

ECE 216

Microprocessors, Microcontrollers and Data Conversion

January 14, 2010

Course Objective

- This course is an introduction to both the data conversion process and the hardware and software aspects of μ processors and μ controllers.
- At the end of this course you should have a good handle on the following:
 - The specifications and operational characteristics of the μ controller subsystems including: Transducer interfaces, ADC, DAC, S/H, MUX, timer/counters, PWM, Comparators, communication interfaces
 - μ controller organization and operation
 - How to develop an embedded controller system for your specific application.
 - Understand the operation of a few communication interfaces; CAN, IEEE488, etc.

First let's go over the course
LOGISTICS

Course Logistics

- **Prerequisites:** ECE112 and ECE113 or permission of the instructor.
- **Basis for grade:**
- homework assignments (25%)
- tests/exams (25%)
- lab write-ups (25%)
- final project demonstration & write-up (25%)

Course Logistics

- Late assignments will not be accepted. Please don't push it. Hand in what you'd done and accept the consequences.
- I will reward results. I'm not interested in how hard you push on a wall, I want to look down and see how far it has been moved.
- If you find an error in a graded homework or lab, please address it within 7 calendar days – otherwise forget it.

Course Logistics

- **Academic Honesty**: Complete policy and information available at www.rochester.edu/college/honesty/.
- **Reading Period**: Begins April 29, 2010. No exam will be given in reading period.
- **Tutoring Assistance**: Please, if you are having difficulty in some topic, please discuss this with the instructor or one of the TA's

Course Logistics

- **Website for Course:**

www.ece.rochester.edu/courses/ECE216/

- **Instructor:** Vic Derefinko:

- Office: Hopeman 305; Office hours – by appointment
- Telephone: 59402
- Email: derefinko@ece.rochester.edu

- **Teaching Assistants:**

- Erica Gelb
- Paul Molta
- Sarah Rosenstein
- TBD

Course Logistics

- **Lectures:**

- Tue and Thurs - 6:15 PM to 7:30 PM
- CSB 523

- **Lab:**

- Wed. (Noon to 5:00 PM)
- Hopeman 202

- **Text:**

- I'm not sure about the text yet. We may end up with a series of handouts on the various subjects that are discussed, or if I find a text, then we will use that.
- One good reference is a book by Martin Bates called "PIC Microcontrollers". Cost is ~ \$20 for a paperback copy. It is really a compilation of info from data sheets.

Syllabus

- Syllabus is on the ECE216 website. It may not be exact, but it give you an idea of the material we will cover and the time frame in which it will be covered.
- There will be ~ 25 lectures with topics delineated in the syllabus.
- There will be about 3 or 4 tests/exams sprinkled in to give you an opportunity to demonstrate what you've learned.
- There will be 14 lab sessions; approximately 7 or 8 will be devoted to projects you will be asked to perform.
- The remaining sessions will be a project you will identify, propose, design/analysis, build/debug, demonstrate, and document.

????? Any Questions ??????

- + Syllabus??
- + Grading??
- + Lectures??
- + Lab Hours??
- + Anything??

First a little background information

What is the difference between a
Microprocessor and a
Microcontroller???

μ processors vs μ controllers

- A μ processor is essentially a computer on a chip consisting of a processor, memory, and I/O ports.
- A μ controller is a device that integrates the key components of a μ processor on a chip along with other modules such as Serial I/O, Counter/Timers, ADC's, DAC's, PWM's, comparators, and one or more of a large number of specialized devices such as CAN controllers, IEEE488 interface, etc.

Introduction

- μ controllers are very widely used, finding applications in everything from toys to automobiles to industrial applications.
- μ controllers are incredibly cheap, with some as inexpensive as < 50 cents.
 - As a result, they can be devoted to a single application.

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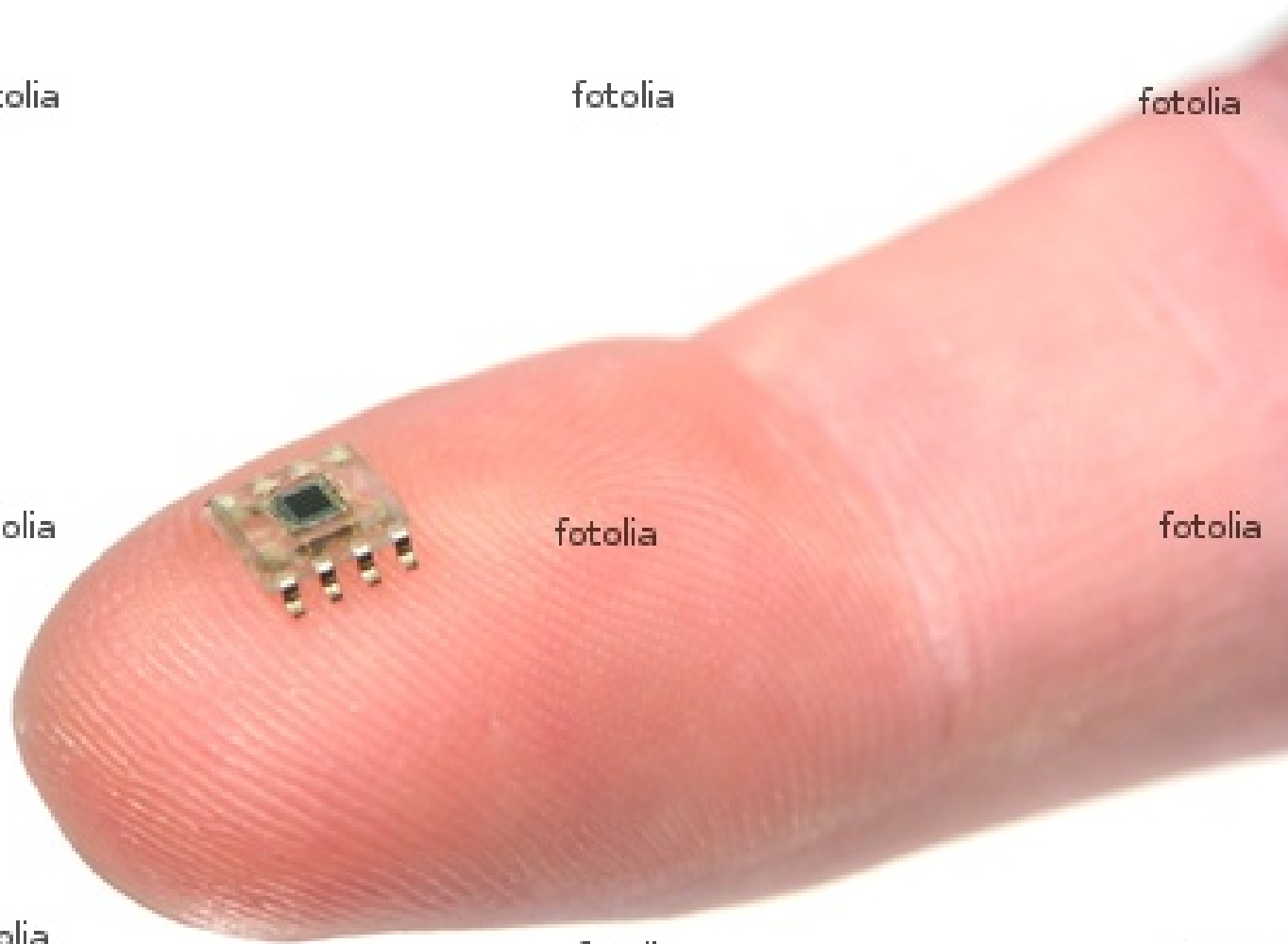
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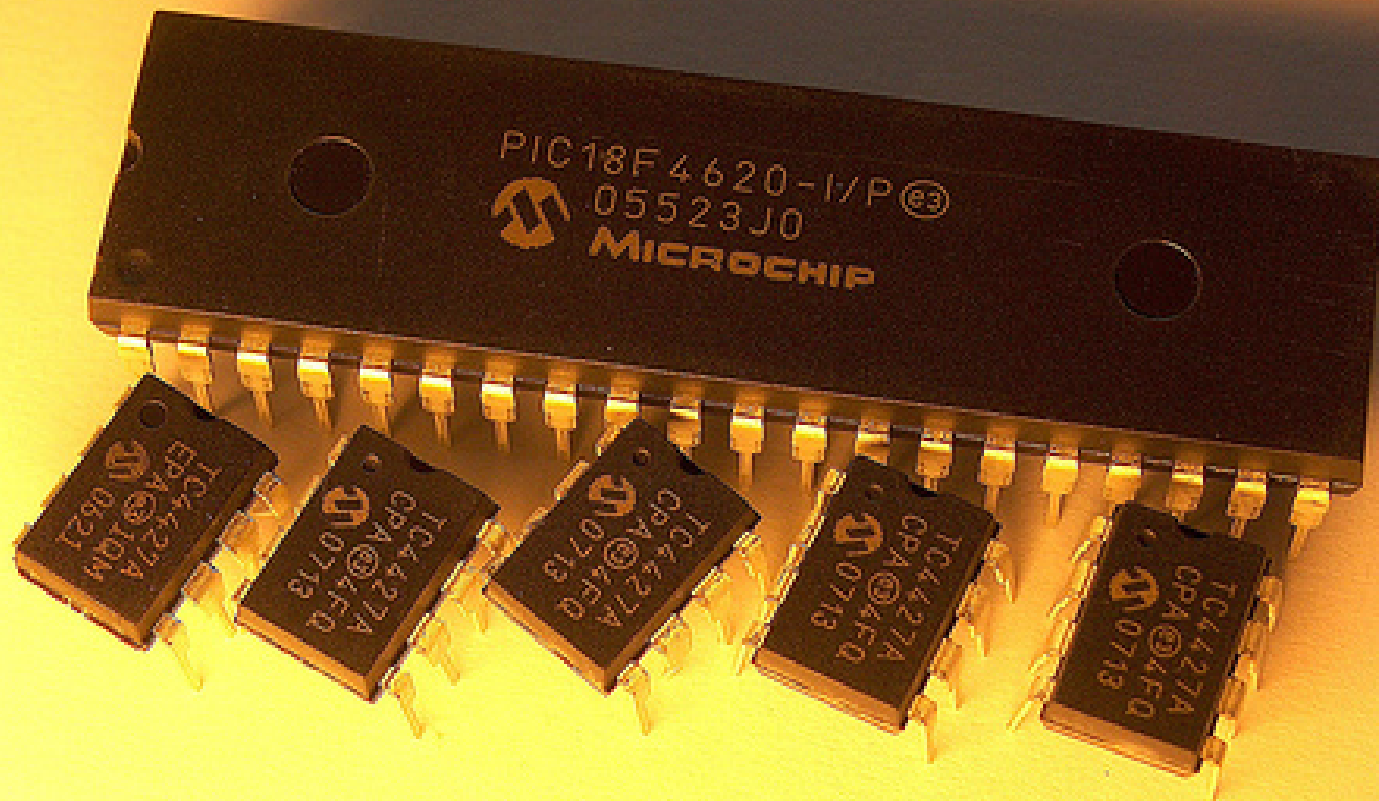
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Embedded systems overview

- Computing systems are everywhere
- Most of us think of “desktop” computers
 - PC’s 
 - Laptops 
 - Mainframes
 - Servers
- But there’s another type of computing system
 - Far more common...

Embedded systems overview

- Embedded computing systems
 - Computing systems embedded within electronic devices
 - Nearly any computing system other than a desktop computer is an embedded controller
 - Tens of Billions of units produced yearly, versus millions of desktop units
 - Perhaps 50-to-100 per household and per automobile

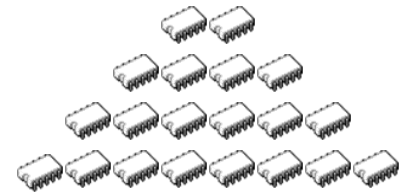
Computers are in here...



and here...



and even here...



Lots more of these,
though they cost a lot
less each.

A “short list” of embedded systems

Anti-lock brakes
Auto-focus cameras
Automatic teller machines
Automatic toll systems
Automatic transmission
Avionic systems
Battery chargers
Bomb fuses,
Camcorders
Cell phones
Cell-phone base stations
Cordless phones
Cruise control
Curbside check-in systems
Digital cameras
Disk drives
Electronic card readers
Electronic instruments
Electronic toys/games
Entertainment systems
Factory control
Fax machines
Film Based cameras
Flashlights
Fingerprint identifiers
Golf clubs
Golf Balls
Home security systems
Life-support systems
Medical testing systems

Modems
MPEG decoders
Network cards
Network switches/routers
On-board navigation
Pagers
Photocopiers
Point-of-sale systems
Portable video games
Printers
Ranges
Refrigerators
Satellite phones
Scanners
Shoes
Smart ovens/dishwashers
Speech recognizers
Sports Equipment
Stereo systems
Teleconferencing systems
Televisions
Temperature controllers
Theft tracking systems
Toothbrushes
Toys
Traffic Control systems
TV set-top boxes
VCR's, DVD players
Video game consoles
Video phones
Washers and dryers



And the list goes on and on and on

Show example here

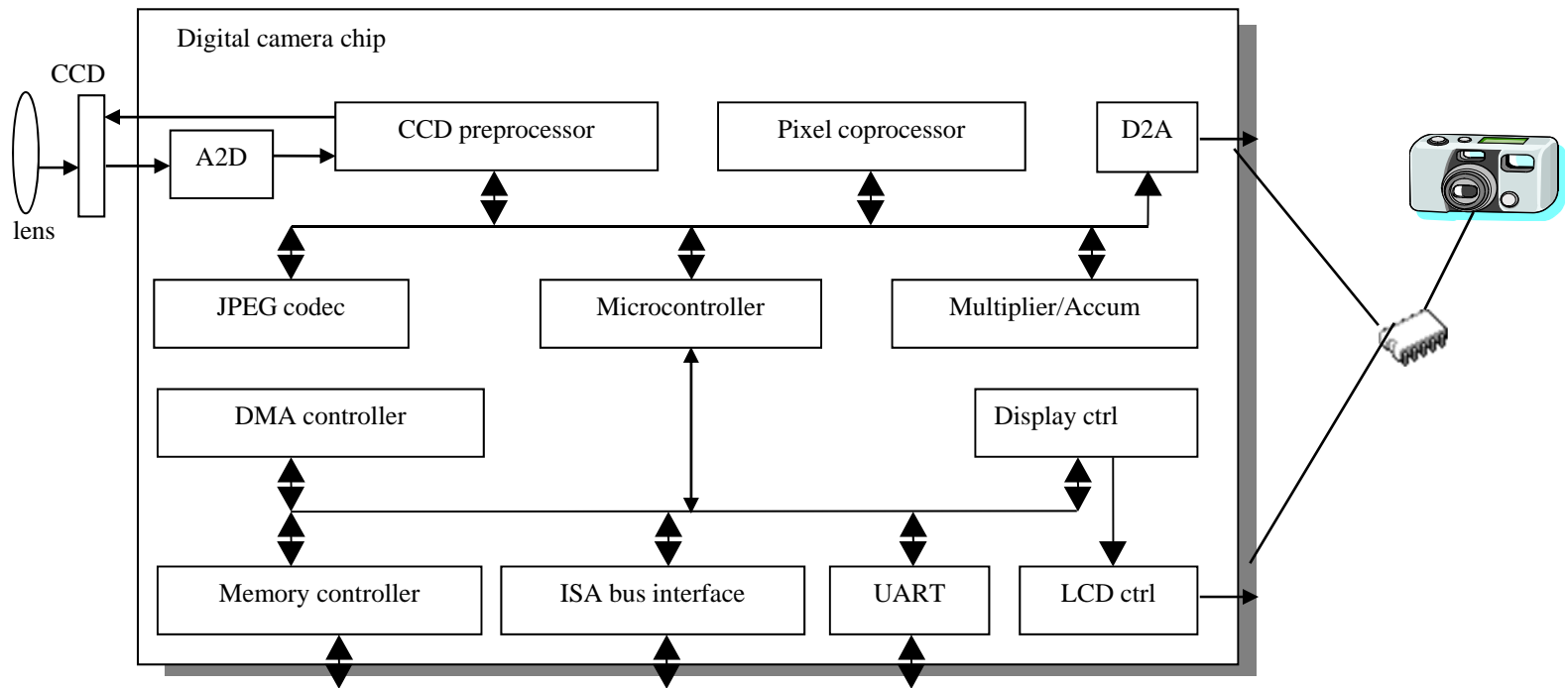
Some common characteristics of embedded controller systems

- Typically single-functioned
 - Executes a single program, repeatedly
- Tightly-constrained
 - Low cost (<\$0.5), low power (μw), small (mm), fast ($\sim 100\text{MHz}$), etc.
- Reactive and real-time
 - Continually reacts to changes in the system's environment
 - Must compute certain results in real-time without delay

Common Characteristics (con't)

- The devices are “computers on chip”.
- It is generally not necessary to add external memory or other IC's to support the μ controller (but IF circuitry to transducers is required)
- They contain almost everything that is needed to make them a functional computer on a chip.
- They are especially useful in creating extremely small, complex devices that perform a specific function.

An embedded system example -- a digital camera



- Single-functioned -- a digital camera and/or functions within the camera
- Tightly-constrained -- Low cost, low power, small, fast

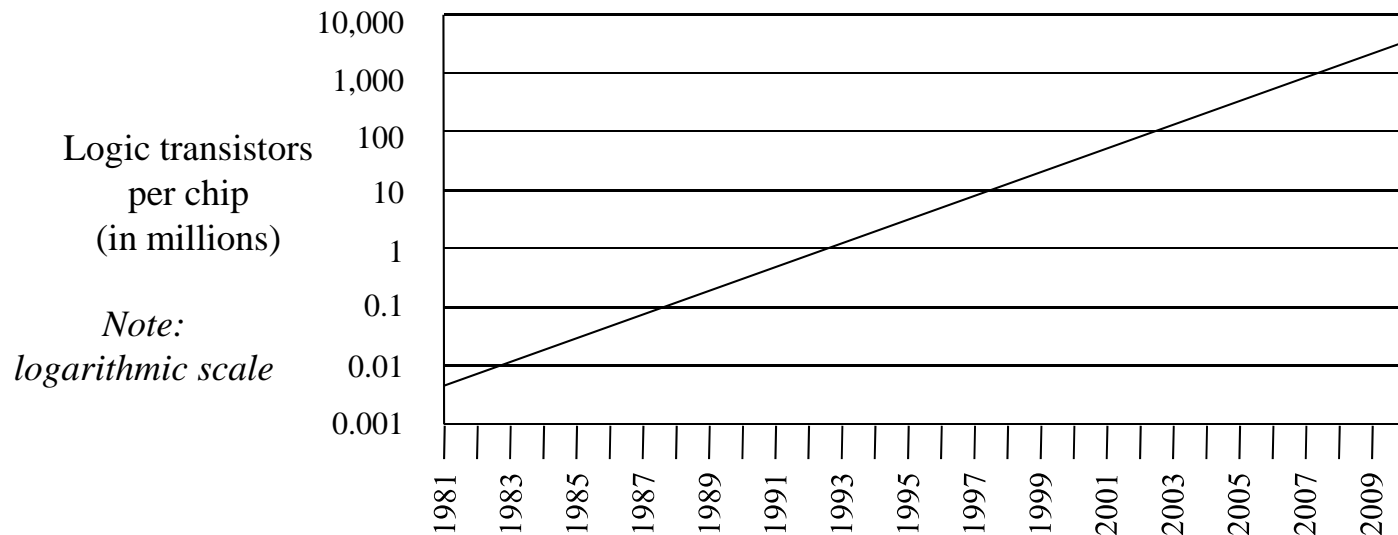
Factors that are driving the proliferation of microcontrollers

- More and more applications
 - Volumes are driving cost reductions
- New technologies reducing
 - Size
 - Power dissipation
- And increasing
 - Operating speed
 - Memory
 - I/O

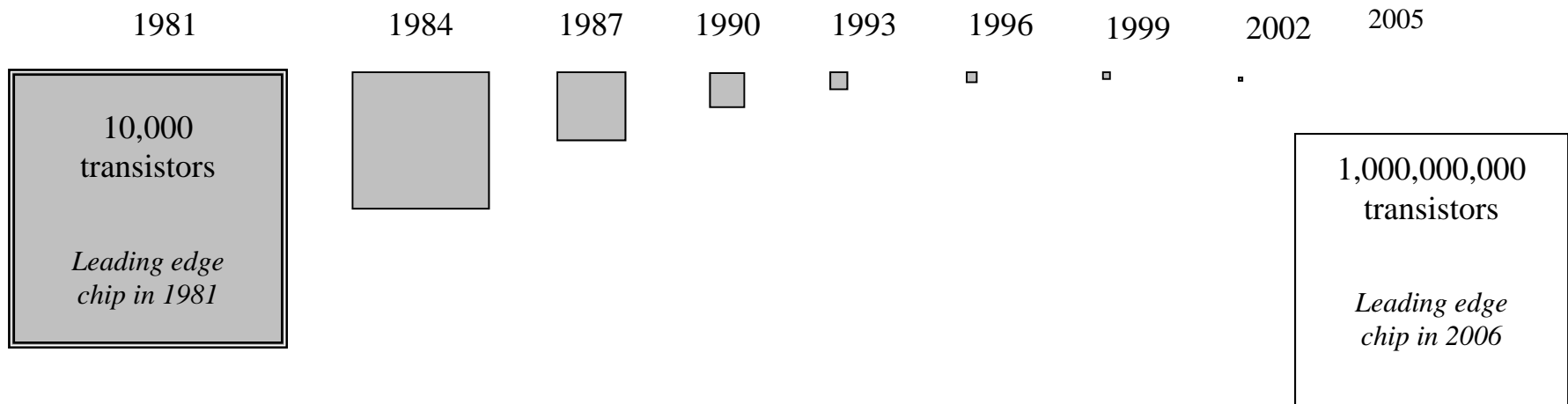
Moore's law

- The most important trend in embedded systems
 - Predicted in 1965 by Intel co-founder Gordon Moore

IC transistor capacity has doubled roughly every 18 months for the past several decades



Graphical illustration of Moore's law



- Something that doubles frequently grows more quickly than most people realize!
 - A 2006 chip can hold about 100,000 1981 chips inside itself

Road Map for the Course



Course Material

- The course will cover all the essential elements necessary to interface the “real world” to a μ controller – both with inputs to the μ controller and outputs from the μ controller.

Course Material (con't)

- To accomplish this, we will discuss the following:
 - Analog transducer interfaces
 - Analog-to-Digital and Digital-to-Analog conversion process
 - The digital data manipulation and control performed by a embedded μ controller
 - Programming techniques (flowcharts, programs, documenting code, etc.)
 - Assembly language programs.
 - High level language programs.

Course Material (con't)

- **Review Basic Electrical Concepts**
 - Transducer Interfaces
 - Signal Conditioning (Analog)
 - Buffers
 - Filters
 - Amplifiers
 - Level Shifters

Course Material (Con't)

Discuss the Basic Processor Interface Devices

- Sample/hold devices
- Multiplexer/Demultiplexer
- Analog-to-Digital Converters
- Digital-to-Analog Converters

Course Material (Con't)

Investigate μ controller Basics

- Structure
- Components
- Language / Instruction sets
- Operations
- Interfaces
- Interrupt Structures

Course Material (Con't)

Look at a μ controller in Detail

- **Discuss/compare the attributes of a few μ controllers**
- **Microchip PIC (2 or 3 different devices)**
- **Motorola 68HC11/12**
- **Siemens 8051**

Course Material (Con't)

Discuss Bus Structures

Operational characteristics and Protocol

- IEEE 488 - GPIB (General Purpose IF Bus)
- ISO 11898 - CAN (Controller Area Network)
- USB 2.0 - (Universal Serial Bus)

Lab Projects

- 1 Analog Circuit Study – Thermal Measurement System. (practice with IF's and scaling)
- 2 Sample and Hold Investigation
- 3 Digital-to-Analog Converter
- 4 Analog-to-Digital Converter
- 5 PIC μ controller 16F84A (Tutorial with I/O)
- 6 PIC μ controller 12F675 (ADC operations)
- 7 PIC μ controller Application (Optical system)
- 8 PIC μ controller Application (stepper motor)
- 9 Student Project using PIC μ controller

Comments on the Lab Sessions

- Lab projects should take about 2 ½ to 3 hours.
- I scheduled a 5 hour block to minimize conflicts.
- You can do a significant part of the lab outside of class; calculations, analysis, building, etc.
- You only have to come to the lab to get help with the lab as needed, or to demonstrate the lab operation to the instructor.
- I want everybody (each team) to demonstrate the lab to me so I have the opportunity to see the quality of your work.

Comments on the Lab Sessions

- You will be asked to do some of the soldering and fabrication of leads onto devices, etc., yourselves.
- Again let me emphasize: I want everybody (each team) to demonstrate the lab to me so I have the opportunity to see the quality of your work.

????? Any Questions ?????

- + Syllabus??
- + Grading??
- + Lectures??
- + Lab Hours??
- + Anything??

Analog Circuits Review

- Lets begin with a review of Transducers and analog circuits used to serve as interfaces to transducers and conversion devices.
- Reference material will be on website (since no text assigned)

Website for the course is

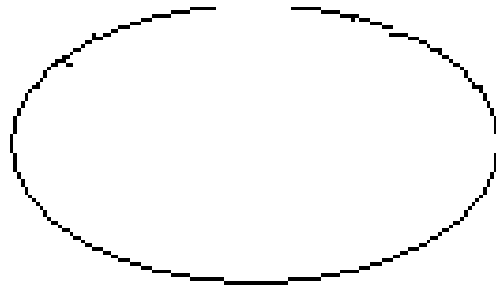
www.ece.rochester.edu/courses/ECE216

- Reference information will be put on the website in the SYLLABUS section of the site.
- I will assign homework and will do some of the problems in class as necessary. (Or better yet, I may have one of you folks do a problem or two).

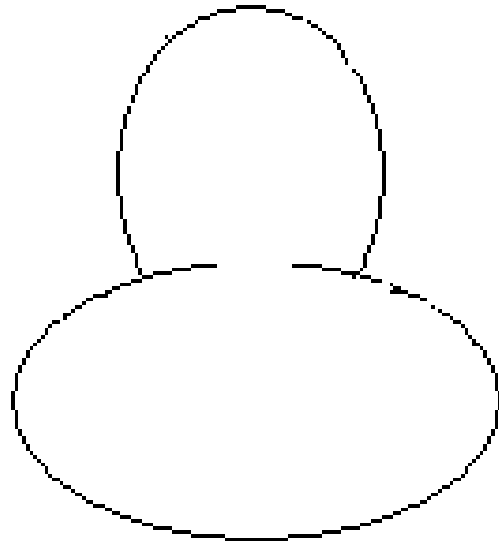
Back to the course

The technique I will use in the lectures is similar to drawing a picture – start with an overview and put in as many details as necessary to satisfy our goal

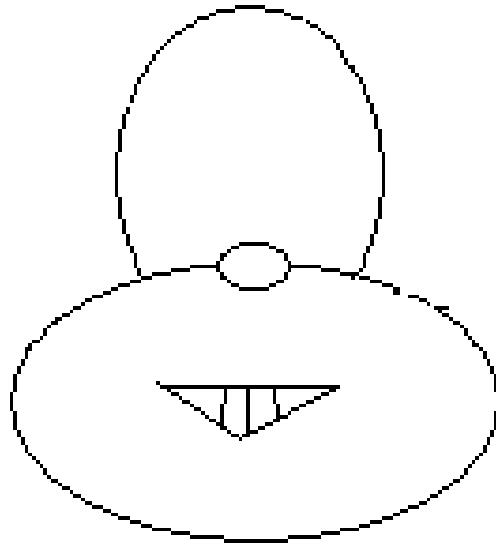
At this point it's difficult to see just what it is.



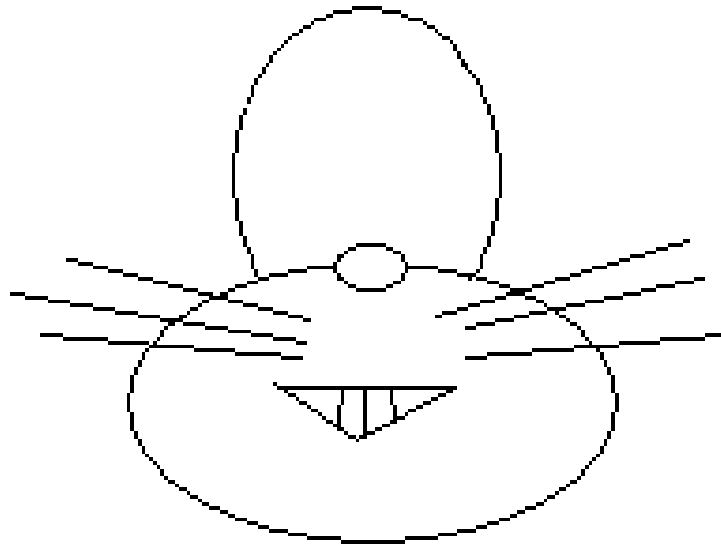
Still not sure what it is, but starting to look like something



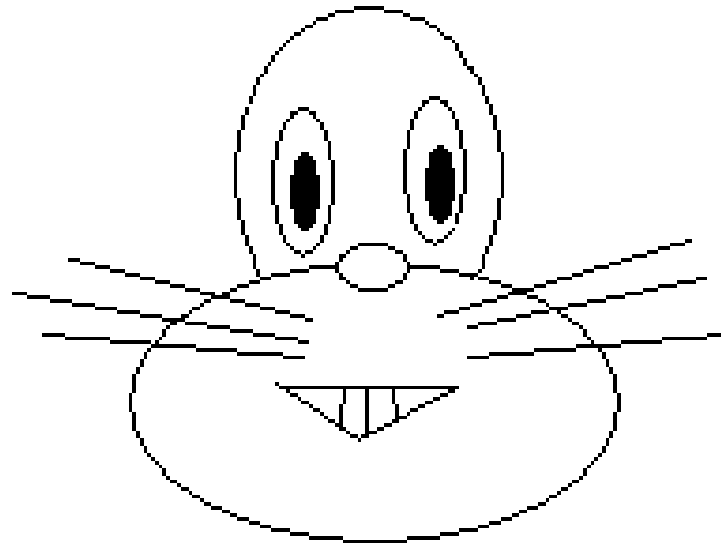
Some kind of a creature

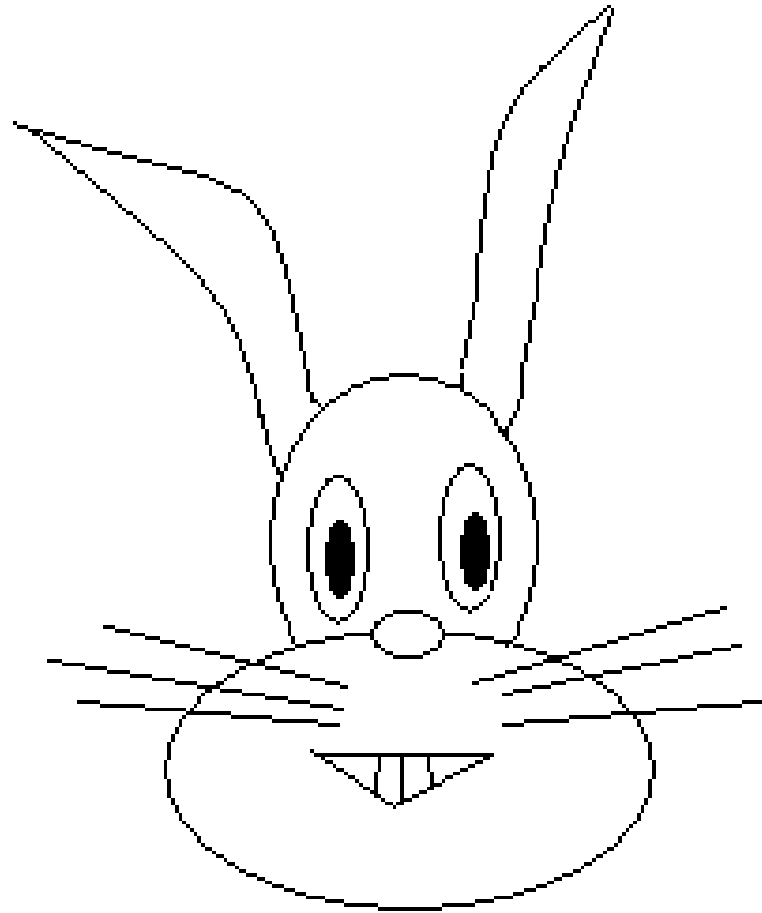


Some kind of an animal? Dog, cat, rat, mouse???



Some kind of an animal? Dog, cat, rat, mouse???





Having discussed the procedure
we will follow in class

I'm then going to cover the elements
of an entire μ controller system

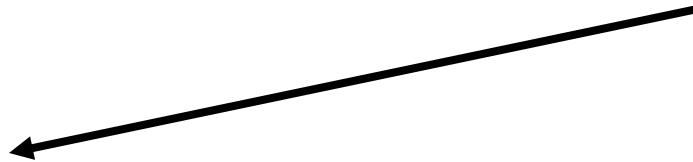
In the order you would consider
them if you were designing a system.

Keep in mind that there are no such things as perfect devices

So everything we put in the system is going to add errors

We must investigate how we handle the error and what impact they have on the overall system.

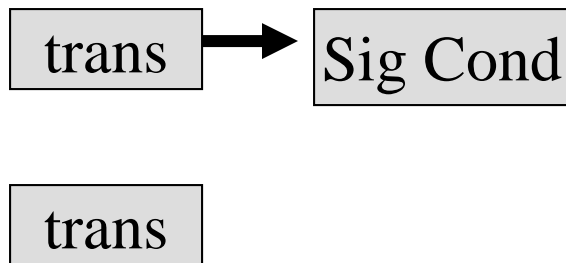
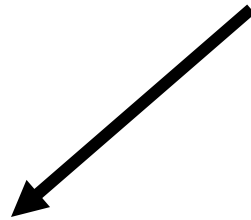
**We will start with the transducers
which could be temperature
sensors, optical sensors,
position/velocity sensors etc.**



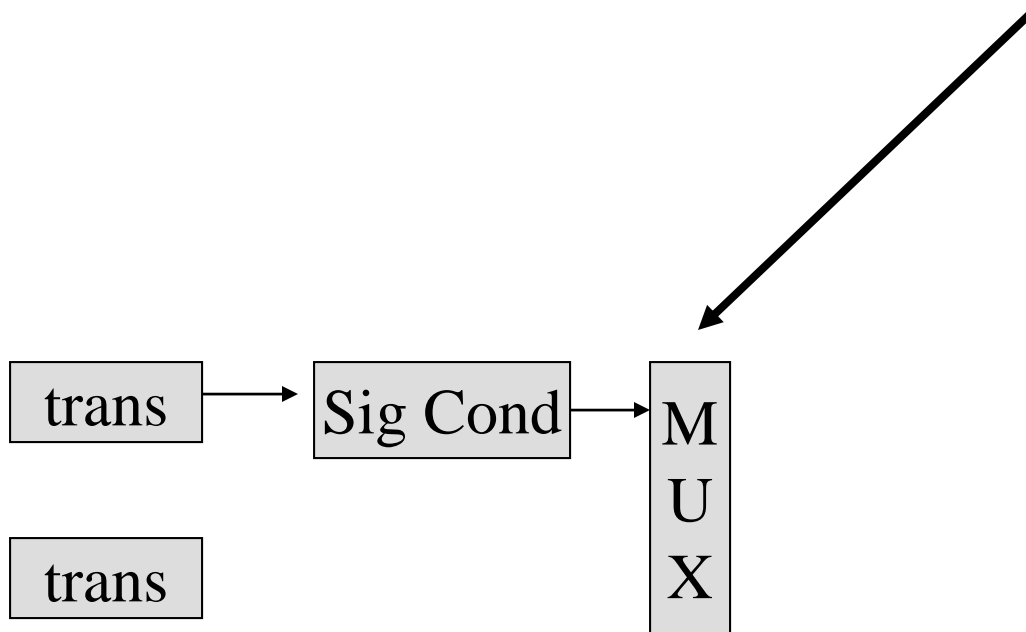
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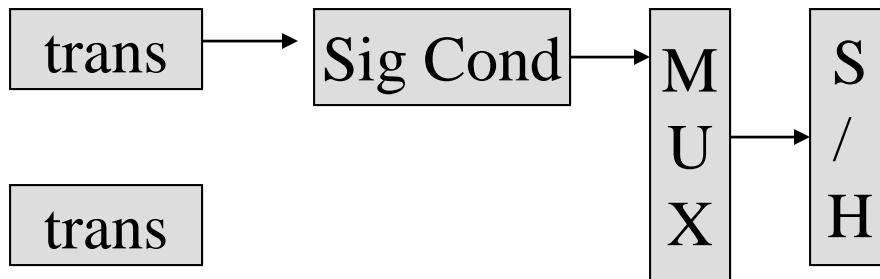
We then design the necessary interface electronics to provide level shifting, filtering, power, etc.



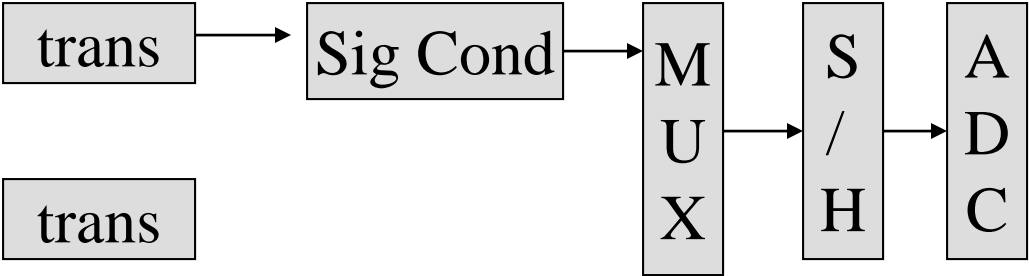
Then any control devices such as
a multiplexer (MUX)



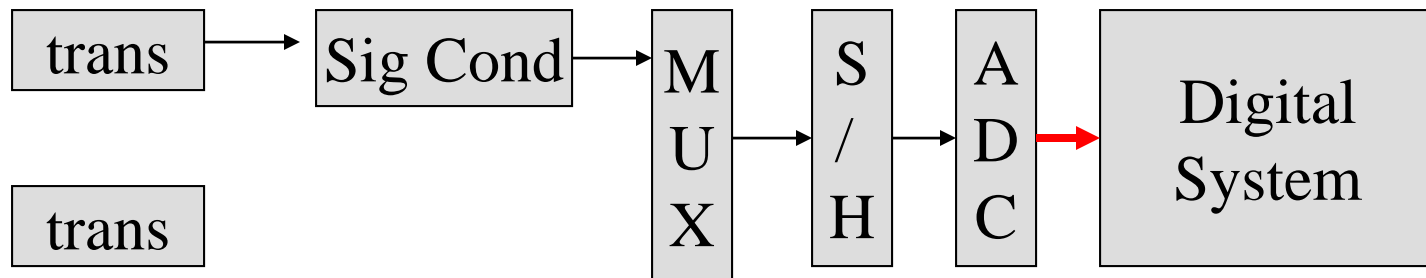
Then, since we want to eventually get to the digital domain, a way to capture the signal so the signal can be digitized. A sample-and-hold device is used for this task.



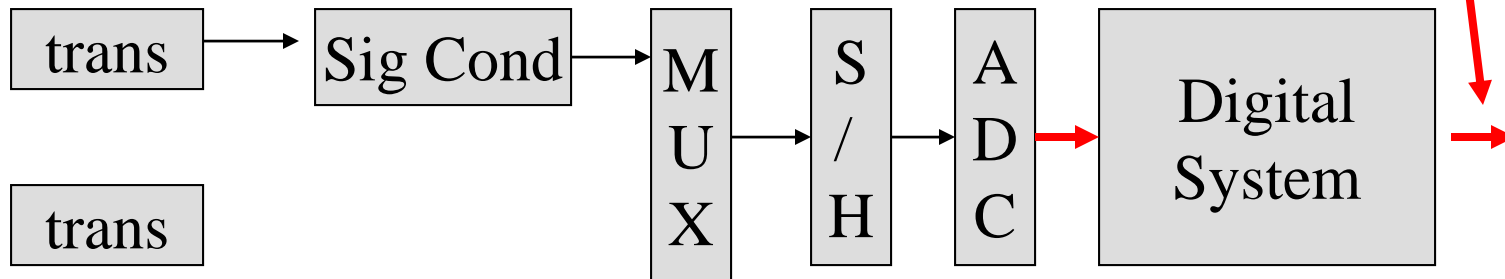
Then of course the digitization of the signal using an analog-to-digital converter



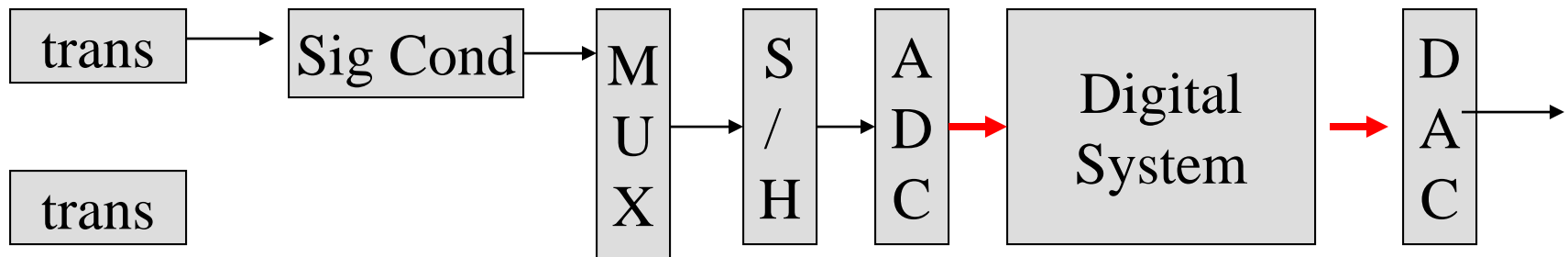
The digital system is essentially the microcontroller that we will be studying.



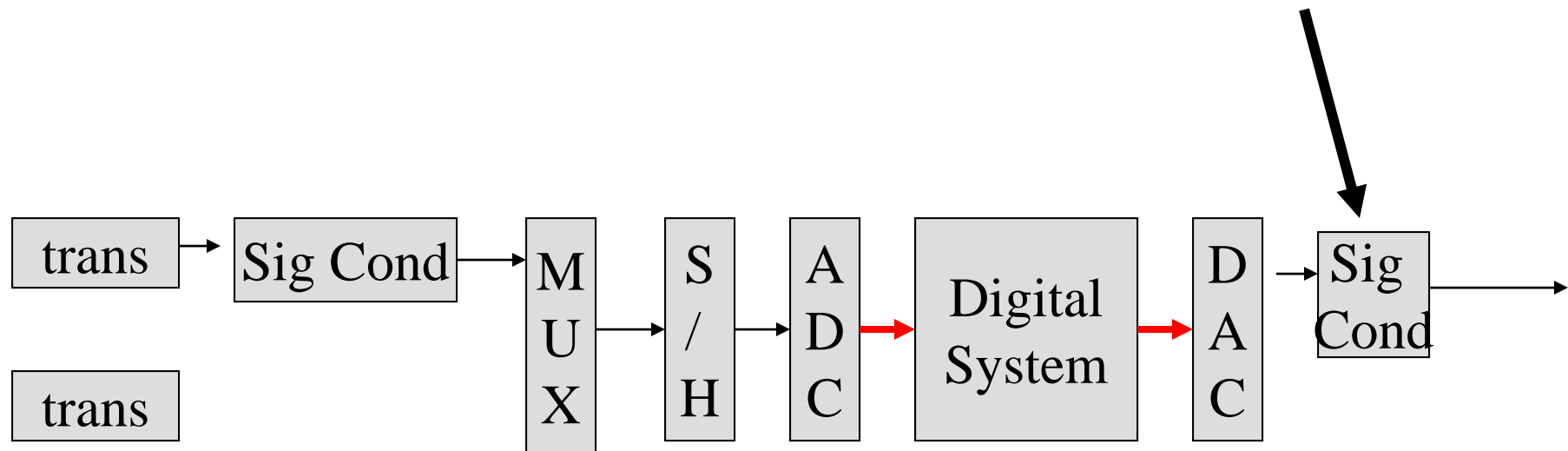
After the signals have been adequately processed, the resulting control signal will be output either as digital data,



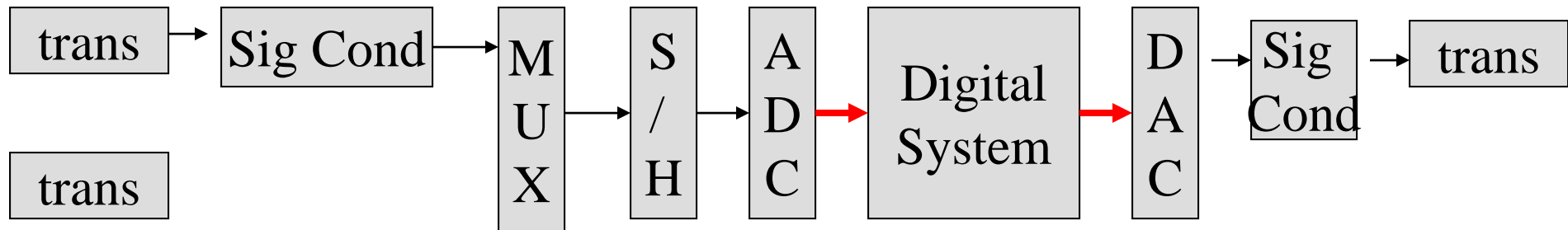
After the signals have been adequately processed, the resulting control signal will be output either as digital data, or converted back to the analog domain.



If the analog signals needed to be conditioned (shifted, amplified, etc.) here is the conditioning circuitry.



And finally, the conditioned analog signals sent out to the appropriate transducer such as a speaker, LED, or whatever.



We will begin by discussing circuits as they apply to our specific needs

- Review some basics to see how analog conditioning is used
- Where it is needed
- Some trade-offs
- Assumptions we can make w/o rigorous analysis.

Lets start with the first elements

Transducers

Transducers

- Devices that convert one form of energy or electrical characteristic to another.
- Could be a device that changes resistance with a change in temperature or displacement.
- Could change light energy to electrical current
- Change in capacitance resulting from a change in displacement
- Change in inductance resulting from a change in velocity or displacement. (LVDT)

Examples of Resistive Transducers

- Angular position
- Linear position
- Temperature sensitive (Thermistors)
- Light sensitive devices

Examples of Electro-Optic Device

- Photo diodes
- Photo transistors

Other types

- Piezoelectric devices (mechanical deformation to generate signals corresponding to
 - Acceleration
 - Velocity
 - Force
- Thermocouples (dissimilar metals)
- Capacitive

Interfacing to Transducers

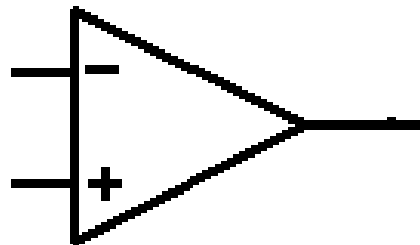
- To effectively interface to these devices, some type of signal conditioning is almost always necessary.
- Conditioning may perform several functions:
 - Buffer – Act to isolate sensing circuit from transducer
 - Translation – Transimpedance Converter to change from I to E.
 - Amplification – Amplify signals

Interfacing (con't)

- Conditioning (con't)
 - Filter – Provide analog filtering at various levels and points in the circuit to minimize noise or interference.
 - Level translation – Change signal levels
 - Non-Linear processing – Manipulate signals to provide non-linear response characteristics such as Logarithms , Integration, Differentiation, Multiplication, Limiting, etc.

Most popular device used to build interfaces is the OP AMP/OP AMP Like Device

- By far the most popular type of device used in interfacing.
- Op amp is a very high gain differential amplifier that is schematically depicted as



OP AMP Characteristics

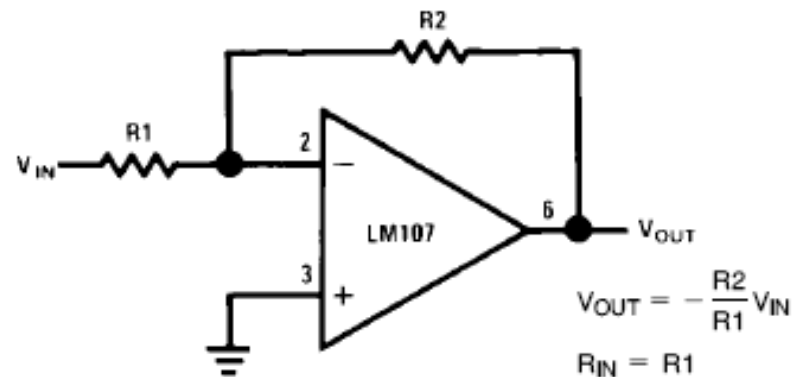
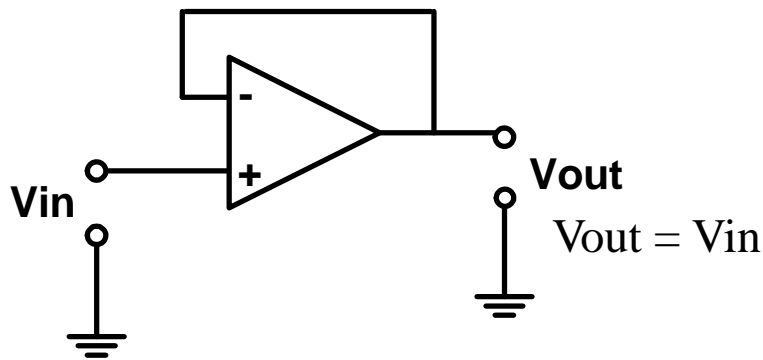
- Input Z
- Output Z
- Gain
- BW
- Offsets
- Power Dissipation
- Physical Size

Operation of an Op Amp

- In signal conditioning applications Negative Feedback is generally employed
- Positive feedback may be used in some applications

Negative Feedback in Op Amp

- Neg Feedback is where the output is “fed back” to the inverting input – either directly or modified by components such as resistors or capacitors.
- Here are a couple of examples of how feedback is implemented in an amplifier.



Next time

- We will talk about the features of the interface devices
- Discuss the design of transducer interfaces.

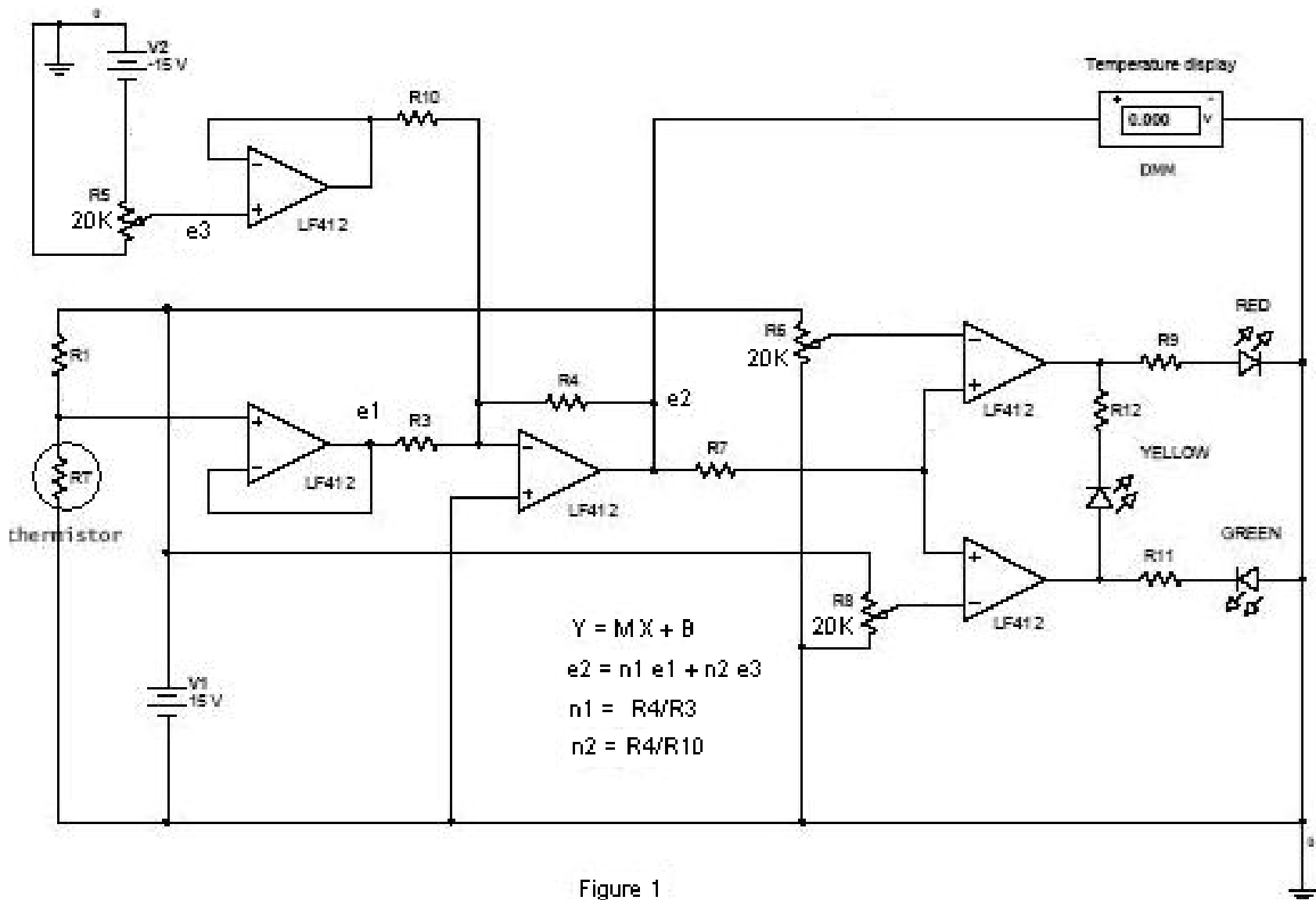


Figure 1

**That's
All
Folks**