Analog Signal Acquisition
The A/D converters
Lecture Overview

- Analog signal acquisition
- The A/D Converters on the 68HC11

REF: Chapters 7 and 8 plus the 68HC11 reference manual.
Analog signals

☐ Analog output is typical of most transducers and sensors.

☐ Need to convert these analog signals into a digital representation so the microcontroller can use it.

☐ Some characteristics of analog signals.
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  - Maximum and minimum voltages
  - Precise continuous signals
  - Rate of voltage change
  - Frequency if not a steady state signal
The ideal transfer function of a 3-bit ADC

Full-scale (input voltage) range (FSR)

Analog signal is continuous

Digital – finite and discrete

- In general n-bit converter
- Total of $2^n$ output codes
Quantization Error and FS

- The smallest input change that can be detected.
- In the 3 bit example it would be 1 Volt and defines the converters LSB accuracy.

- Another term – Full Scale input – the largest analog voltage that a converter can detect. Voltages greater than the FS input will result in a converted value of 111---11.

- Similarly inputs less than the minimum input voltage result in 000---00.
Quantization Error of the 68HC11

- Graphical view
- Note how discrete values represent the analog signal
The 68HC11

- The 68HC11 has an 8 bit A/D converter which results in 256 possible digital output values.
- The resolution = FSR/256
- The FSR of the 68HC11 is 0 to 5.12V so the resolution is 20mV/1bit
  - $5.12V/256 = 0.02031 \text{ V/bit} = 20.3 \text{ mV/bit}$
  - Meaning – input change of 20mV changes LSB
68HC11 ADRs

- 68HC11 has 4 A-to-D conversion registers
- When a conversion is done, result is placed in one of the ADRx registers, where x is 1 to 4.
The output-input characteristic equation of an ADC

\[ D = \frac{1}{\text{resolution}} V_m \]

Where \( D \) is the decimal value of the output word and \( V_m \) is the measured voltage.

Example (from Ex 7.3)

The input voltage is 2.56V – what is the converted digital value?

Output

- \( D = \frac{1\text{bit}}{20\text{mV}} \times 2560\text{mV} = 128 \)
- Converting to binary gives \( 1000\ 0000 \) which will be stored in one of the 4 result registers.
Port E and ADR addresses

- When using Port E as a digital port the port is accessed through address $100A
- The A/D control register, ADCTL, is at address $1030
- The ADR registers are at addresses – these are read only registers.
  - ADR1 - $1031
  - ADR2 - $1032
  - ADR3 - $1033
  - ADR4 - $1034
To use the A/D converter on the 68HC11 the users only needs to write to ADCTL for the CPU to read results from the register. There are 8 A/D channels but only 4 results from one of the two groups of 4 can be stored at any one time.

Could also use the 4 registers to save 4 conversions from one input pin.

ADCTL register – controls how the A/D converter works and how the registers are used.
The bits in the control register

- Bit 7 – Conversion complete – a read only bit
  - Cleared any time the control register written to
  - Set when the A/D completes the 4\textsuperscript{th} conversion and results stored in registers.
  - Conversion starts immediately after a write to this register. If a conversion was in progress it is aborted to allow the initiation of the new conversion.
  - When set up for continuous conversion results are updated automatically.
Control register continued

- Bit 6 – unused
- Bit 5 – SCAN
  - Value of 0 – single conversion mode – conversion takes place after a write to the register.
  - Value of 1 – continuous conversion mode – conversions take place in round robin mode on the enabled analog input pins.
- Bit 4 – Multiple/Single Channel Control (MULT)
  - Value of 0 – Single channel – Consecutive conversions results are stored in consecutive ADRx registers
  - Value of 1 – each pin in the group is converted and the result stored in the ADR register.
More on control register

- Bits 3,2,1,0 – Channel select bits
  - For the 48-pin package – only 4 A/D inputs
  - How the CD, CC, CB, CA control bits work
- The MULT bit says
  - 1 channel or all 4
- Table lists specific group and pin(s)

<table>
<thead>
<tr>
<th>CD</th>
<th>CC</th>
<th>CB</th>
<th>CA</th>
<th>Port E</th>
<th>Result Register</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>PE0</td>
<td>ADR1</td>
</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>PE1</td>
<td>ADR2</td>
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<td>1</td>
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<td>ADR4</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>PE7</td>
<td>ADR4</td>
</tr>
</tbody>
</table>
Example of interface setup

- What configuration is needed in the ADCTL register for the A/D to convert continuously group 0?

- **Solution:** Bits 7 and 6 are don’t cares

- Bit 5 = 1 convert continuously

- Bit 4 = 1 group of 4 channels

- Bits 3 and 2 = 00 group 0, PE0-3

- Bits 1 and 0 are not used.

- Value of **xx11 00xx** or could store **0011 0000**

- $30
Setup example 2

- What value needs to be written to the ADCTL register to have continuous conversions of pin PE0? What assembler language instructions would you use to set up this?

- Set ADCTL as follows:
  - Bits 7 and 6 – don’t cares
  - Bit 5 – 1 convert continuously \( \text{val} = 0010\ 0000 \)
  - Bit 4 – 0 single channel
  - Bit 3,2,1,0 – 0000 the value for PE0

- The assembler code (assumes A accumulator is free)
  - LDAA \#20
  - STAA \$1030
Example 3

- Your system has 2 analog sensors. You only need to acquire the value of a given sensor at certain points. How would this be set up.
- Probably through subroutines.
- Specifications of the problem
  - Sensor 1 – on pin PE0-ADR1
  - Sensor 2 – on pin PE1-ADR2
- The valx values for the code
  - val1 – 0010 0000
  - val2 – 0010 0001
- How is the A/D being set up for conversion?
  - Could also be done with 0000 0000 and 0000 0001
Signal setup for A/D use

- The 68HC11 needs 2 reference input voltages.
  - A low voltage reference – $V_{RL}$ – pin 51
  - A high voltage reference – $V_{RH}$ – pin 52
- To prevent damage the analog input signals must be current limited.
  - Input current should not exceed 25mA
- Connect signal through a resistor of value 1kΩ to 10kΩ
Input sensors

- Transducers, such as pressure, temperature, and acceleration, covert the physical quantity being monitored into and output of voltage, current, or resistance.

- To get the signal to the 68HC11 the signal needs to be a voltage.

- A simple connection for the LM335 temperature sensor can be accomplished.
  - Application circuit from Jameco page.
Lecture summary

- Use of the 68HC11 A to D converter
  - Basic setup of use
  - The A/D configurations
  - Software setup
  - Interfacing signals
Assignment

- None