) The output voltage reaches at least 10% and 90% \( V_{CC} \) at the specified toggle frequency.
AC Specs of the HCS12 (I2C example)

USCI (I2C Mode)

Over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted) (see Figure 20)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>$V_{CC}$</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{USCI}$ USCI input clock frequency</td>
<td>SMCLK, duty cycle = 50% ± 10%</td>
<td>3 V</td>
<td>0</td>
<td>400</td>
<td>MHz</td>
<td></td>
</tr>
<tr>
<td>$f_{SCL}$ SCL clock frequency</td>
<td></td>
<td>3 V</td>
<td>0.6</td>
<td></td>
<td>kHz</td>
<td></td>
</tr>
<tr>
<td>$t_{HD,STA}$ Hold time (repeated) START</td>
<td>$f_{SCL} \leq 100$ kHz</td>
<td>3 V</td>
<td>4.0</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f_{SCL} &gt; 100$ kHz</td>
<td>3 V</td>
<td>0.6</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>$t_{SU,STA}$ Setup time for a repeated START</td>
<td>$f_{SCL} \leq 100$ kHz</td>
<td>3 V</td>
<td>4.7</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$f_{SCL} &gt; 100$ kHz</td>
<td>3 V</td>
<td>0.6</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>$t_{HD,DAT}$ Data hold time</td>
<td></td>
<td>3 V</td>
<td>0</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>$t_{SU,DAT}$ Data setup time</td>
<td></td>
<td>3 V</td>
<td>250</td>
<td></td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>$t_{SU,STO}$ Setup time for STOP</td>
<td></td>
<td>3 V</td>
<td>4.0</td>
<td></td>
<td>μs</td>
<td></td>
</tr>
<tr>
<td>$t_{SP}$ Pulse width of spikes suppressed by input filter</td>
<td>3 V</td>
<td>50</td>
<td>100</td>
<td>600</td>
<td>ns</td>
<td></td>
</tr>
</tbody>
</table>

Figure 20. I2C Mode Timing
Sensors / Transducers

- Convert physical quantity into electrical voltage (analog)
  - temperature
  - position
  - pressure
  - flow
  - humidity
  - velocity
  - acceleration
  - rotation
  - light
  - smoke
  - motion detection
Thermistors / Thermocouples

- Convert temperature into electrical voltage (analog)
  - Thermistor – some material’s resistance change with temperature
  - Thermocouple - two different metals are spot welded together causing a voltage between them proportional to temperature
Example: Honeywell 40PC Series

These miniature pressure sensors are fully compensated and amplified.

The 0.5 V to 4.5 V analog output voltage signal is linearly proportional to input pressure. These devices operate on a single end supply voltage of 5.0 Vdc.
Dipswitches and Push Buttons

- HCS12
- ph0
- ph1
- ph2
- ph3
- ph4
- ph5
- ph6
- ph7

100k ohms
4.7k ohms
Rotary Encoders

Amount of rotation translated into 3 bit number
Keypads

HCS12

pa0
pa1
pa2
pa3
pa4
pa5
pa6
pa7

J29

optional external keypad
Actuators

- Convert electric voltages into physical quantities
  - heaters
  - micro-propulsion (ink jet)
  - displacement
  - pumps
  - valves
  - LEDs
  - gauges
  - motors
    - DC Motors (PWM)
    - Servo Motors (PWM)
    - Stepper Motors (GPIO)
Solenoids and Relays

- Use electromagnet to control large mechanical plunger
- Used to allow a small current to control a large current
Relays

- One signal (small) controls another signal (large)
- Either Electromagnetic or Solid State (no moving parts)
  - Solid State more reliable and faster
  - Mechanical – possible more current handling capability
- Number of Poles describes number of switches controlled
  - Single Pole – one switch
  - Double Pole – two switches
  - Triple Pole – three switches
- Number of Throws describes number of contacts per switch
  - Single Throw – two contacts either opened or shorted
  - Double Throw – three contacts with one common
Relays – Single Pole / Single Throw Normally Open
Relays – Single Pole / Single Throw Normally Closed
Relays – Single Pole / Double Throw
Relays – Double Pole / Single Throw Normally Closed
Relays / Buffers / Tristates / Line Drivers

- Integrated circuits that can be used to re-drive signals
- driving different voltages (0-5V TTL to 0-12V RS232)
- adding tristate capability (e.g. multi-master access)

Hex buffer/line driver; 3-state

74HC/HCT367

<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>SYMBOL</th>
<th>NAME AND FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 15</td>
<td>1OE, 2OE</td>
<td>output enable inputs (active LOW)</td>
</tr>
<tr>
<td>2, 4, 6, 10, 12, 14</td>
<td>1A to 6A</td>
<td>data inputs</td>
</tr>
<tr>
<td>3, 5, 7, 9, 11, 13</td>
<td>1Y to 6Y</td>
<td>data outputs</td>
</tr>
<tr>
<td>8</td>
<td>GND</td>
<td>ground (0 V)</td>
</tr>
<tr>
<td>16</td>
<td>VCC</td>
<td>positive supply voltage</td>
</tr>
</tbody>
</table>
Transceivers

- Chips for comm
  - Ethernet
  - RS232
  - Wireless RF
  - Modem

Figure 13. Manual Port Select with Seeq 8005 Controller

Bias resistor RB1# should be located close to the pin and isolated from other signals.
Displays

- Actuator (output) for human interface
  - can be as simple as several BCD digits with 7 segment display
    ● to display temperature
    ● to display velocity
  - can be rows of ASCII encoded characters (LCD)
    ● LCD with integrated controller
      - sends data either serially or in parallel
    ● to display more sophisticated message to user
      - “divide by 0”
      - “pump backflow”
      - “completed successfully”
  - can be flat panel screen with 16 bit color (320x240 TFT LCD)
    ● to display video
    ● to provide a graphical user interface
7 segment display
Hantronix on the Dragon Board

- RS – selects between commands and data
- EN – Falling edge causes data to be sampled
- RW – selects between reading and writing (we always read)
- Data – 8 bits (of which we use 4 in the launch pad board)

HCS12 to 16 x 2 LCD:
- RS – selects between commands and data
- EN – Falling edge causes data to be sampled
- RW – selects between reading and writing (we always read)
- Data – 8 bits (of which we use 4 in the launch pad board)

Diagram: HCS12 connected to 16 x 2 LCD with pins labeled RS, EN, Data, and RW.
Hantronix on the Dragon Board

*Display on a 16x2 Character Module

* Display Character Position and DDRAM Address of a 16x2 Character Module.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>00</td>
<td>01</td>
<td>02</td>
<td>03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0D</td>
<td>0E</td>
<td>0F</td>
</tr>
<tr>
<td>Second</td>
<td>40</td>
<td>41</td>
<td>42</td>
<td>43</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4D</td>
<td>4E</td>
<td>4F</td>
</tr>
</tbody>
</table>

DDRAM Address
Hantronix Timing

PK0
PK1
PK2-5

Tied
Low

Figure 1. Write Timing Operation
### Table 2. Bus Timing Electricals

<table>
<thead>
<tr>
<th>Spec</th>
<th>Symbol</th>
<th>Min</th>
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<th>Max</th>
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<tr>
<td>Enable pulse width (high level)</td>
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<td>Enable rise and decay time</td>
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<td>Data hold time (read)</td>
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<tr>
<td>Address hold time</td>
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Motors

- Check out On-Line Tutorials
  - Motorola
  - Electronics Information Online (www.eoi.com)
- All but the smallest cannot be driven by MSP430
  - MSP430 IO can only drive ~50 mA, most motors draw 100 mA
  - Motors are inductive
    - Current cannot be immediately stopped
    - Possible to generate back EMF – similar to spark plug (unintentional)
  - Must be driven by H-Bridge Circuit
- DC Motors
- Servo Motors
- Stepper Motors
- AC Motors (not usually used with microcontrollers)
DC Motors

- Can not be driven by HCS12
  - Must be driven by H-Bridge Circuit
- Speed is dependent on load
  - Must have feedback control
- Controlled by PWM
  - duty cycle is proportional to speed
Servo Motors

- DC Motor integrated with feedback circuit
- Typically 180 degrees of rotation – turn stop
- Precise
- Applications:
  - Robotics
    - arm movement
    - clamp
  - Camera / Telescope tilt
  - Rudder for remote control boat
- Controlled by PWM at 60 Hz
Stepper Motors

- Can not be driven by HCS12
- Precise Rotation Control
- Speed is not dependent on load
  - does not require feedback control
  - assuming no slipping
- Controlled by digital sequence
Steppers - Half Step Phase Sequencing

Phase 1

Stepper Motor Operation (Unipolar, Half step)
H-Bridge Circuit for driving Motors

- **TIP110**
- **1N4004**
- **7486**
- **Control Inputs**
- **Polarity Table**:

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