ECE 363 QUIZ 5 (F19) NAME: Solutions

1 problem for 20 pts

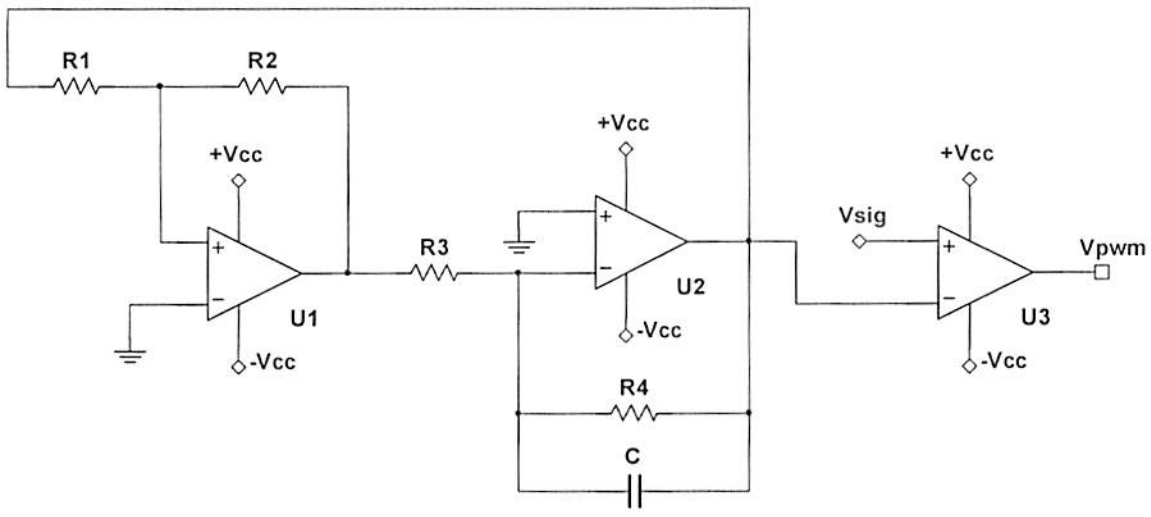
Pulse Width Modulator

Consider the pulse width modulator shown in the figure below. The circuit uses three op amps (two for the triangle wave generator, one for the comparator). The desired specs are the following:

- Triangle wave: 8 volt peak-to-peak (within 5%) at 4 kHz (within 5%)
- All op amps powered with split power supplies (+/- 12 V).
- Assume $V_{SAT(+)} = +(V_{CC} - 1)$ and $V_{SAT(-)} = -(V_{CC} - 1)$
- $V_{SIG} = +2$ V
- Use standard 5% resistor and 10% capacitor values.

The following formulas may be useful:

- Triangle wave frequency: $f = R_2 / (4R_1R_3C)$
- Threshold voltage: $V_{TH} = (R_1/R_2)(V_{SAT(+)} - V_{SAT(-)}) / 2$
- Reference voltage: $V_{REF} = (V_{SAT(+)} + V_{SAT(-)}) /2$



a) Choose R_1 and R_2. Remember that R_2 is typically in the 100 kohm range.

b) Choose R_3 and C. Remember that C is typically between 1 nF and 100 nF.

c) Choose an appropriate value for R_4.

d) Based on your component values, compute the actual frequency and peak-to-peak amplitude to confirm they satisfy the design requirements.

e) Sketch the PWM output over a 1 ms interval and include the duty cycle. Note: Be careful with analyzing the input connections to the comparator.

(extra sheet for work)

$V_{Sat(+)} = 11V$, $V_{Sat(-)} = -11V$

(a) Want $V_{TH} = 4V = \frac{R_1}{R_2}\frac{11-(-11)}{2} = 11\frac{R_1}{R_2}$

$\rightarrow \frac{R_1}{R_2} = 0.364$ Choose $\boxed{R_2 = 100K,\ R_1 = 36K}$ ← -1% error

(b) $f = \frac{R_2}{4R_1R_3C} = 4kHz \rightarrow R_3C = \frac{100K}{4(36K)(4\times10^3\,Hz)} = 1.736\times10^{-4}\,s$

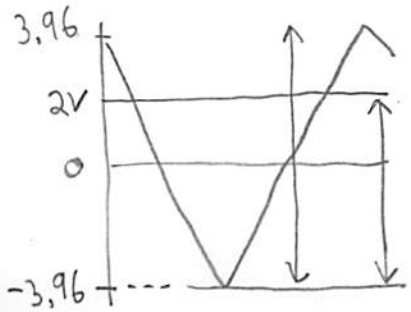
C	R_3 (ideal)	R_3 (5%)	Error
8.2nF	21.17K	22K	+3.92%
10nF	17.36K	18K	+3.69%
12nF	14.47K	**15K**	+3.66% ← smallest (barely)
15nF	11.57K	12K	+3.72%
18nF	9.64K	10K	+3.73%

(c) $R_4 > 10R_3 = 150K$ Choose $\boxed{R_4 = 160K}$ or higher

(d) $f = \frac{100K}{4(36K)(15\times10^3)(12\times10^{-9})} = \boxed{3858\,Hz}$ ✓ $\%error = \frac{3858-4000}{4000}\times100\% = -3.6\%$

$2V_{TH} = 2\frac{36K}{100K}11V = \boxed{7.92V}$ $\%\,error = \frac{7.92-8}{8}\times100\% = -1\%$ ✓

(e)



Duty Cycle $= \frac{2+3.96}{7.92}\times100\% = \boxed{75.3\%}$

$\frac{1}{4kHz} = .25\,ms$ per cycle