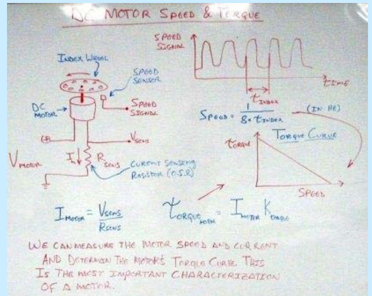
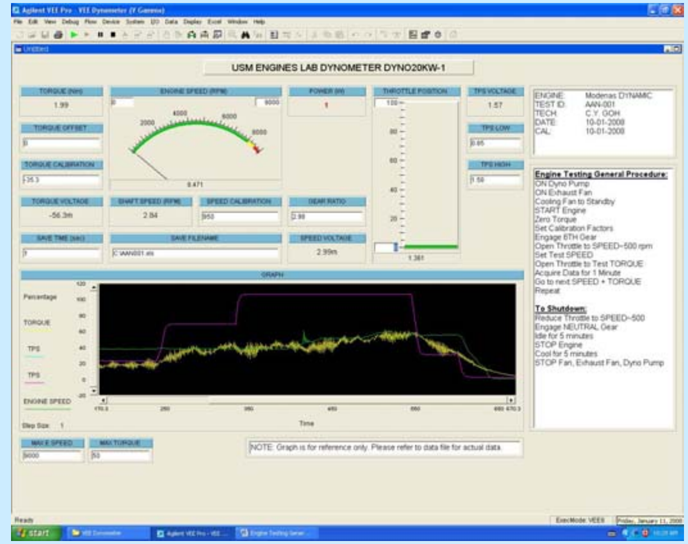
Measurements Seminar
USM Mechanical Engineering
28-05-2008 10:00 to 1:00

This is a laboratory type "hands on" seminar featuring many of the common sensors and techniques used here in the department. We will cover the basics of signals and measurement tools and demonstrate their use in various real-world applications.



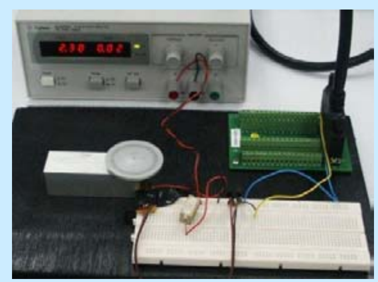
Part 1 **Signals**

Slow/Dynamic/Time Based
Voltage vs. Current
Signal Offset



Part 2 **Measurement Tools**

Volt Meter: AC vs DC
Current vs Voltage mode
Analog Scope
Digital Scope
Serial ADC
USB ADC
Board in Computer



Part 3 **Demos (Agilent Lab)**

Part 4 **Hands On Training (Agilent Lab)**

Various Lab exercises
Load Cell Checkout and Measurement

INTRODUCTION

WHY do a seminar on Measurements?

USM is a "High Tech" environment, we do a lot of "fancy" measurements

- We need to know how to make sensitive (and accurate) measurements
- We need to know how maintain and calibrate the equipment

You need to learn how to maintain, calibrate, and use measurement equipment.

APPLIED Education is what "sticks"!

What we need is another long-winded, boring, theoretical analysis like we need another hole in the head.

The best way to ***learn*** is by ***DOING***.
Today we will not just cover "theory" but we will actually USE it in the lab on real-world examples of the equipment we use here every day.

GOALS of this SEMINAR

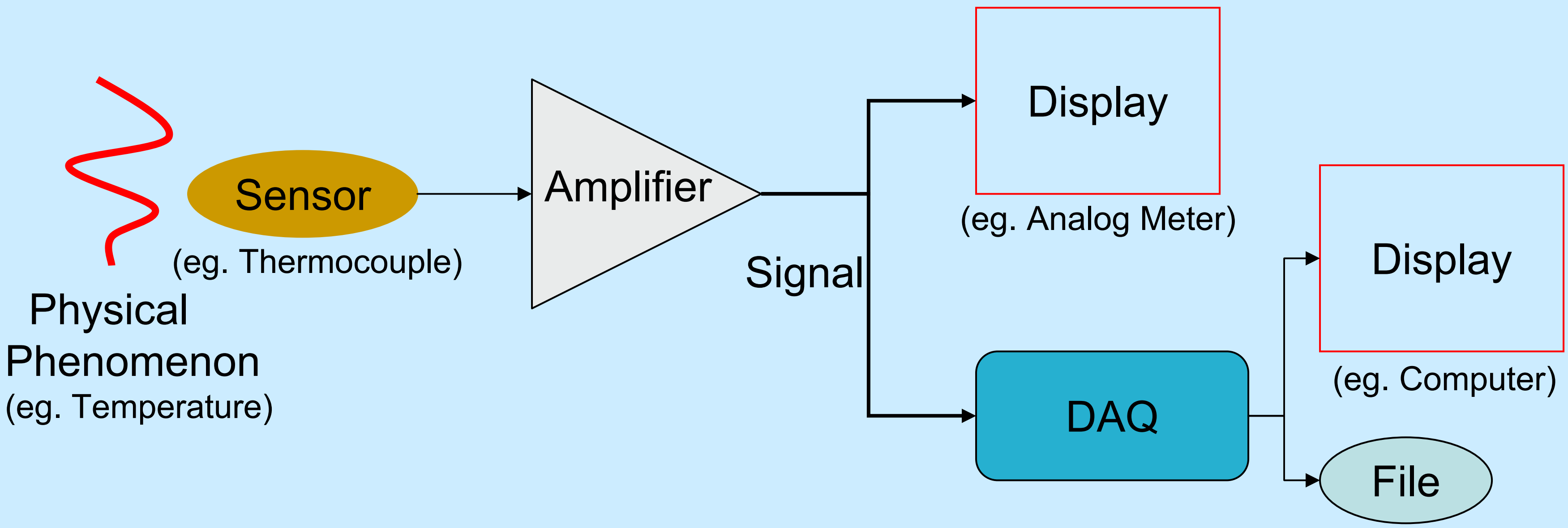
By then end of the day (by lunch time actually) you should:

1) Have a better understanding of measurements system trouble shooting
   How they are assembled
   How they can fail
   How to test them

2) Measurement system design
   What are the options for implementing a measurement system
   Advantages/Disadvantages of various options

The hope is that each technician, student, engineer, or professor will be able to get more out of existing tests and experiments, design better experiments in the future and improve the quality and ease of data acquisition here at USM.

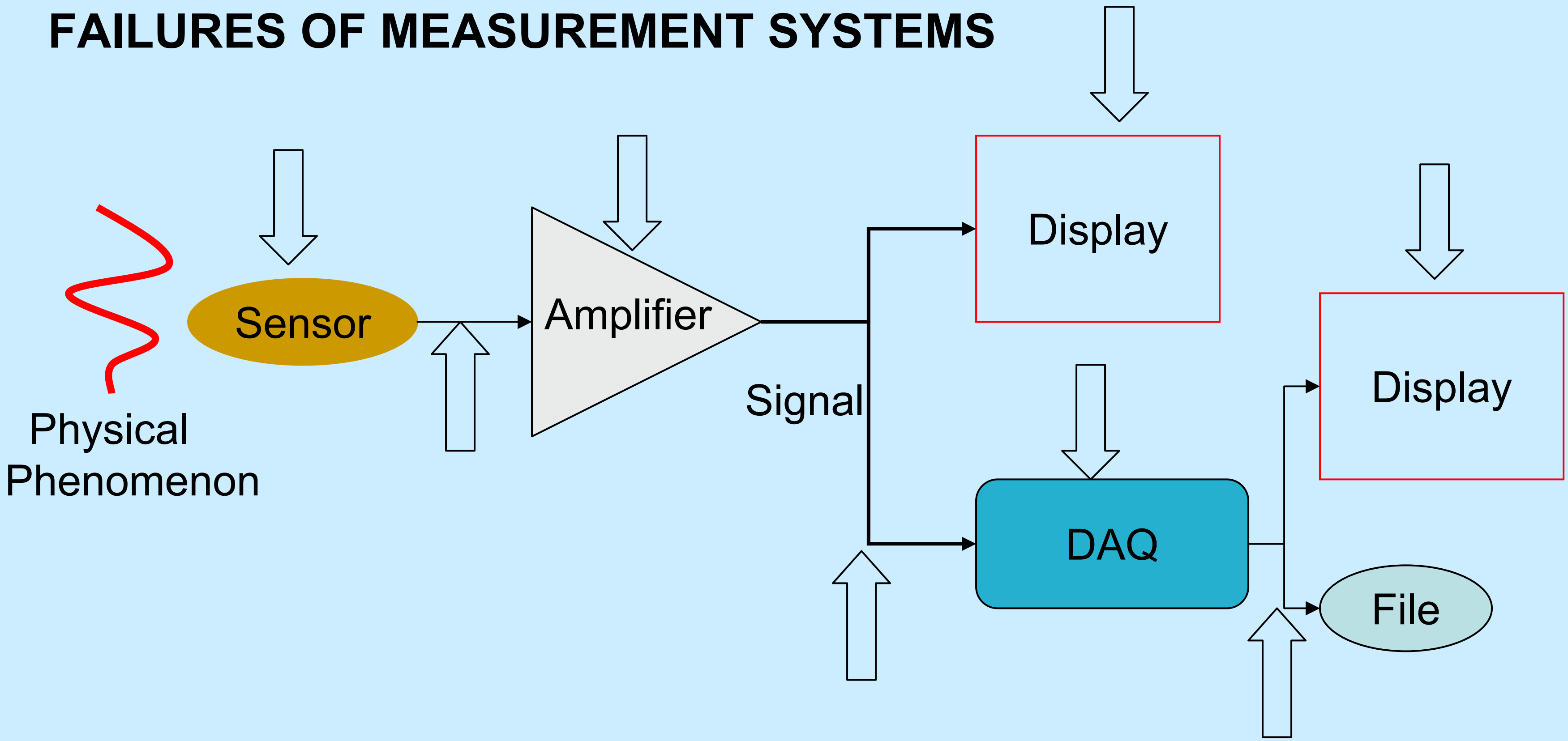
OVERVIEW OF MEASUREMENT SYSTEMS



- Some physical phenomenon (such as temperature or strain) is converted into an electrical signal by a sensor.
- Amplifiers are often required to convert the signal to a readable signal strength.
- The signal can be directly displayed on an analog or digital display.
- Alternatively the signal can be by Data Acquisition Unit (DAQ) which converts it to a digital signal for display or recording using a computer.

Computerized DAQ systems have become the standard for laboratory and scientific applications. These systems are now so inexpensive that they are rapidly replacing older “analog display” systems in many applications including automotive and building controls.

FAILURES OF MEASUREMENT SYSTEMS



Most failures are noticed only at the “Display” level: either the system is not responding, or responding incorrectly.

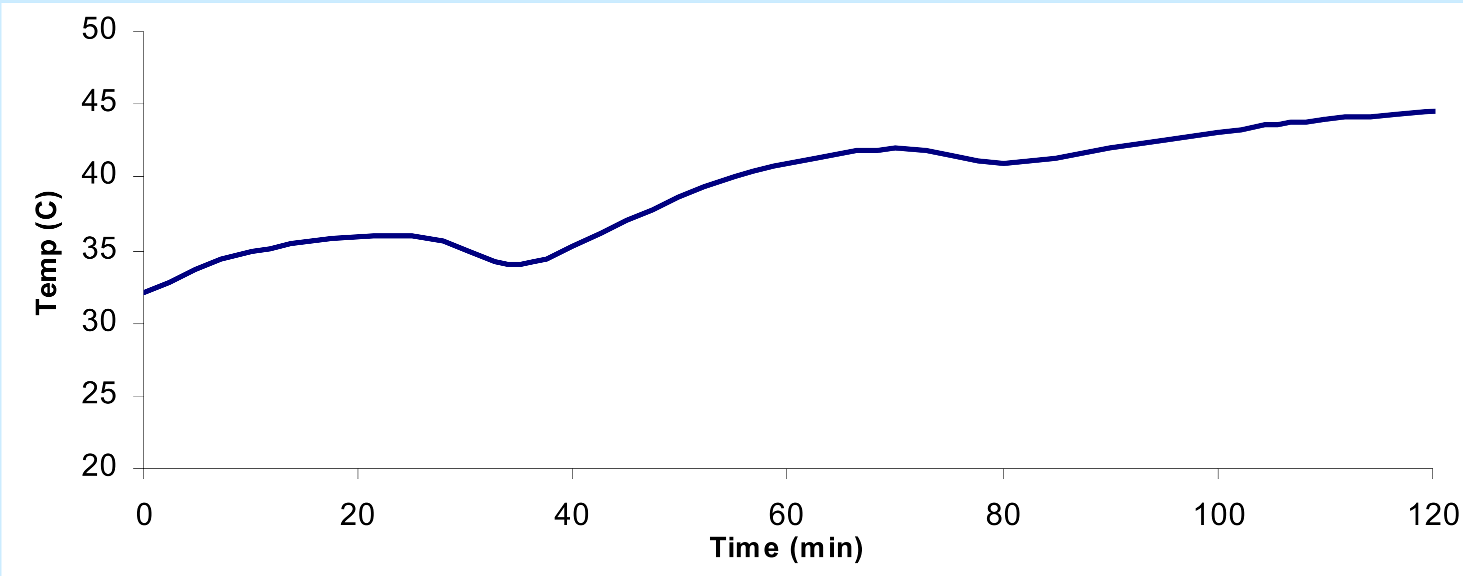
Any sub-system or link (ie. wires) can fail (indicated by arrows).

The key to fixing the system is to test it at each step, and confirm each component in a systematic manner.

SIGNALS

Slowly Varying Signals
Their time constant is ~1 sec. or greater
They can be read by simple direct displays, or volt meters

Common Examples: Temperature
Barometric Pressure
Static Load, Force, Torque



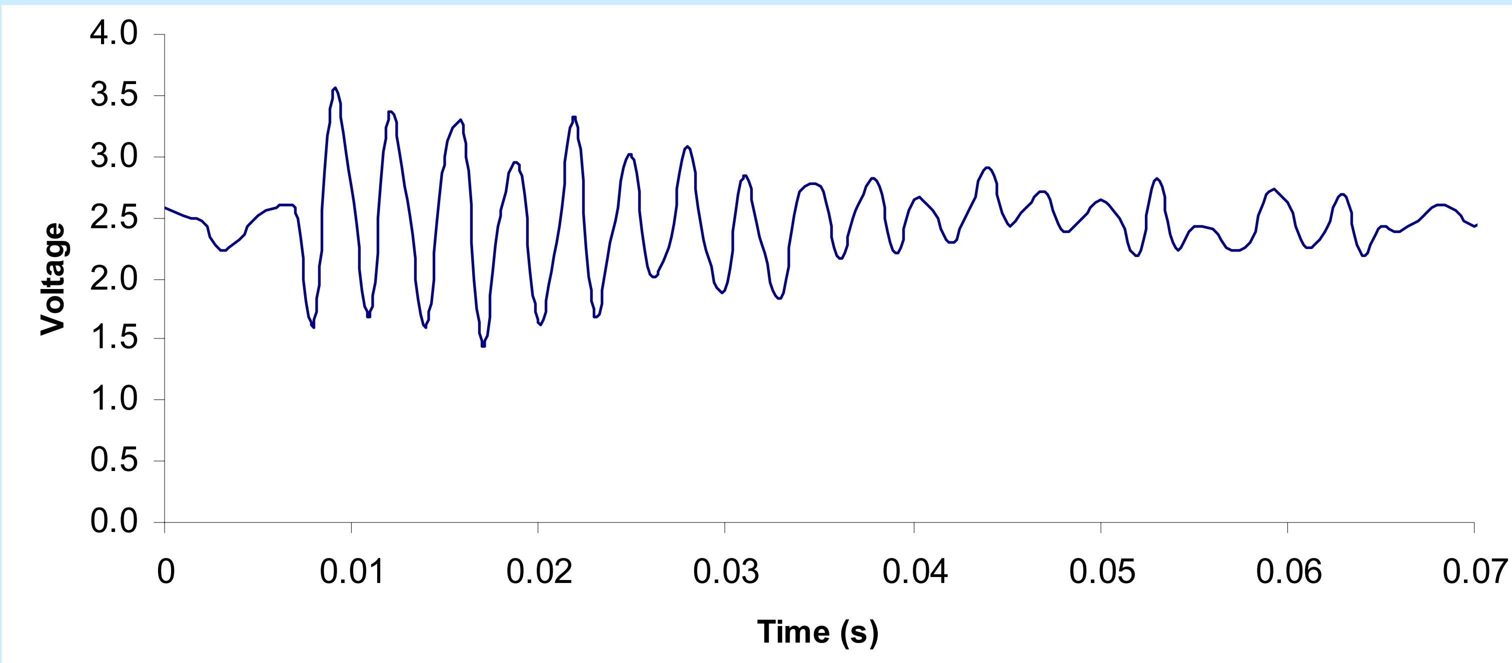
SIGNALS

"Dynamic" Signals

These are higher speed or transient signals

They require an oscilloscope or computerized data acquisition system for reading

Common Examples: Impact Testing
Combustion Pressure
Accelerometers



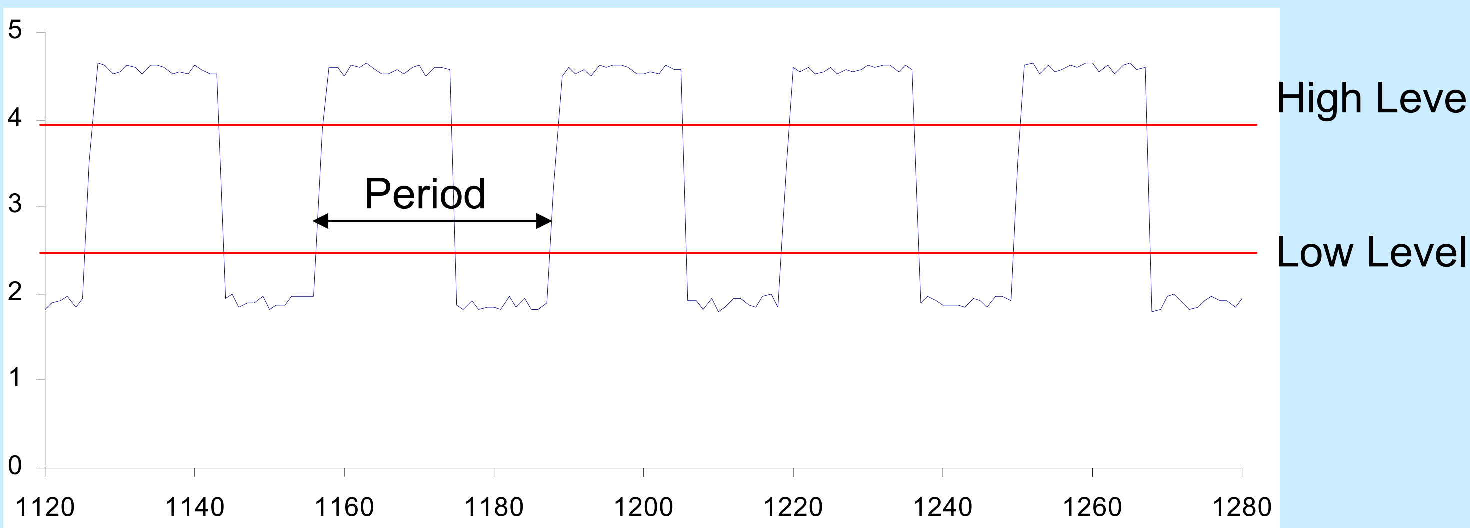
SIGNALS

Time based Signals

These are generally “digital” signals, where voltage is either “high” or “low”
The important part of the signal is the timing of the transitions.
This is usually used in one of two modes:

1) Events (transitions) per unit time (frequency measurement)
2) Time between events (period measurement)

Examples of this are: Engine Crank Position/Speed Sensors
Relative Position Encoders (ie. Computer Mouse)
ABS Break Speed Sensors

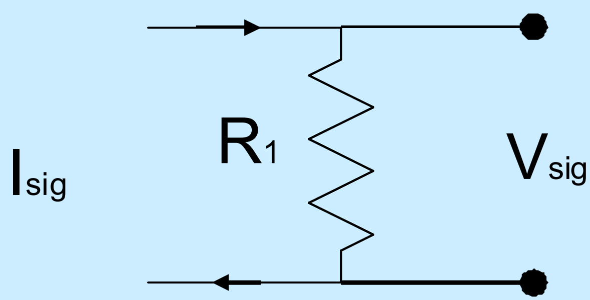


SIGNALS

Voltage vs. Current based signals

•Many sensors and amplifiers have a DC Voltage Output
Eg. 0 to 5V is 0 to 50 kg load
You can directly read these by reading the voltage
Typical ranges are: 0-5V, 0-10, 0-12, -5 to +5, -10 to +10…

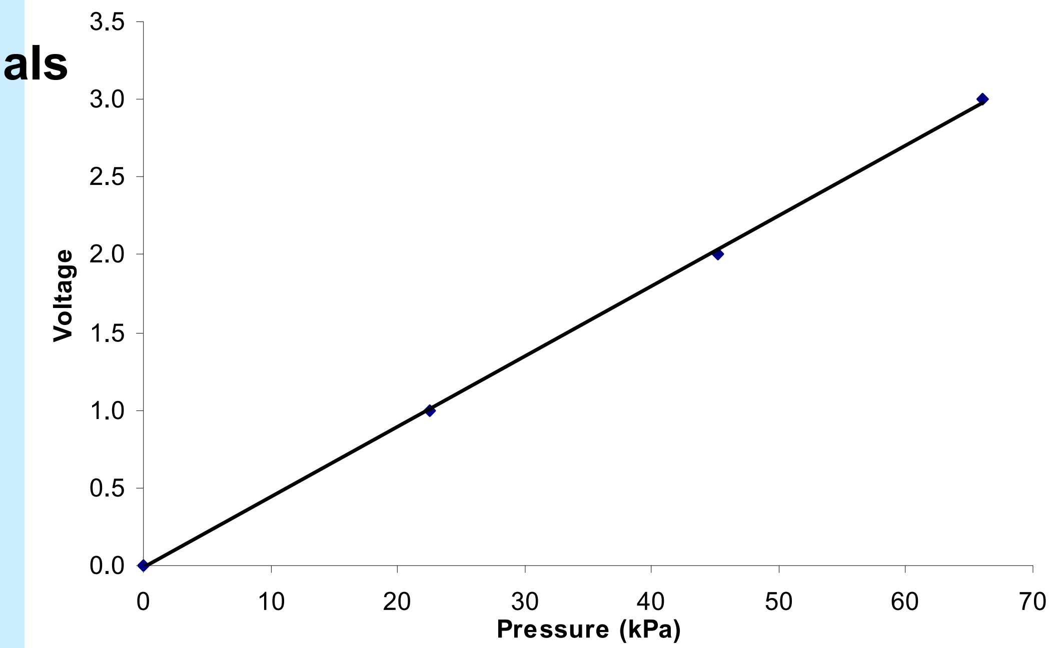
•Some transducers output a current based signal (called a current loop)
Eg. 4 to 20 mA is 0 to 50 kg load
These are common in industrial applications and when there is a long distance from the sensor to the measurement system (less sensitive to line loss).
You need to use a current reader, or mA meter, or convert it to a voltage using a resistor in series with the signal: $V_{sig} = I_{sig} \times R_1$



SIGNALS

Directly Proportional Signals
ie. 0V = 0°C

Examples:
Light Sensors (0=dark)
Temperature (0=0°K)
Strain



This kind of signal is common when an amplifier has been used which is calibrated to “zero” at 0 units.
It is easiest to read as there is no “offset” in the signal.

SIGNALS

Signals with baseline Offset

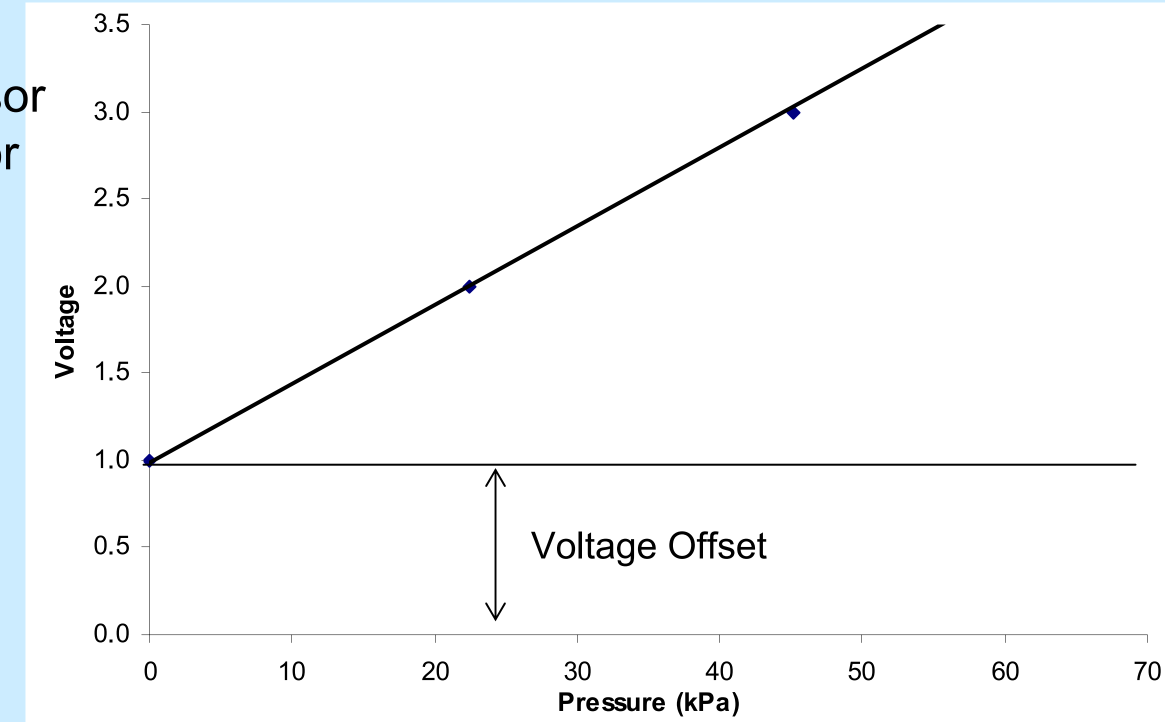
Many signals will have some sort of offset (ie. 0V ≠ 0°C)

Examples:

Hot Wire Air Flow Sensor

Throttle Position Sensor

Tensional Load Cell



This is often the case when reading directly from a sensing element.

Note also that the resulting calibration curve is not necessarily linear.

MEASUREMENT TOOLS

Volt Meter
Simple to use and very common.
Usually only good for very slow signals.

AC vs DC
Make sure you are in the proper voltage mode!
This is the #1 error made with voltmeters.

Current vs Voltage
To measure currents you usually need to put the probes (wires) in different holes.
PUT THEM BACK IN VOLTAGE MODE AS SOON AS YOU ARE DONE!

In current mode, current runs through the voltmeter, which has near 0 resistance.
If you try to measure the voltage of a battery with the wires switched, you SHORT all the battery current through the meter, burning it out, or popping a fuse.

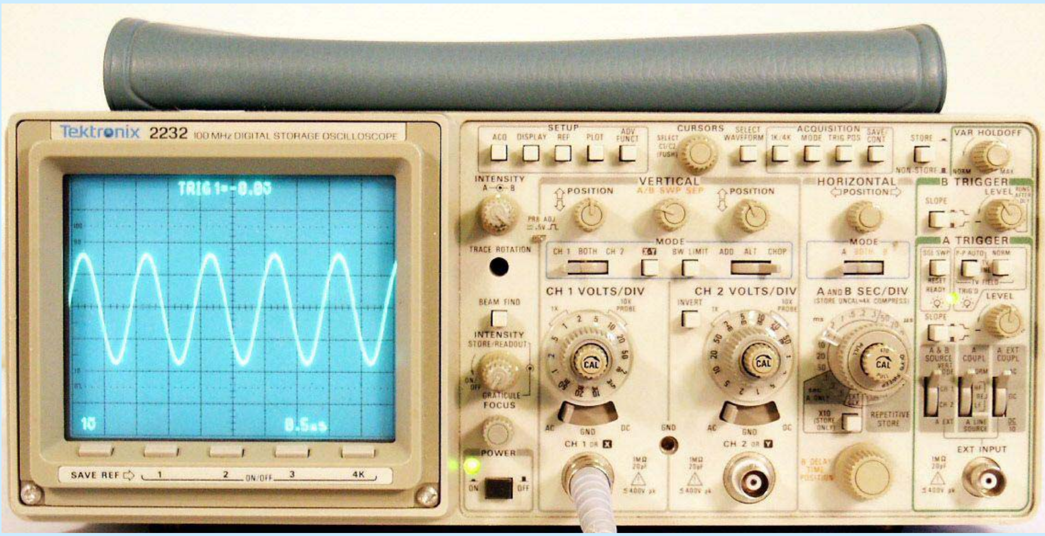
MEASUREMENT TOOLS

Analog Scope
Can be used for viewing high-speed signals.
Usually the signal must be “repeating” (ie. it can’t catch a single “transient” signal and display it form more than a moment)

User needs to adjust the X (time base) and Y (voltage offset and gain) properly.

Also “triggering” is very important to get a good looking signal (like below).
If the triggering is not set, the wave fore will appear to “run” across the screen.

Analog scopes are very useful, but underutilized as few know how to run them.

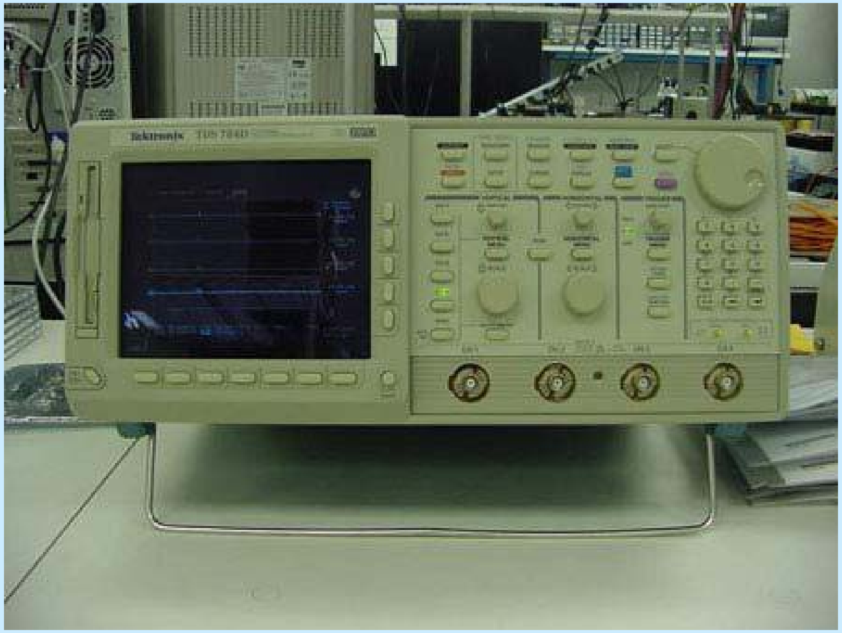


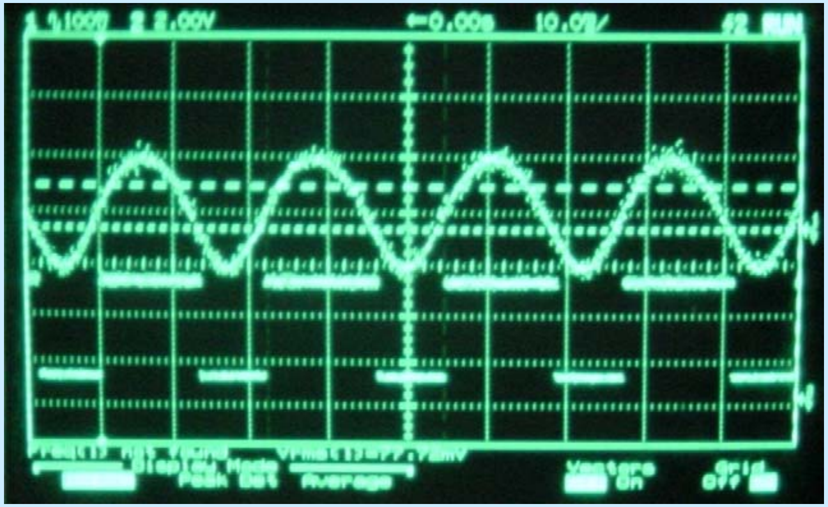
MEASUREMENT TOOLS

Digital Scope

Similar to Analog scope but can “capture and hold” data.
Can capture transient signals at high speed (fastest are in the GHz range).
Usually also has math functions (FFT and etc.).
New ones are as cheep as 3000RM.

This is probably the most versatile tool for engineering measurements.





MEASUREMENT TOOLS

Serial ADC
This is like a digital Oscilloscope without the display or control panel.
It takes commands from the computer via the serial line (RS232)
Data is sent to the computer via serial lines.

Can use "canned" O-scope programs or be user programmed.

These systems can be very inexpensive (<100 RM)

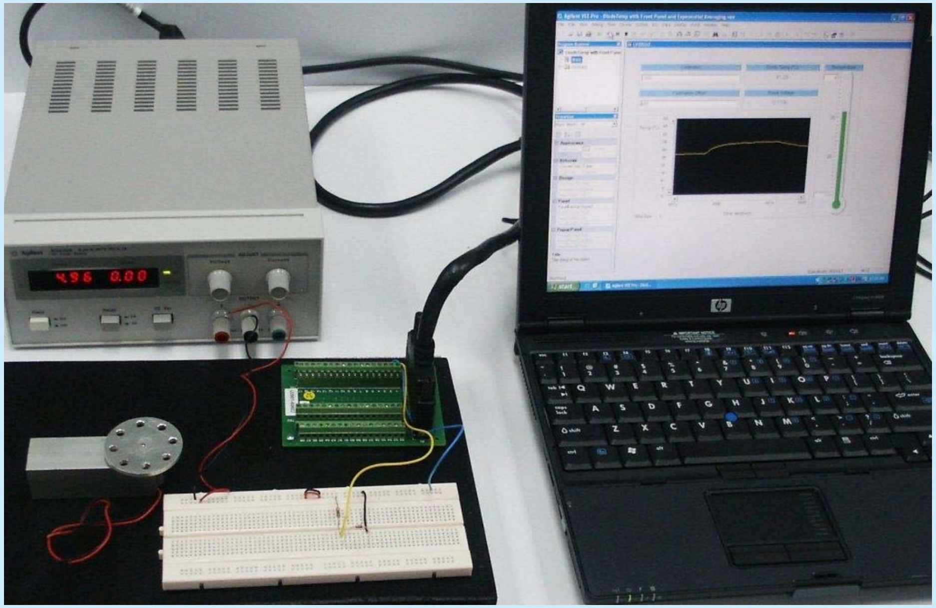
They can have high speed (MHz), but downloading over the serial port is relatively slow (9600 baud ~> 1kB per sec).

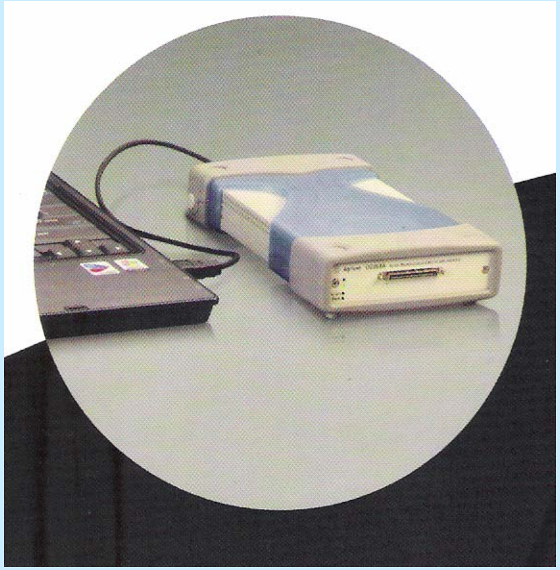
These are widely used in industrial applications where a basic measurement is required repeatedly.

MEASUREMENT TOOLS

USB ADC (or DAQ units)
Same as Serial ADC but with faster transfer rates.
Typically uses “canned” “O-scope” software.
This is the standard in low-cost (~100s of RM) data acquisition today.

We have chosen Agilent USB DAQs for our instrumentation lab.

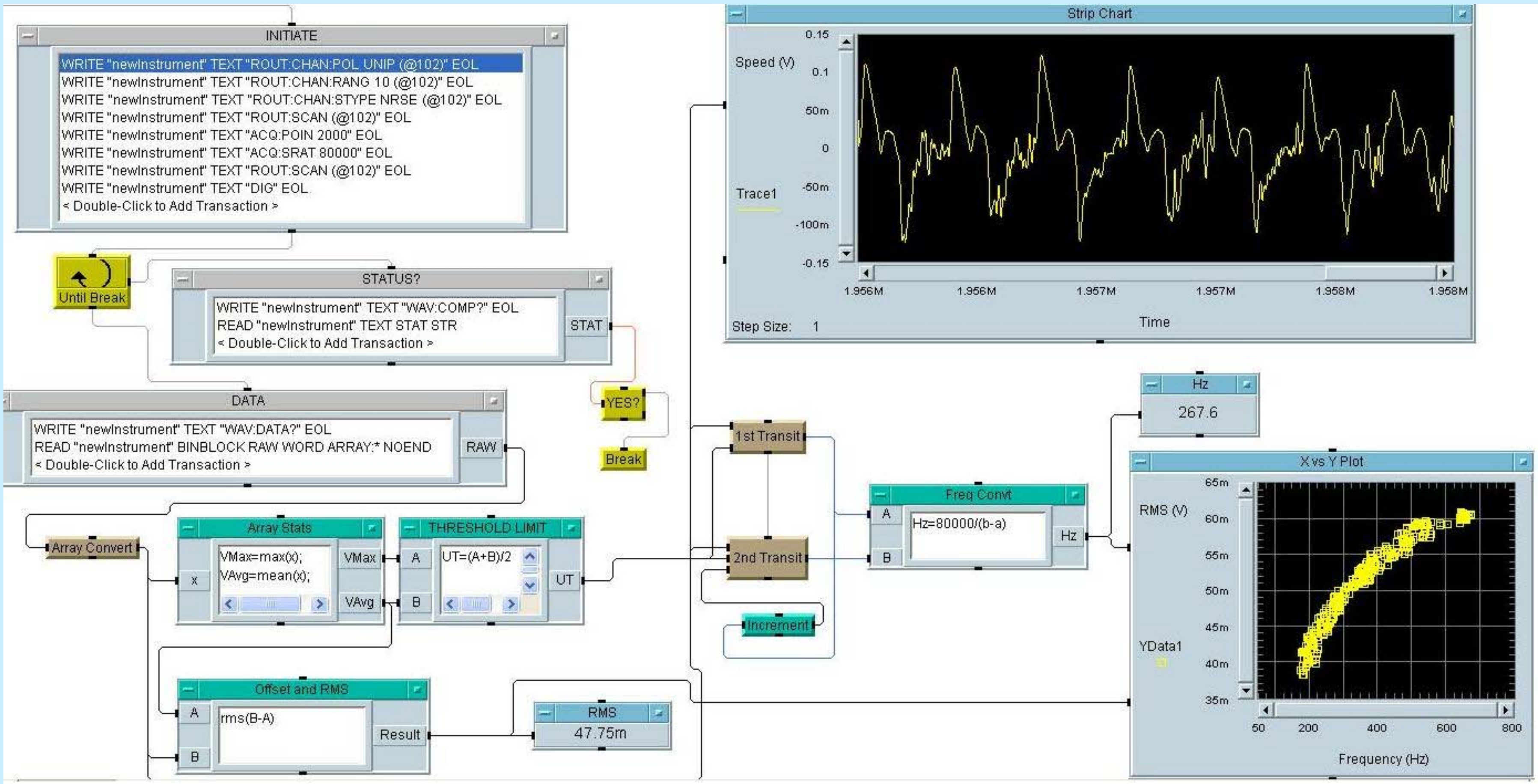




MEASUREMENT TOOLS

Aglient VEE Programming

VEE is a “visual” of graphic programming language which is integrated with their various measurement instruments (GPIB, USB DAQs and etc.). This makes an extremely versatile measurement system which is easy to program up for custom applications.



MEASUREMENT TOOLS

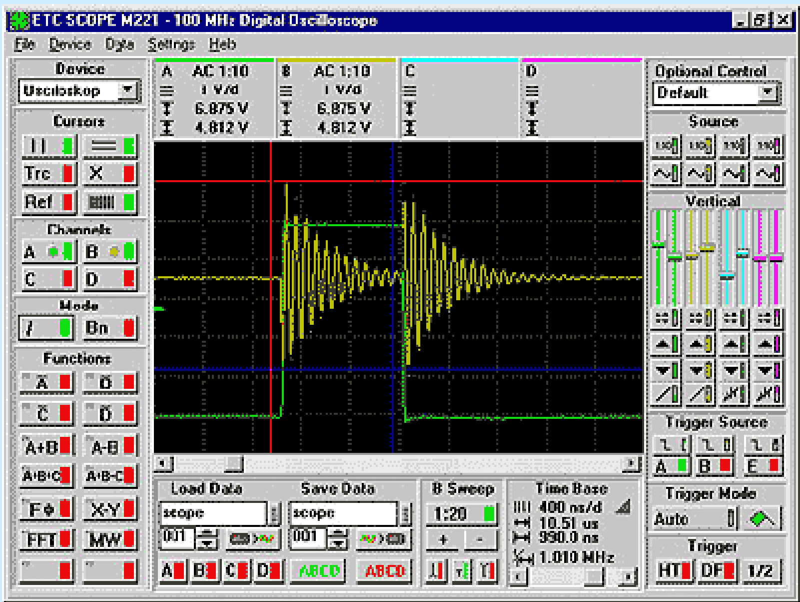
ADC Board in Computer

These systems can transfer data at even higher rates using DMA (Direct Memory Access).

This was the standard for computerized laboratory measurements, but now the market is shifting towards “external” systems like the USB DAQs.

High speeds and reasonably low costs are common.

These are generally user programmed, although “canned” O-scope programs are available.



DEMOS

1) TPS Signal with Ohm Meter
Show Resistance with Multi-meter

2) Pressure Measurement with Voltmeter and Serial DAQ

3) Load Cell checkout with Voltmeter and Agilent DAQ

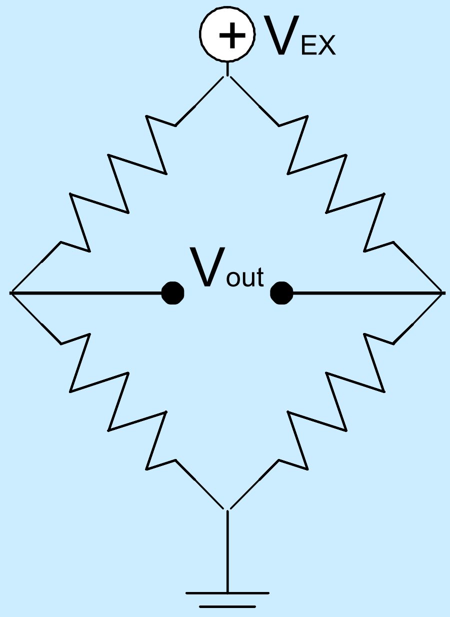
4) Demo Board Motor Throttle, Motor Current
Show slowly changing signal
Show Current Calculation

5) Motor Speed
Show Dynamic Signal and Calculation

6) Torque vs. Speed Curve
Multi-Variable Analysis

LOAD CELL: The most problematic sensor at USM

A Load Cell is usually a “Wheatstone bridge” consisting of 4 elements.
It must have an excitation voltage applied to it, typically 5 to 10V.
The output is a small differential voltage, typically only a few mV.



Usually the sensor is not connected to the amplifier correctly, or there is a break in the sensor or sensor wires.
These are things you can easily check with an ohm meter and volt meter.

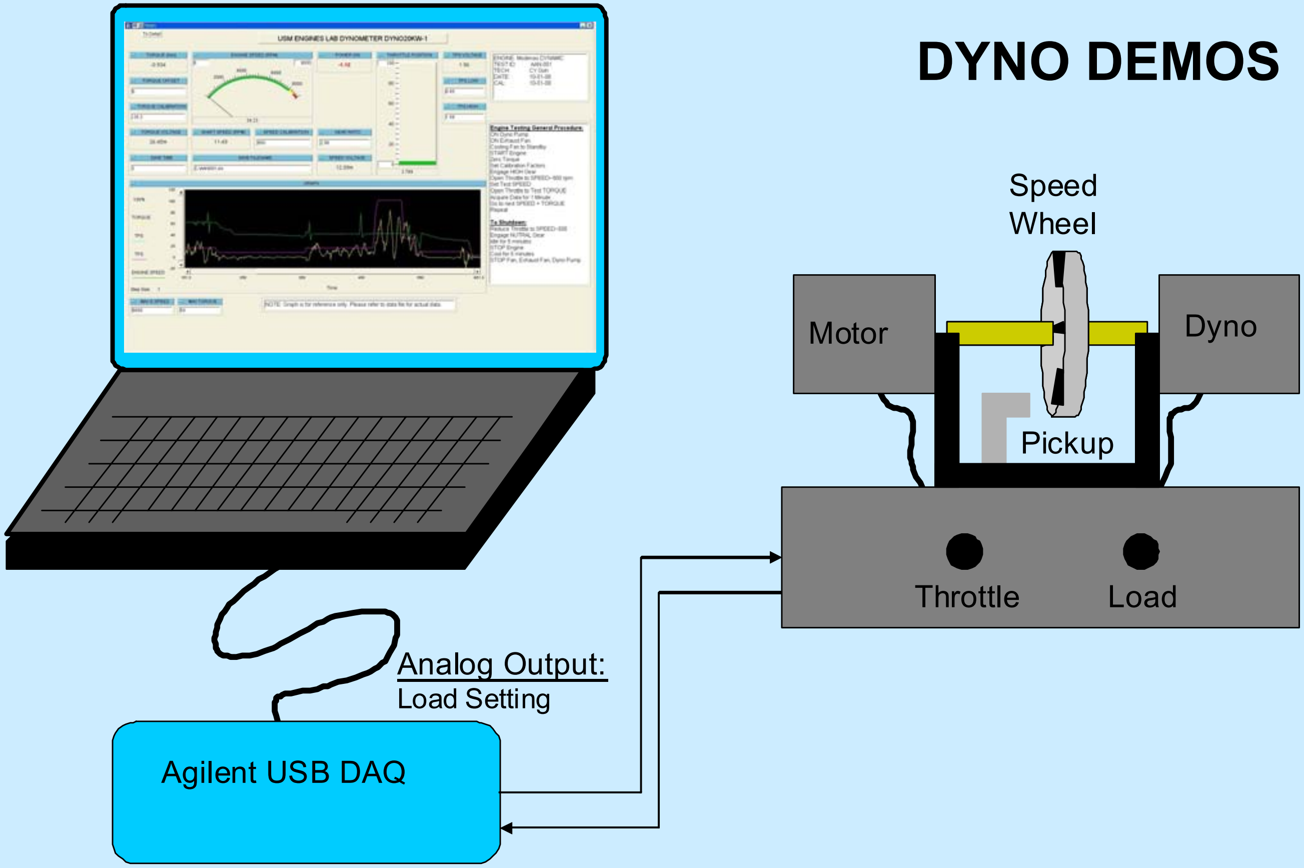
DYNO DEMOS

Demo Board Motor Throttle, Motor Current
Show slowly changing signal
Show Current Calculation

Motor Speed
Show Dynamic Signal and Calculation

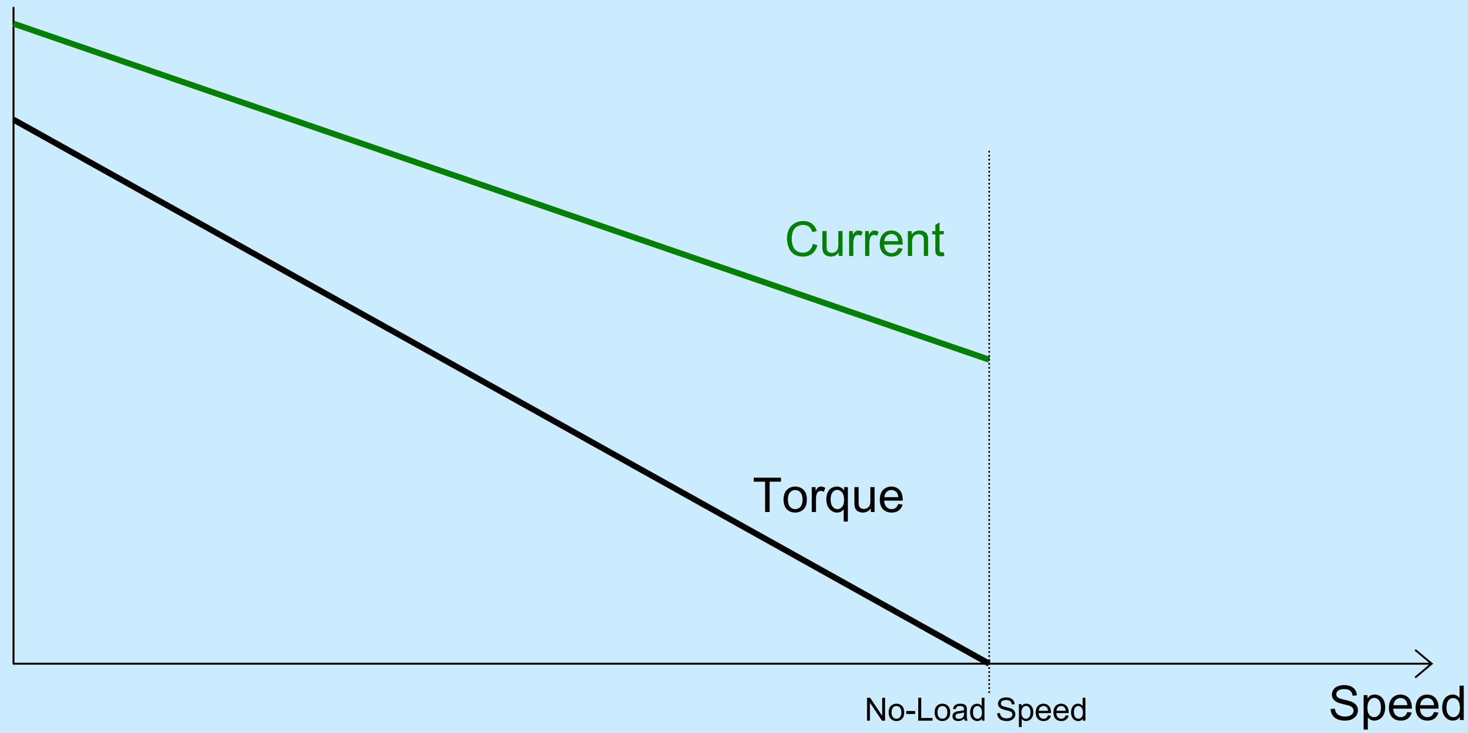
Torque vs. Speed Curve
Multi-Variable Analysis

DYNO DEMOS



This is an example of an electric motor Dynamometer.
The Motor drives the Dynamometer (variable load device).
The Motor’s throttle and Dynamometers Load are adjustable.
We can measure the resulting motor current and systems speed at any Throttle/Load setting.
This is how various motors and loads are tested and characterized.

Permanent Magnet –DC Motor Characteristics



The Torque curve for a PM-DC motor is a straight line descending from the stall torque at zero speed to zero torque at the no-load speed.

The current curve is similar but it does not go to zero at no-load speed as some current is required to overcome friction of the motor (ie.at Zero current it will not run).

HANDS ON TRAINING: AGILENT LAB

Diode Temperature Measurement
Zero offset and Calibration

CdS Cell
Show slowly changing signal

Fotocell
“Flicker” measurement of Fluorescent lights