ECEN 4013

Design of Engineering Systems

Agenda

Project 1

Agile Scrum

AD Conversion

Multisim Homework

Project 1

It is now Sprint 1

- Scrum masters should set up your projects in iceScrum and add team members
- Project description has been posted on our canvas webpage

Questions?

What are options for voltage reference?

Voltage divider with buffer amplifier

Zener diode with buffer amplifier

Reference diode with buffer amplifier
    multiple voltages available
    2.56 V and 4.096 V are available

IC voltage references have internal buffer amp
    multiple voltages available

Boost converters

Voltage regulators

Options for digital output?

Can we use LEDs to signify the value?

Yes – it would be a good visualization tool

However, the ultimate output should be a digital nibble or word that can be read and processed by a typical processor.

LEDs may require a discrete transistor driver.

Can we use any types of IC in our design?

In general, yes. No processors (except for control) or commercial A/D or D/A converters.

Good digital logic families are 74HC or 4000 series, but others are possible.

Be sure to check the Stockroom Catalog for parts available with little delay. Parts not in the stockroom will have a purchasing delay.

Logic and COTS Modules

Can the control and sequencing logic be done by an Arduino/Pi? Can the output of the comparator be used to set the values of the SAR?

Yes. My hope is that you challenge yourselves and create an SAR using logic, flip-flops, and a state machine of some sort, but you can also use a Pi or Arduino to do the sequential logic. You can even buy an SAR chip if you desire.

Are we allowed to just buy a part that is one of these six submodules?

Yes. Feel free to use things like 555 timers for your clocks, sample and hold chips, comparator chips, with one exception, the DAC. I don't want to make the project too easy and an R-2R ladder is not too difficult to implement. However, sample and hold circuits and Schmitt triggers are not difficult and I will go over them in class.

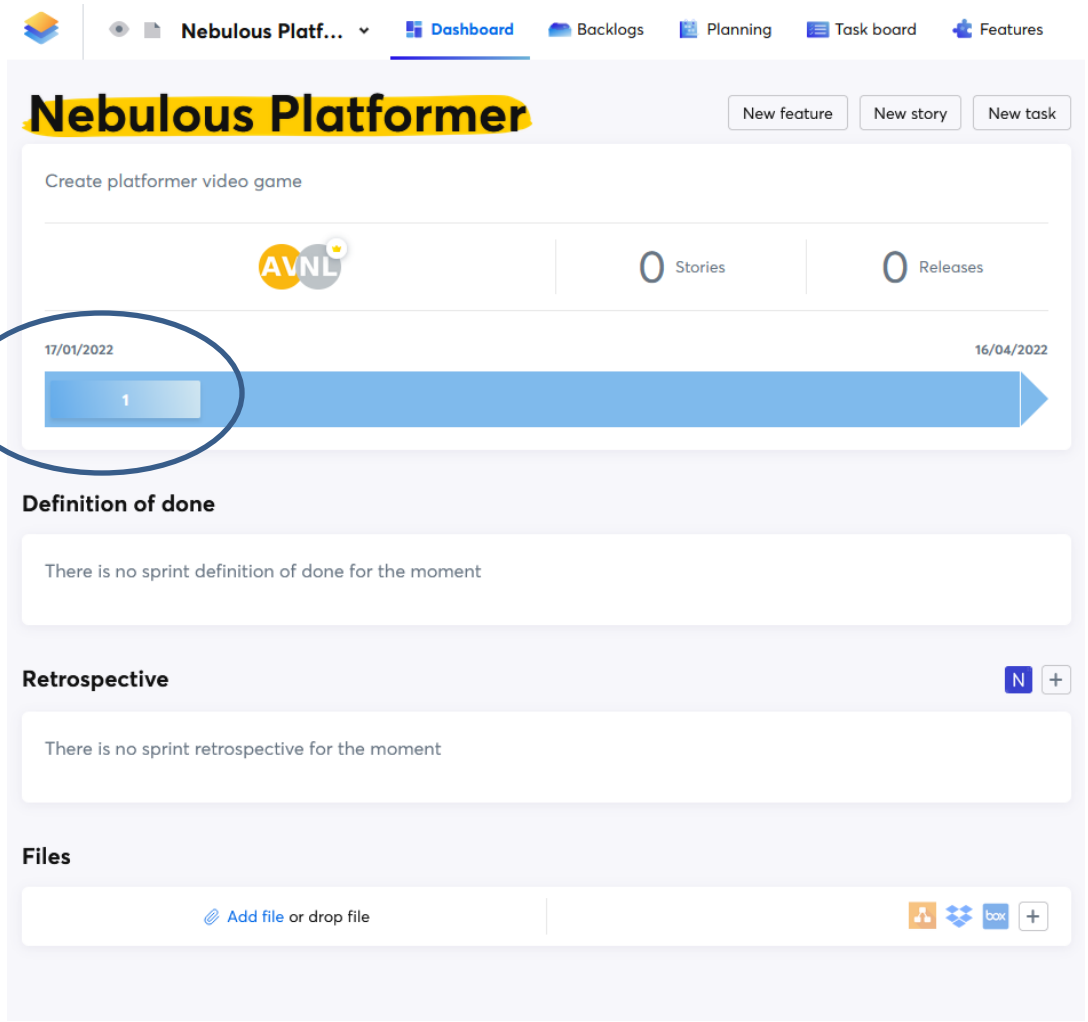
Agile Scrum Intro

- Project framework designed in 2001
- Aim is to please the customer through early and continuous delivery and an emphasis on a shortened timescale
- Welcomes changing requirements
- Most efficient and effective method of conveying information is face-to-face conversation

Agile Scrum Intro

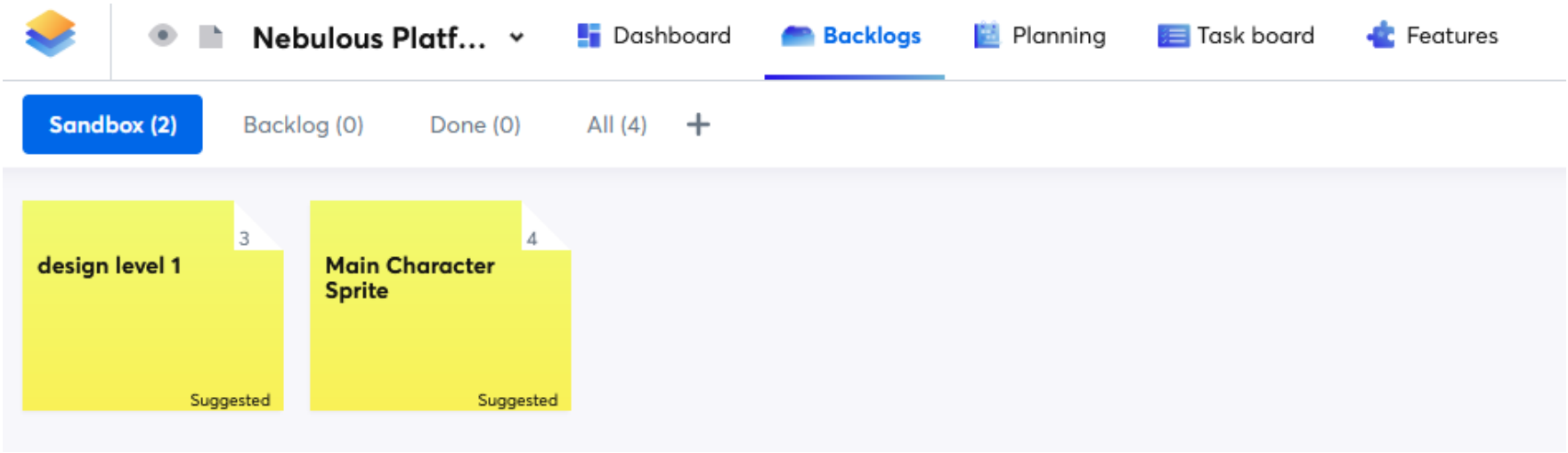
- At regular intervals the team reflects on how to become more effective
- Testing is done hand in hand with development to ensure a finished product at each development phase

Agile Scrum Intro



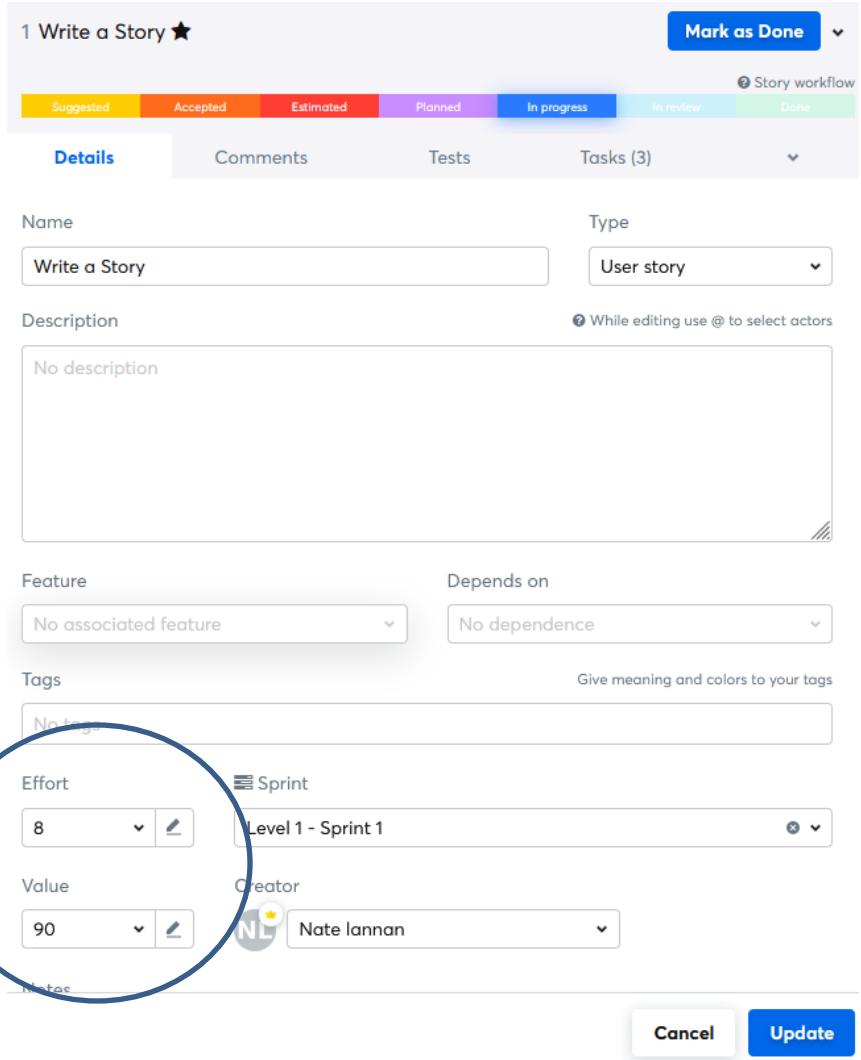
- Development phases are called "sprints" and are typically short periods of time (2 to 4 weeks)

Agile Scrum Intro



- Large tasks are referred to as "user stories" and are generally broken down as much as possible so that they can be achieved in a sprint
- A user story can exist in 3 phases, backlog, in progress, done

Agile Scrum Intro



- Each user story is given an arbitrary point value by the team based on the degree of difficulty to complete the task
- At the end of the sprint the completed stories values are tallied. This acts as a guide for how much you can achieve each sprint

Agile Scrum Intro

- Special roles
  - Scrum master – person in charge of initially organizing the scrum. Makes sure meetings stay on task and guides the team's day to day activities
  - Product owner – person in charge of user story backlog and acceptance criteria

Agile Scrum Intro

- Special phases
  - Sprint planning – team goes over backlog and assigns "sizes" to the stories using a method called planning poker
  - Retrospective – team gets together after a sprint and discusses what went well and what didn't as well as what can be done to improve

Agile Scrum Intro

- Scrum Cycle in 7 steps
  - Determine a Product Backlog (a list of product requirements in order of priority)
  - The Scrum Team makes estimates and arrangements for the workload based on the Product Backlog list
  - Hold a Sprint Planning Meeting to define the sprint goal of this iteration, then select a list of user stories to bring into the sprint. These user stories are now "In-Progress".
  - Each Story is broken into tasks that the team will then take responsibility for (the workload of each task should be completable within a few days)

Agile Scrum Intro

- Scrum Cycle in 7 steps
  - Within the Sprint, a Daily Scrum Meeting is required and each of the meetings is time-boxed in about 15 minutes. Everyone must speak and face-to-face to interact with all members for reporting what you did yesterday, and commit what you want to accomplish today, and you can ask questions related to impediment or problems that you can't solve.
  - When the sprint is completed, we need to conduct a Sprint Review Meeting. Every member of the Scrum Team will demonstrate to the product owner the working portions of the project they have completed.
  - Finally, The Sprint Retrospective is held after the sprint review at the end of each sprint. During the retrospective, the team self-identifies elements of the process that did or did not work during the sprint, along with potential solutions.

Agile Scrum Intro

Agile Scrum Intro

IceScrum Demo

Details of A/D converter operation and major specifications

Resolution

Theoretical resolution is determined by the voltage range to be converted and the number of bits used to represent this voltage range:

LSB = $$\frac{V_{max} - V_{min}}{2^N}$$

Where N is the number of bits

Resolution

Let us consider a problem with low bit resolution. Let us consider a 4-bit converter:

$$LSB = \frac{V_{max} - V_{min}}{2^4} = \frac{V_{max} - V_{min}}{16}$$

If the voltage range to be converted is 0 to 5 VDC,

$$LSB = \frac{5}{16} = 0.3125V$$

Resolution

What are the switching points (bit boundaries) of an ideal 4-bit converter with 5 VDC reference?

Boundary (V)	Code		Boundary (V)	Code
0.0000	0000		2.500	1000
0.3125	0001		2.8125	1001
0.6250	0010		3.1250	1010
0.9375	0011		3.4375	1011
1.2500	0100		3.7500	1100
1.5625	0101		4.0625	1101
1.8750	0110		4.3750	1110
2.1875	0111		4.6875	1111

Resolution

Any signal between 2.1875 V and 2.500 V will return the same code as a result: 0111

This signal is often identified as being of amplitude “7 LSB.”

Resolution

A signal of 7 LSB is equivalent to 2.1875 V

A signal of 6 LSB is equivalent to 1.8750 V

In reality a signal that has a digital value of 0111 could be a voltage within the range:

$$1.8750 < V_{in} \leq 2.1875$$

The difference between the actual signal amplitude and quantized equivalent is called the quantization error. What is the maximum quantization error?

Resolution

We often think of the nominal code value as being the midpoint of the signal range for that binary code.

That way, quantization error will be no more than $\pm\frac{1}{2}LSB$.

Resolution

We often think of the nominal code value as being the midpoint of the range for that code.

If we define 0111 as

$$1.8750 + \frac{2.1875 - 1.8750}{2} = 2.03125V$$

The maximum quantization error will be no more than $\pm\frac{1}{2}LSB$

Resolution

As testing of your project converters are likely to show, not all codes occupy the theoretical value of 1 LSB. Typically, some bit boundaries are a little wide, others are a little narrow.

This type of error is called a differential error.

Resolution

In a theoretically linear A/D converter, the center of each bit boundary lies along a straight line. In real A/D converters, there is usually some amount of departure from the straight line.

This is called an integral error. Your project converter may show both integral and differential errors.

Your testing should look for these errors.

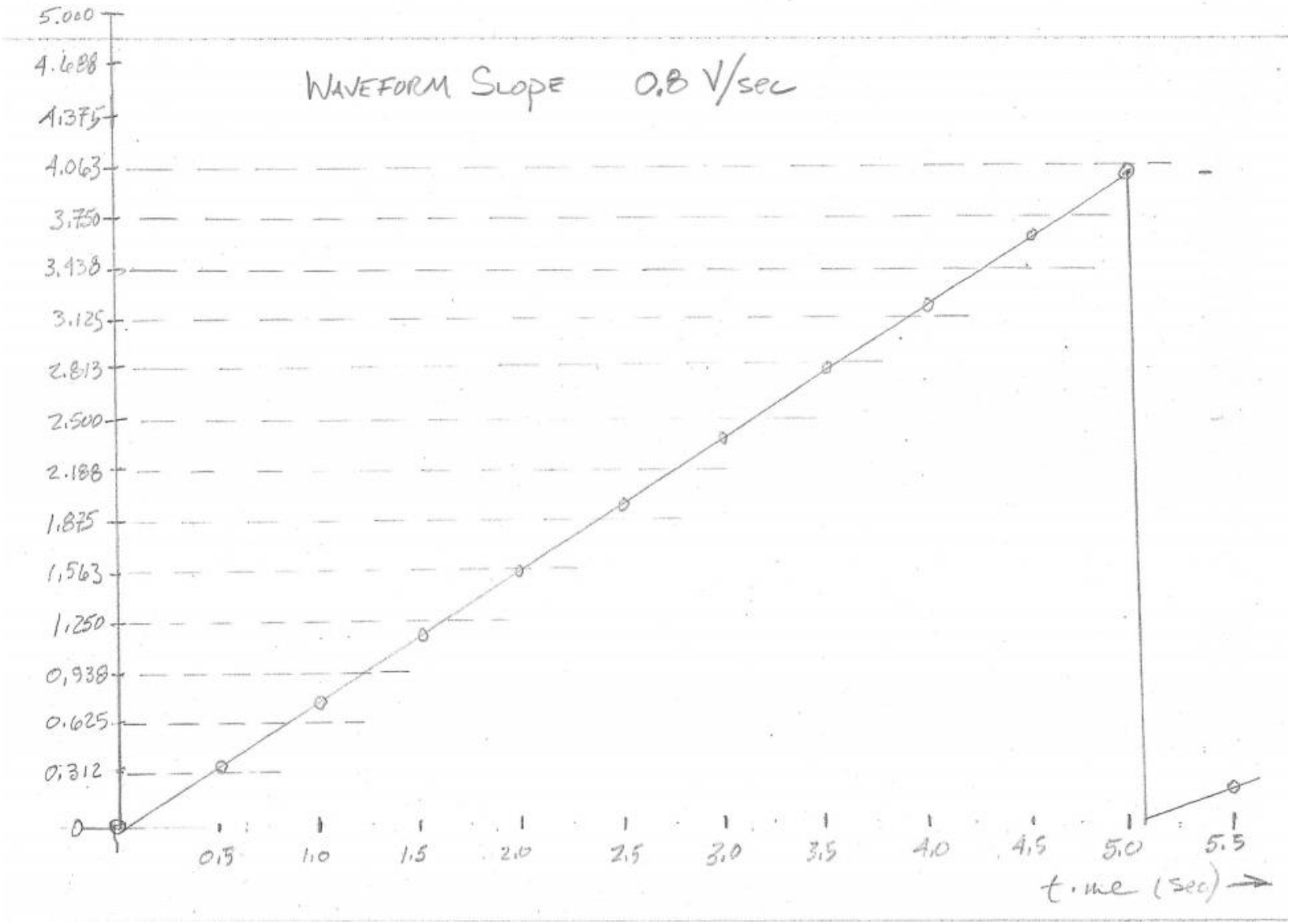
Resolution

Digitized data can give a few surprises. Aliasing is one that is well known, but it's not the only one.

Let's look at an example of something simple – a slow 4.0 Volt sawtooth waveform with slope of 0.8 Volts/second.

Assume 0-5 VDC A/D with one sample every 0.5 seconds.

Sampled waveform



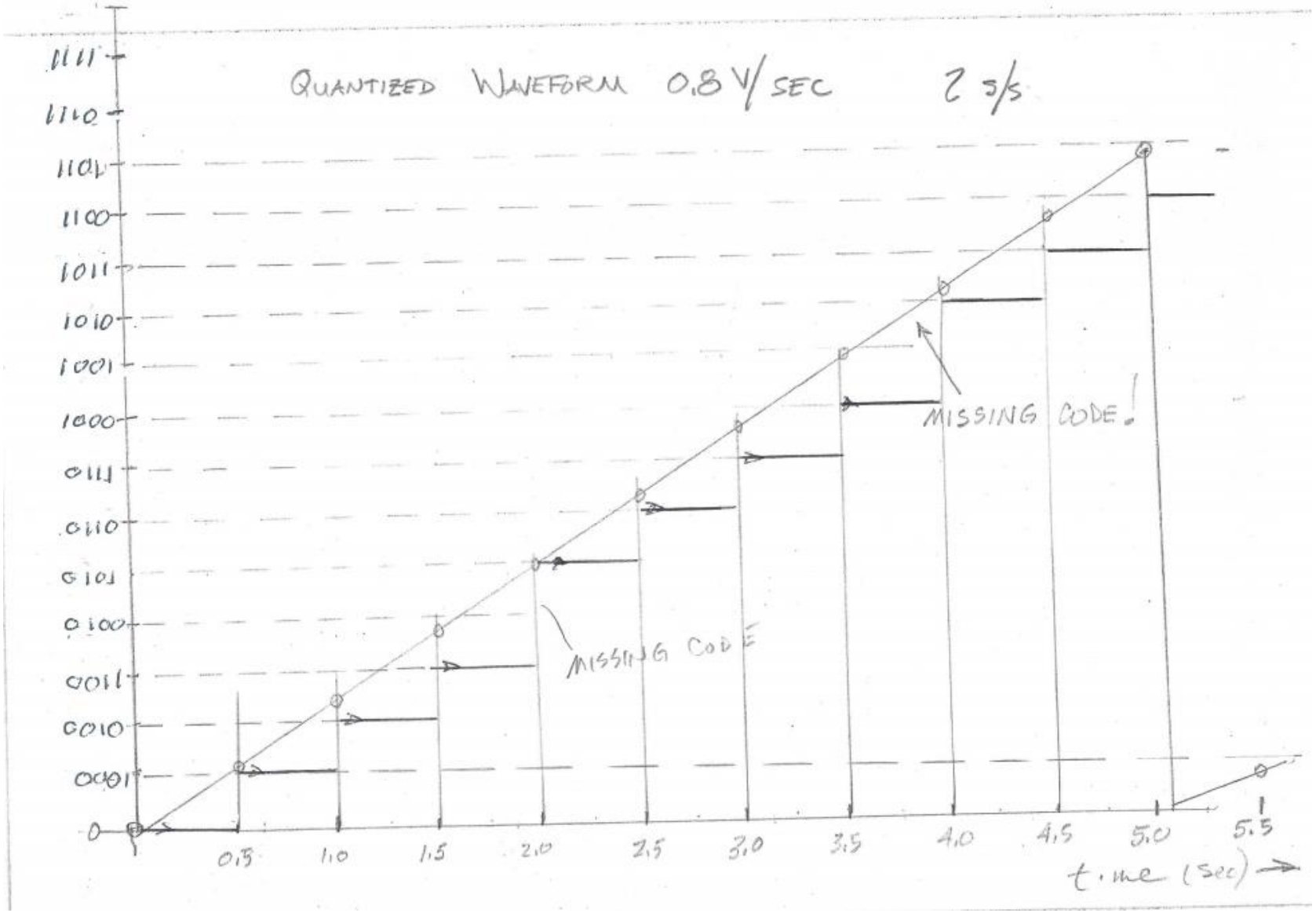
Sampled waveform

Time (sec)	Waveform value (Volts)	Quantized value
0.00	0.00	0000
0.50	0.40	0001
1.00	0.80	0010
1.50	1.20	0011
2.00	1.60	0101
2.50	2.00	0110
3.00	2.40	0111
3.50	2.80	1000
4.00	3.20	1010
4.50	3.60	1011
5.00	4.00	1100
5.50	0.40	0001
6.00	0.80	0010

Resolution

Does anything look odd in the digitized data stream?

Digitized waveform



Resolution

A 4-bit A/D converter is coarsely quantized, and the frequency of conversion is too slow.

There will always be quantization errors, but look out for errors due to a slow sample rate.

Multisim Options

Lab computers – ENDV 325

Multisim Live - https://www.multisim.com/
- Limited to 25 circuit components
- Basic component library

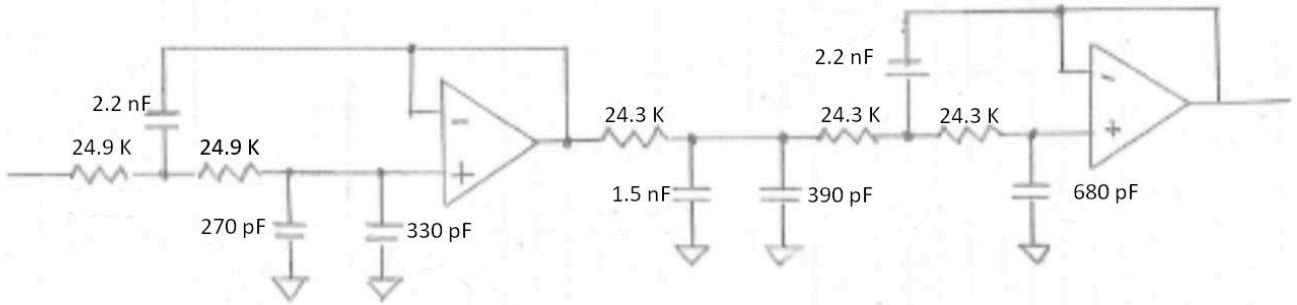
Bootcamp Dual boot or VirtualBox Virtual machine

CEAT computer checkout - https://ceat.okstate.edu/itservices/computer_services.html

Library semester long laptop checkout
- Starting Sept. 2023
- https://info.library.okstate.edu/laptops/longtermloan

Multisim Homework

In Multisim or another equivalent simulation environment, simulate the following low pass filter:



N=5 Bessel LPF Av = 0, fc = 3 kHz

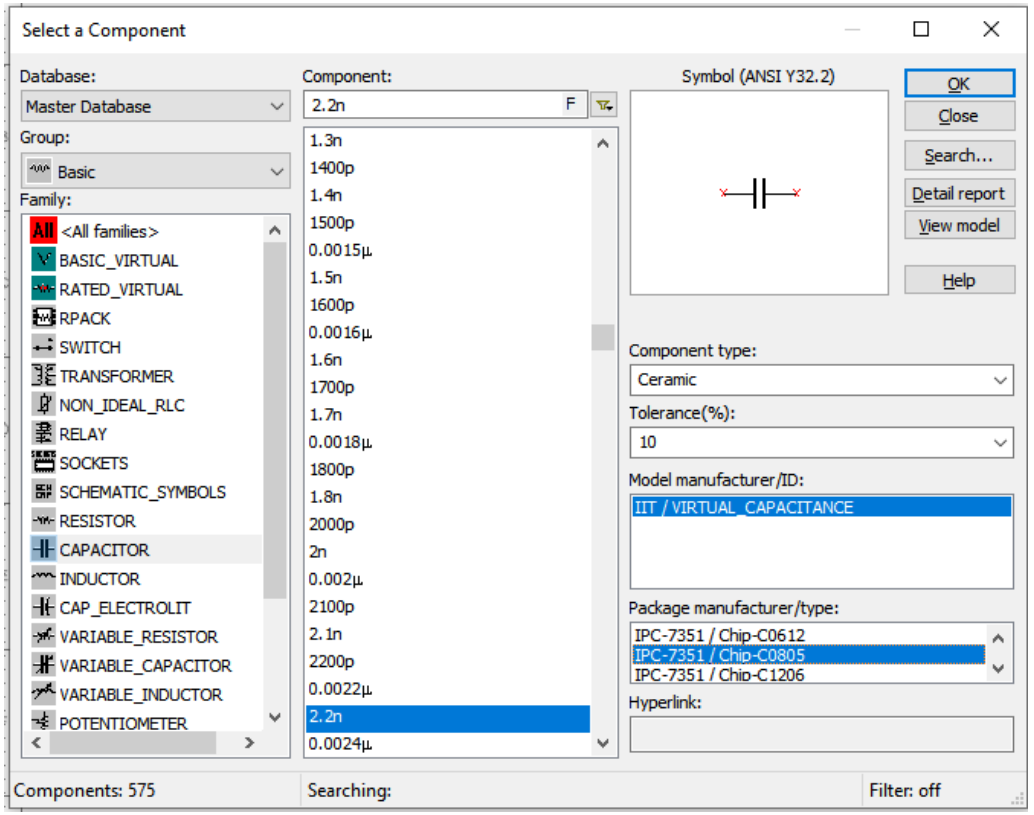
All capacitors type X7R, 0805 pkg, 10% or better
All resistors metal film, 1/10 W, 1%
Suggested Op-Amps:
LT 1007
LT 1037
OP-27
OP-37
LF355
TL081

Multisim Homework

The X7R dielectrics are ceramic based class II capacitors:

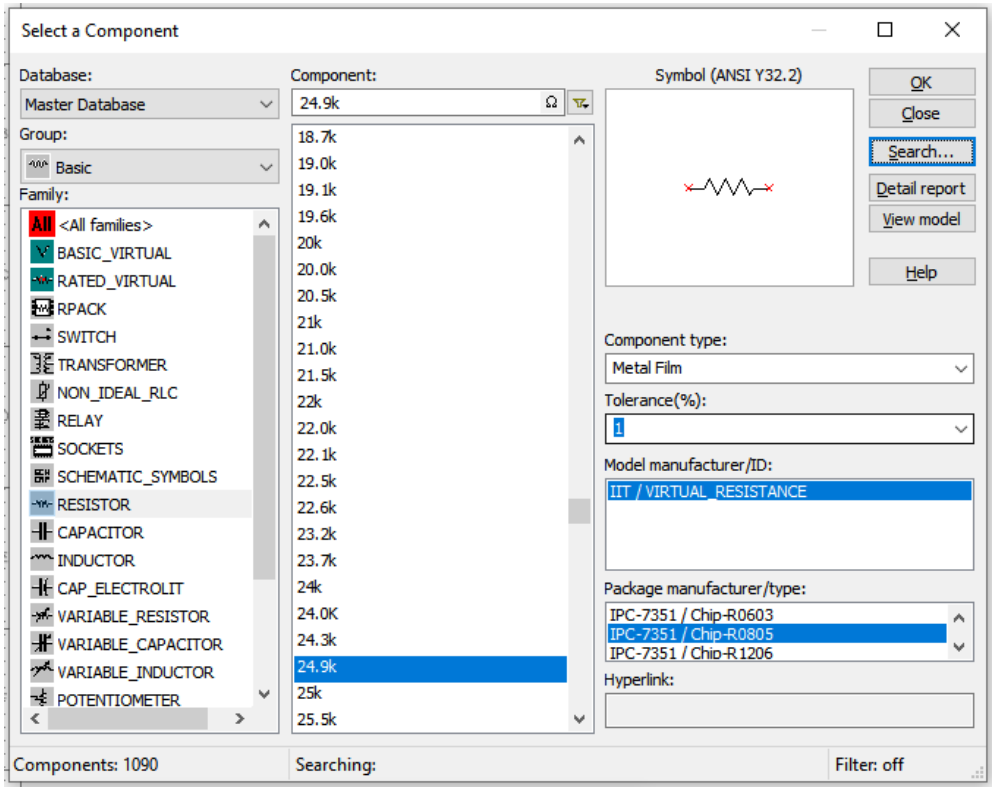
https://datasheets.avx.com/X7RDielectric.pdf

This is how you would enter in these caps into Multisim with an 0805 package:



Multisim Homework

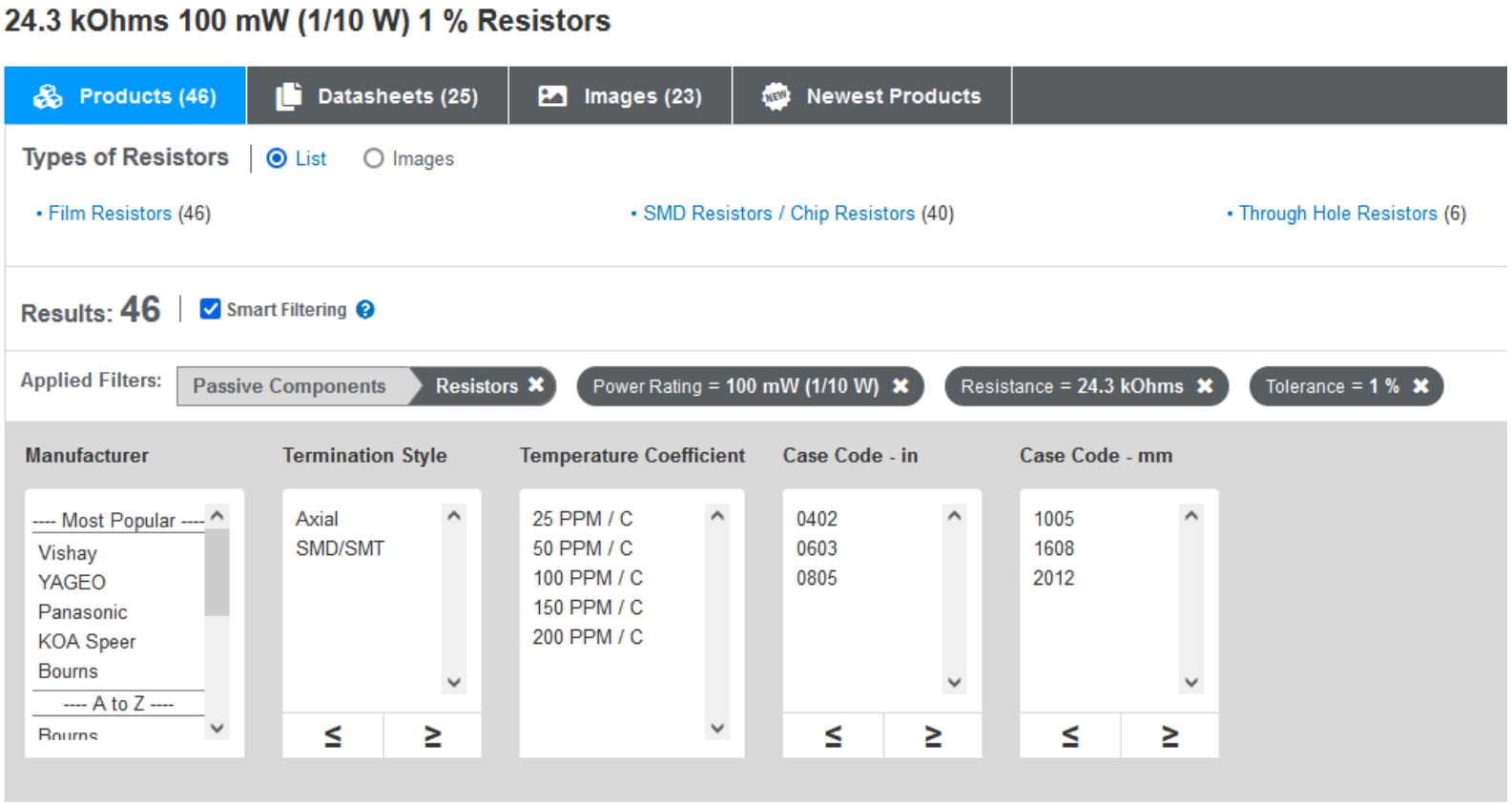
For the resistors, the spec sheet says metal film, 1/10 watt, +/- 1%:



If you want to simulate if the power across your resistors will exceed 1/10 watt you can monitor them or use a RATED_VIRTUAL resistor for testing. This will alert you when the power in your circuit has exceeded the rating specified in your resistor.

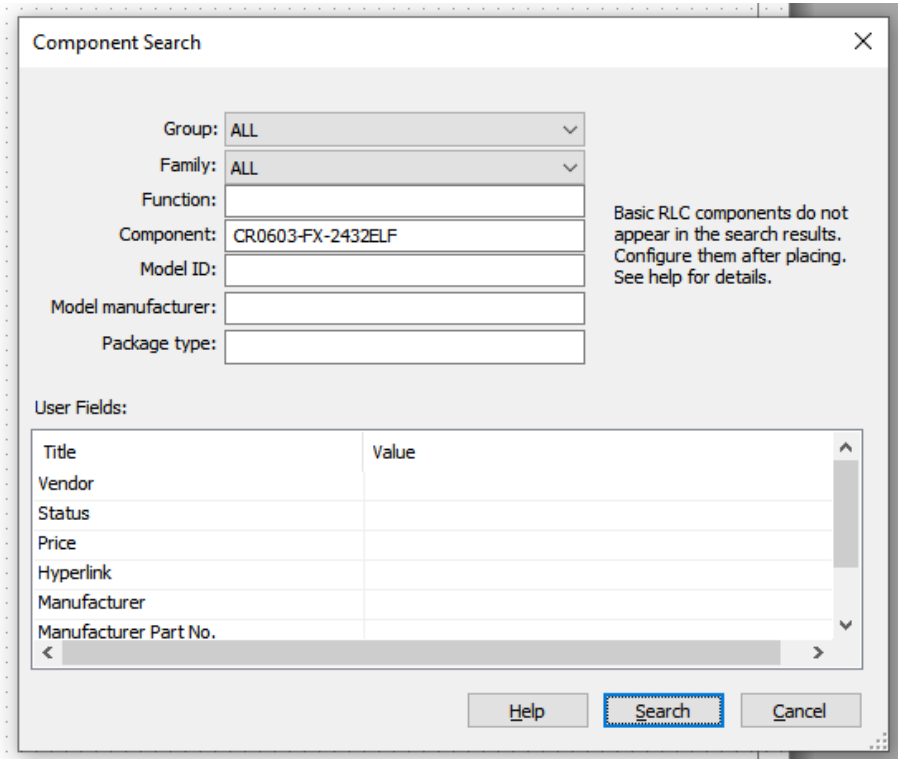
Multisim Homework

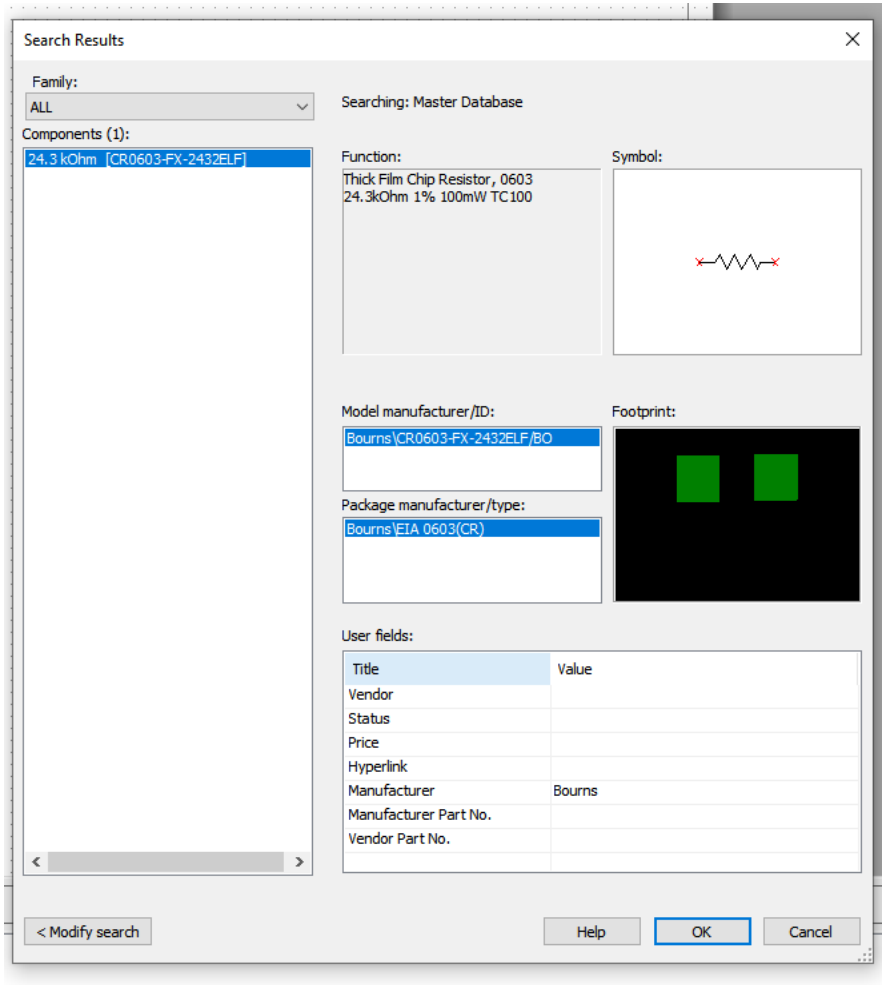
Alternatively, for precise parts (assuming you are ready for part selection) you can find your part on Mouser and search for them in Multisim. Here is a 1/10 W 1% metal film resistor:



Multisim Homework

Which you can then search for in Multisim:





Multisim Homework

All of the listed op amps will suffice for the circuit. The extra pins on the op amps are for supply voltage for the op amp (pins 4 and 7), and two offset voltage pins (pins 1 and 8). For our purposes, the offset voltage pins can be ignored, but if you are curious about why they are needed in precision work, here is a little more reading:

https://www.analog.com/media/en/training-seminars/tutorials/MT-037.pdf.

You can find this information by searching a pinout for your part. Here is a pinout for the OP27 line:

https://www.analog.com/en/products/op27.html