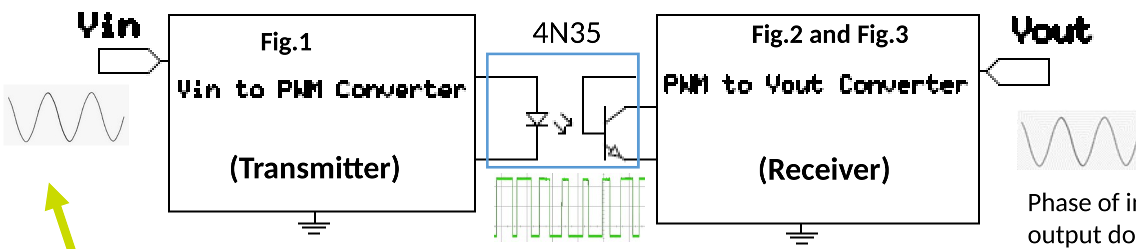
ECSE 371 LAB #8: Mixed Signal V24.4

Please study the interesting and appropriate sections of H&H, Ch. 10, 12,and 13.5.1. You should already be familiar with the mathematical “Boolean” sections, so please concentrate on the sections relating to electrical characteristics, flip-flops, one-shots, debouncing, etc.as well as sampling theory.

Part1, PWM Modulation/Demodulation

Design a circuit that will produce a PWM waveform that will be the digital representation of an input signal. This waveform will be sent over a transmission channel to a receiver/converter which will reconstruct the original signal. The transmitter and receiver will be coupled by an opto coupler which will substitute for an optical fiber link or other digital transmission channel. For demo purposes, make your PWM (sample) frequency adjustable with a pot over at least one decade.



Phase of input and output do not have to match. Amplitude should be similar.

Fig.1, Vin to PWM CONVERTER:

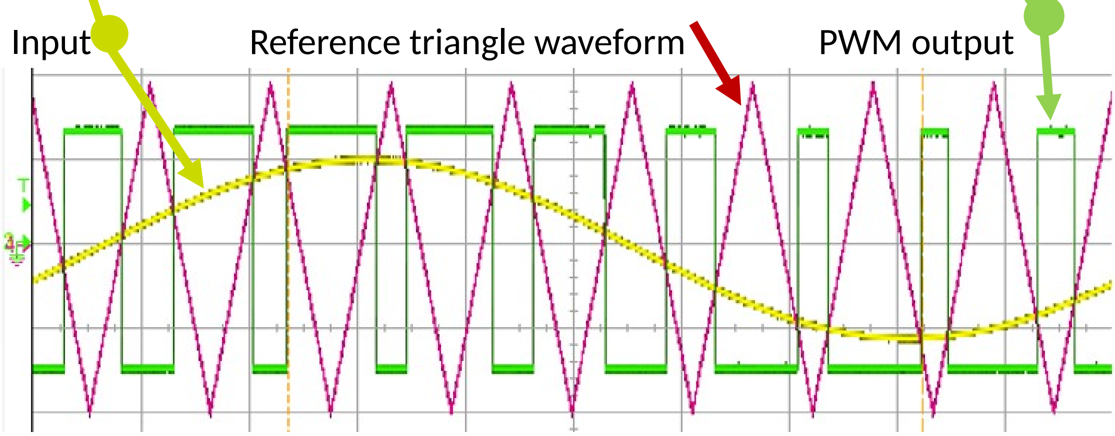
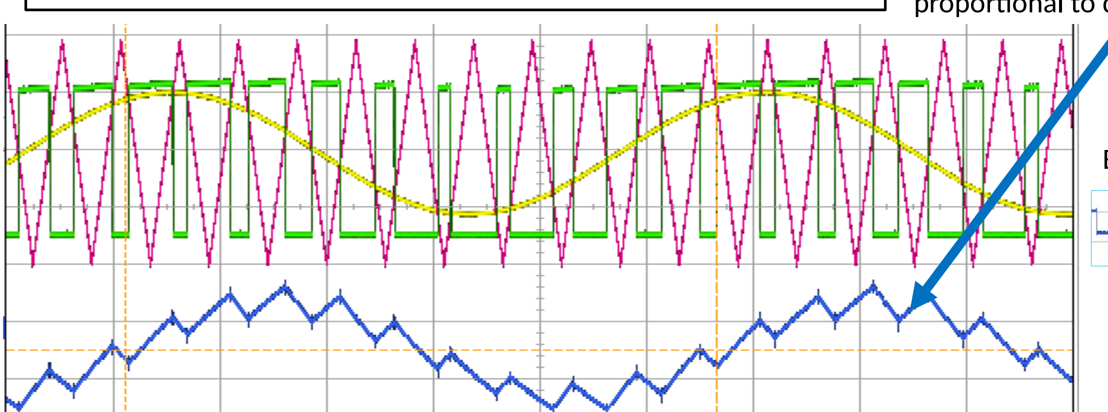


Fig.2, PWM to Vout, with CONVERTER #1:

Converter #1 incorporates a simple RC filter for averaging the PWM signal (green) to produce a voltage proportional to duty-cycle.



Before filtering:

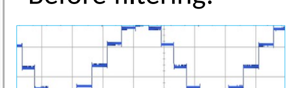
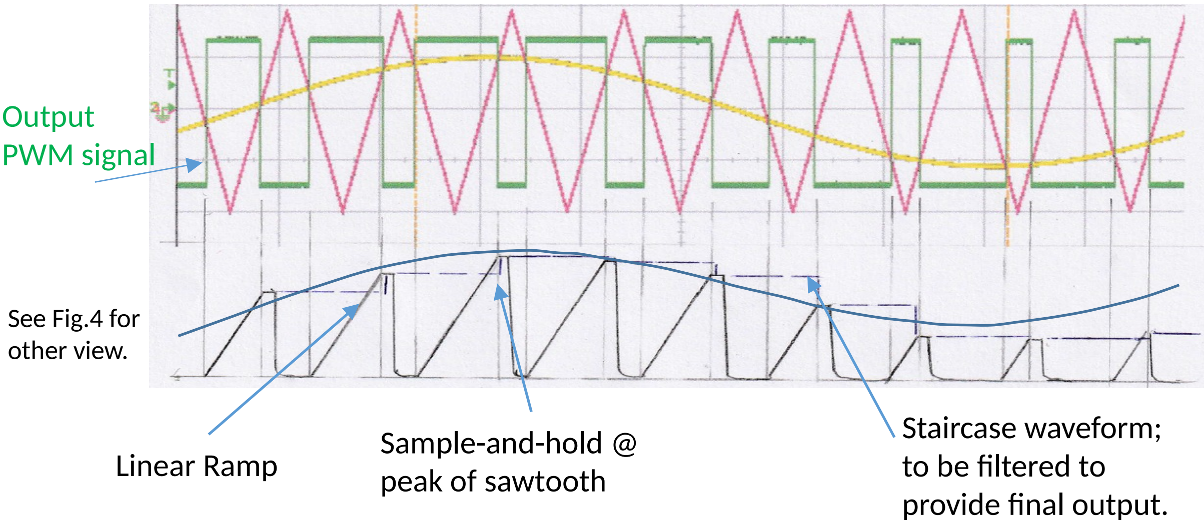


Fig.3, PWM to Vout, CONVERTER #2:

Converter #2 produces a "staircase" output using a linear ramp and a sample-and hold; this is much easier to filter and provides a better result (much faster response time) than converter #1.



<u>You will use Converter #2</u> This is a pulse width-to-amplitude converter; it produces a staircase waveform which is much easier to filter.

Specifications:

<u>Input</u>: 0 Hz to 200 Hz sinewave from generator, 0 to 10Vpp (include DC). Be careful when selecting the triangle-wave amplitude, which does not vary.

<u>Output</u>: Same as input. Will drive a 1K load.

<u>Power Supply</u>: 15V single- supply, both transmitter and receiver. Use the CMOS 4066 analog switch with the 15V supply. Naturally, the "in" and "out" signal lines must stay between the rails. The control input must be switched by a logic-level voltage. Consult a 4N35 data sheet for its specifications.

<u>Discussion</u>: This is a circuit- design course, so you should not be too concerned with theoretical aspects of sampling. Nevertheless, you will want to vary the ratio of sampling rate (pot-adjustable) to the frequency of the input sinewave and see what happens. Can you relate this to Nyquist criterion? Also try different input wave shapes besides than the sinewave; remember that waveforms other than a sinewave include higher- frequency components that must be considered when sampling. Use converter #2 (sample- and- hold design) In Fig.3 above.

Before you head to the lab, carefully draw accurate diagrams of the waveforms that you will be working with. These waveforms should precisely reflect amplitude and timing relationships; only then can you begin to design the required circuitry.

<u>For Saturday</u>. Provide a block diagram, waveforms, and preliminary schematic for both the transmitter and receiver.

<u>To record oscilloscope traces:</u> Do not use a camera. Use a USB stick and press *Save/Recall* under *Measurement*; then the *Press to Save* soft button. Transfer your picture to PowerPoint and then clearly and unambiguously annotate the trace.

Fig. 4

LAB 8 Receiver Waveforms: PWM input / Staircase Output

Yellow = PWM signal from optoisolator. Green = one-shot. Red = sawtooth. Blue = staircase = output

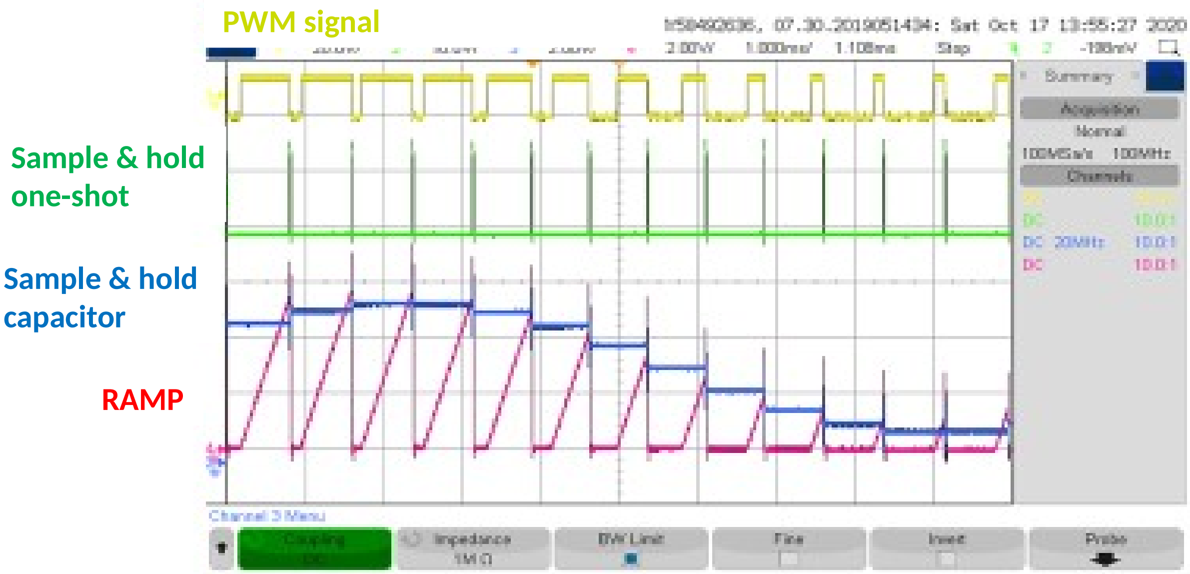
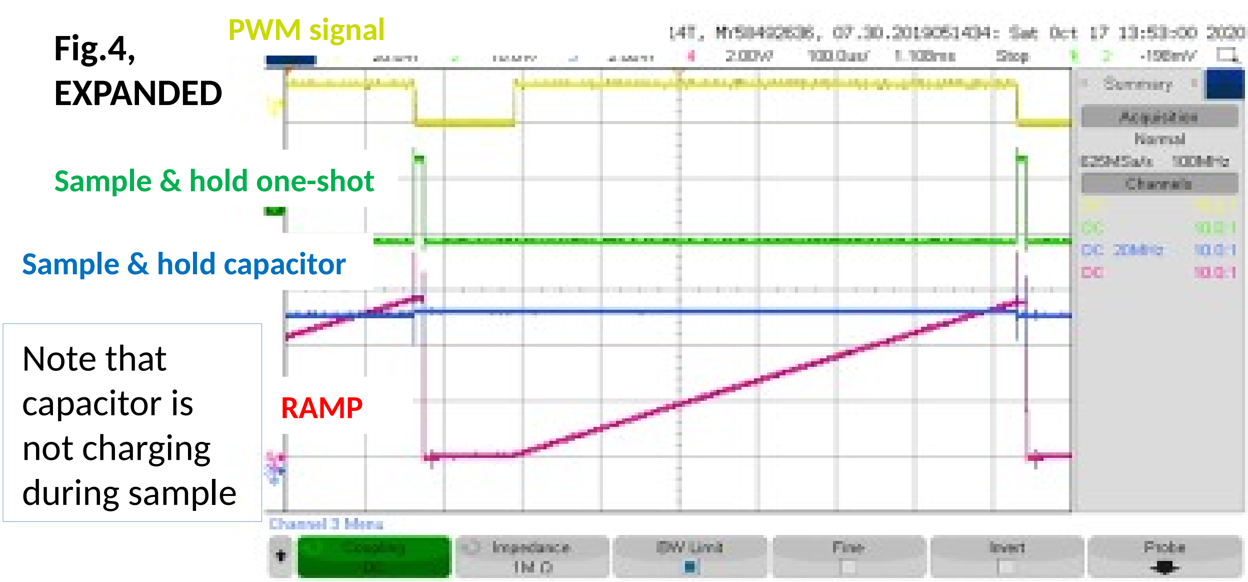


Fig.4, EXPANDED



The sequence is:

ramp – halt ramp – sample (and hold) – reset ramp

<u>In your Lab Report.</u> Provide clear, complete schematics and scope traces: For the transmitter, show input, triangle, and PWM output waveforms (simultaneously, use 3 channels). For the receiver show input PWM, ramp, and staircase waveform. If a fourth scope probe is available, or in a separate display, show the output sine wave. It is only necessary to record scope traces at a single, representative input frequency and amplitude. <u>The oscilloscope should be set up to clearly depict waveforms with enough amplitude and horizontal resolution to provide a meaningful, informative display</u>.

TEST to verify performance:

1. **Measure THD:** Compare the THD of the input waveform with the THD of the reconstructed waveform at the output record results.
2. **DC accuracy and linearity:** Input 0V, 1.00 and 5.00 VDC; measure the DC output; use a DMM. Record results.

Please set up your circuit to demo for your recitation.

POINTS TO PONDER REGARDING LAB #8

•Before you design your circuit, be sure to prepare a timing diagram to show the various states and timing of your circuit. An example is shown below. Be sure to show amplitude (above and below ground?), pulse length, etc.

•**Before you go too far, be sure you completely understand the sequence of operations and have determined the maximum and minimum values of amplitude and period that you expect.**

•**Remember that distortion of the input signal will occur if your ramp or sawtooth is not perfectly linear.**

•In this lab you may be using comparators, op amps, one- shots, logic, and analog switches. Use a single 15V supply for both sections. To maintain the best accuracy and signal-to-noise ratio, the swing of your signal, triangle, ramp, etc. should be around 0 to 10V. This should work well with single-supply op amps, comparators, and the 4066. Carefully check your design and wiring!

•If the function generator common is floating (not connected to building ground like the oscilloscope), you could connect it to the center of the single 15V supply by creating a +/- 7.5V split supply with a resistor network (bypassed). Ideally, however, you should connect the generator common to the negative of your 15V supply (we always like to keep our grounds common). You can do this if you provide a clever summing network at the generator input of your circuit. As stated above, you want to have the signal within your circuits swinging between zero and +10 so it can be processed - as shown in the attached waveforms; therefore, when the generator sinewave is zero, the voltage at the output of the summing network will be ½ the supply.

• Remember to build and test **step-by-step** where possible. Learn to obsessively glance at the *AMPS* display on your power supply; this will help you notice if you have miss-wired, plugged in a component backwards, shorted something out, etc. Review the Lecture, “Digital Logic V22.x” in Canvas *modules*.

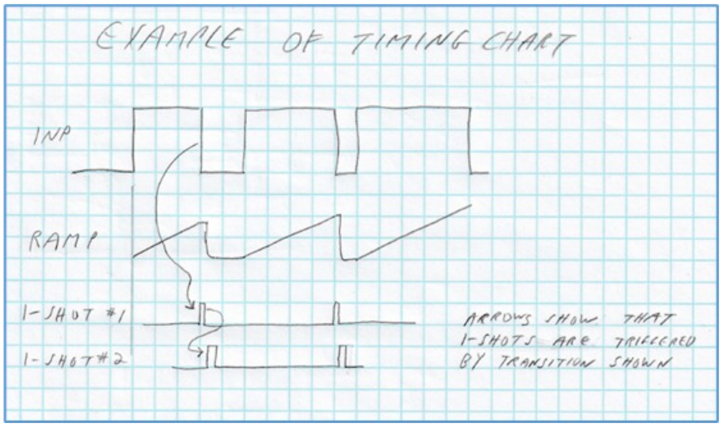
•Be sure that you understand the relationships and limits of certain basic functions. For example, you might use an analog switch to discharge an integrating capacitor used in a ramp or triangle-generating circuit. In this case, a key consideration is the size of the capacitor and charging current. To determine its value, you would probably first determine a reasonable constant-current value with which to charge the capacitor and create the ramp; to determine this current, you might start with considering the possible range of charging-current values. An example of a maximum value might be the short-circuit current of the op amp or the collector current of a transistor. In the case of the transistor, however, at high collector currents both reduced beta and power dissipation could be a problem. On the other hand, the minimum value might be determined by capacitor leakage (unlikely), or the input bias- current of a following op amp. (Use a better op-amp?) When it comes to quickly discharging the capacitor with the analog switch, you must consider the ON resistance of the analog switch; if the capacitor is too large you may not be able to discharge it quickly enough. In any case, you would probably never use capacitors less than a several hundred picofarads because it is important to swamp out the parasitic capacitance of the solderless breadboard and wiring.

•**Test** with a steady DC voltage instead of a sine wave; record the input voltage versus output voltage at a few points and **include this in your lab report**. This is a good way to precisely evaluate your circuit's performance.

•It’s not necessary to excessively filter your output sine wave; I’m more interested in seeing that the ramp and sample- and- hold are correct. In fact, filtering may not even be necessary. For your recitation and lab report, please provide, at the very minimum, scope waveforms similar to the ones attached. Remember that scope traces <u>should always be clearly annotated</u>. To provide the most information, it is sometimes best to show one picture with a 2-3 cycles for best resolution, and another version with 10 or 12 cycles; I have done this with some of the attached scope traces. Also, be sure that the displayed amplitude of the traces is optimized.

There are several changing, interrelated things going on here, so DO NOT GUESS AT VALUES. Before construction, look at your timing diagram and calculate one-shot periods, slope of the ramp, signal swings, etc.

Example of Timing Diagram



PART 2; <u>DEBOUNCE CIRCUIT AND 555 ONE-SHOT</u>

Design a one-shot using a 555. The one-shot should produce a single, 1ms pulse every time a switch is closed (and only when it is closed, not when it is opened). Initially, build and test the circuit without incorporating an anti-bounce circuit; carefully observe and record the circuit performance. **(P)**

Next, incorporate an anti-bounce stage, using separate CMOS logic, to interface with the switch. For recitation, provide a clear schematic and a 3-channel scope trace showing the switch waveform, the anti-bounce circuit output, and the 1-shot output. **(P)**

Use a momentary push button as provided in the lab, or any other SPST switch.(two wires). You might also investigate the characteristics of one or two switches or pushbuttons that you find in the flea market. Operate the switch and circuit on a 15 VDC supply. <u>Note that for purposes of this lab, the duration of the contact bounce may be as long as 300 ms</u>. The maximum rate at which the pushbutton will be pressed is once per second.

Question: if the output of the one-shot is longer than the contact bounce, is the anti- bounce circuitry still necessary?

PART 3; <u>Tachometer</u> (Frequency-to-voltage converter)

Design, build, and test, a tachometer circuit that will provide a voltage proportional to the speed of the motor shown below. Use the magnetic reed switch to sense rotation. The output of your circuit should be 1.00 V per 1000 RPM. This is the motor/reed-switch assembly that was used in lab #0.

You may choose a different reed switch connection; pulling up, for example. The 100- ohm resistor is included in the fixture to protect the reed switch in the event of a wrong connection.