E2.1 – Digital Electronics II

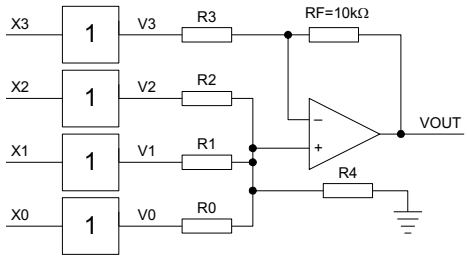
Problem Sheet 5 – Data Converters (Lectures 9 and 11)

(Question ratings: A=Easy, …, E=Hard. All students should do questions rated A, B or C as a minimum)

1B. A 3½ digit Digital Voltmeter has a display range of ±1999 and an accuracy of ±2 on the display. How many bits would a binary A/D converter need to have for its ±0.5 LSB accuracy to be as good as that of the DVM?

2B. A 12-bit converter has a resolution of 1 mV (i.e. 1 LSB = 1 mV) and input voltages in the range ±0.5 mV are converted to the value 0. What range of input voltages will be converted to –2047 ?

3B. A 10-bit converter converts an input voltage x to the value floor(x / 10mV). If 1 V < x < 8 V, what range of output values will be obtained ?



4C. X3:0 is a 4-bit signed number whose value, X, lies in the range –8 to +7. If the logic levels of V3:0 are 0 V and +5 V, choose values for R0 to R4 so that VOUT is equal to X/8 volts.

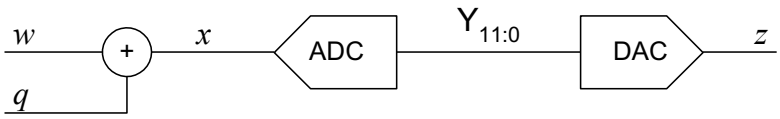
5C. The composite video signal to drive a monochrome TV monitor takes one of three different voltages according to the values of two digital signals DATA and SYNC:

DATA	SYNC	V_{OUT}
0	0	0.0
1	0	0.7
0	1	–0.3
1	1	Don't Care

Design a circuit to generate VOUT having a 50 Ω output impedance. You may assume that output logic levels are 0 and 5 V and that +5 V and –5 V power supplies are available should you need them. You do not need any op-amps although you will need at least one logic gate.

6B. Signals on a compact disc are stored as sequences of 16-bit numbers. Determine the maximum undistorted signal-to-noise ratio obtainable for a music signal whose peak amplitude is 10 times as great as its RMS value.

7B. Traingular pdf dither, q, of amplitude ±1 mV is added to an input signal, w, before conversion to a 12 bit number Y11:0. This is then sent to a DAC to generate an output voltage z. If all voltages are measured in mV then $z = \text{round}(w+q)$ and the pdf of q is equal to $p(q) = 1 - |q|$ for $|q| < 1$.



(a) Assuming that $|w| < 0.5$, show that the probability that $z = -1$ is given by $pr(z=-1) = 0.125 \times (2w-1)^2$.

(b) Derive similar expressions for $pr(z=0)$ and $pr(z=+1)$ for $|w| < 0.5$.

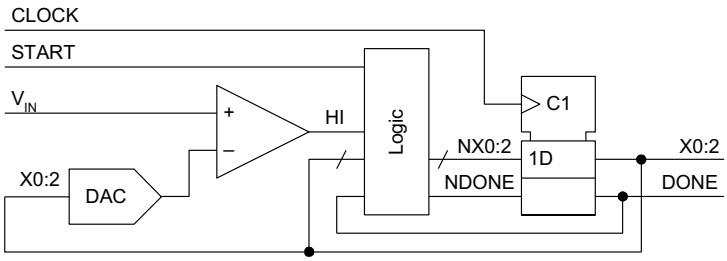
(c) Determine the mean and variance of z in terms of w.

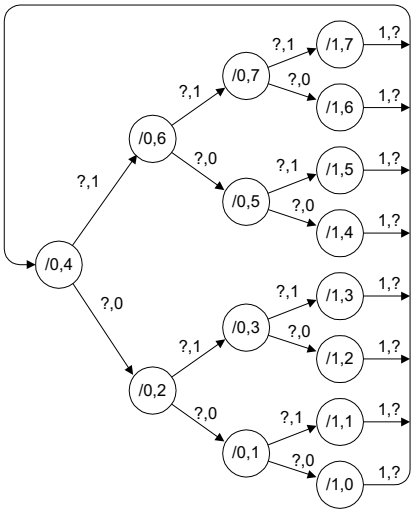
8C. A sample-hold circuit is used to store the input voltage of a 12-bit A/D converter during each conversion. The sample-hold circuit has an aperture uncertainty of 5 ns and a leakage current of ±1 nA. The A/D converter has an input voltage range of ±10 V.

If the input voltage is a sine wave of amplitude 10 V, calculate the input frequency at which the aperture uncertainty will result in an error of ±0.5 LSB [surprisingly low].

If the sample-hold uses a storage capacitor of 200 pF calculate how long the input voltage can be held before it changes by 0.5 LSB due to the leakage current.

9D. The circuit and state diagrams for a successive approximation converter are shown below. The output signals X2:0 and DONE are also used as the state bits. Derive Boolean equations for NX2:0 and NDONE. You should ensure that your circuit can never get stuck.





I/O Signals: START,HI/DONE,X0:2