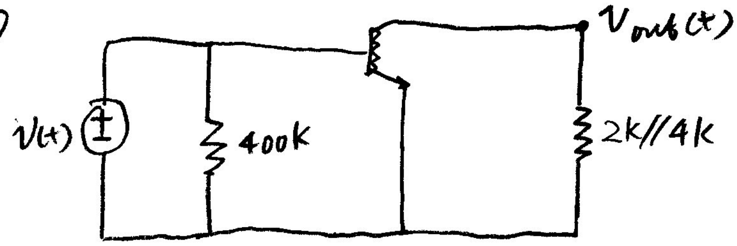
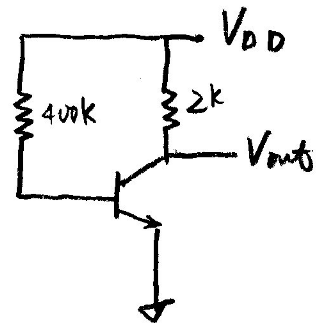
P1. (a)



(b) DC:

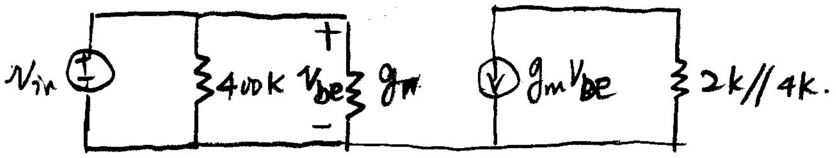


$$I_B = \frac{10-0.6}{400k} = 23.5\,uA$$

$$I_C = I_B \cdot \beta \approx 2.35\,mA$$

$$\therefore V_{outQ} = V_{DD} - I_C \cdot 2k \approx 5.3\,V$$

(c)



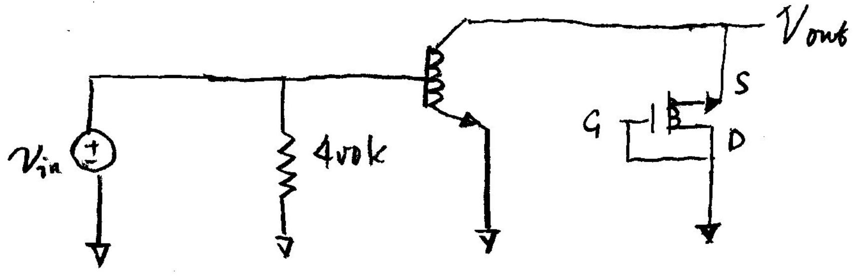
$$A_v = \frac{v_{out}}{v_{in}} = \frac{-g_m v_{be} \cdot (2k//4k)}{v_{be}} = -g_m \cdot (2k//4k)$$

$$= -\frac{I_{CQ}}{V_t} \cdot \frac{8}{6}k \qquad \left(V_t = \frac{kT}{q} \approx 25mV\right)$$

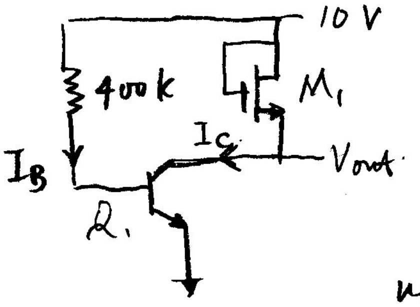
$$= -\frac{2.35m}{25m} \cdot \frac{8k}{6}$$

$$= -125.3$$

P2. ⓐ Small Signal.



ⓑ DC.



$$I_B = \frac{10-0.6}{400k} = 23.5\mu A \Rightarrow I_C = \beta I_B = 2.35mA \quad \text{--- ①}$$

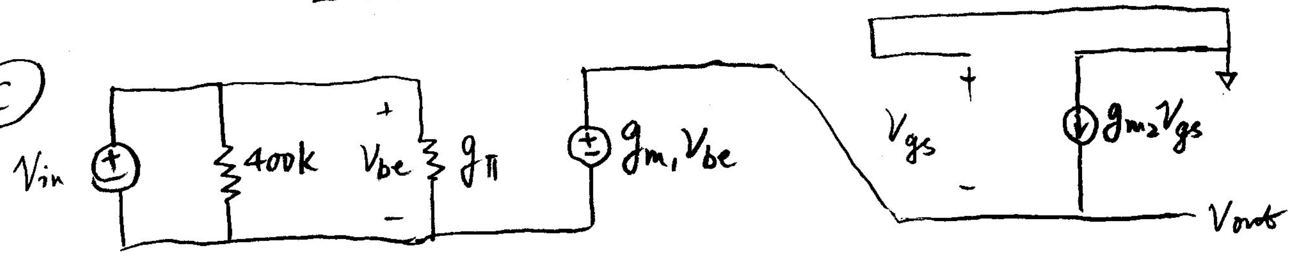
$$I_C = \frac{\mu C_{ox} W}{2L} (V_{GS} - V_T)^2 \quad \text{--- ②}$$

$$V_{GS} = V_{DD} - V_{out} = 5V \quad \text{--- ③}$$

using ① ② ③ we have.

$$\frac{100\mu \cdot W}{2 \cdot 2\mu} \cdot (5-1)^2 = 2.35 mA \Rightarrow W = 5.875 \mu m$$

ⓒ



$$g_{m1} = \frac{I_{CQ}}{V_t} = \frac{2.35m}{25m} = 0.094$$

$$g_{m2} = \frac{2 I_{CQ}}{V_{GSQ} - V_T} = \frac{2.35m}{5-1} = 1.175m$$

$$\begin{cases} g_{m1} V_{be} = g_{m2} V_{gs} \\ V_{be} = V_{in} \\ V_{out} = -V_{gs} \end{cases} \Rightarrow A_v = \frac{v_{out}}{v_{in}} = -\frac{g_{m1}}{g_{m2}} = -80$$

P3 $\frac{V_{REF}}{10^m} = \frac{V_{REF}}{2^n} \Rightarrow n \approx m \log_2 10 = 13.29$

$n = \lceil 13.29 \rceil = 14$ bits

P4 $V_{LSB} = \frac{V_{REF}}{2^n} = \frac{2}{2^{14}} \approx 122\,\mu V$

P5 $V_{LSB} = \frac{5}{2^{12}} = 1.22\,mV$

$\text{Output} = \left\lfloor \frac{V_{in}}{LSB} \right\rfloor = 2730 = (101010101010)_2$

P6 ⓐ $V_{in} = 2.5 + 0.5 \sin(\omega t) \rightarrow |V_{in}|_{max} = 3V$

$V_{LSB} = \frac{V_{REF}}{2^{10}} = 4.883\,mV$

$\text{Output} = \left\lfloor \frac{3V}{V_{LSB}} \right\rfloor = 614 = (1001100110)_2.$

$\text{error} = \frac{3 - 614 \cdot V_{LSB}}{3} = 0.067\%$

ⓑ $V_{in} = 2.5 + 2.5 \sin(\omega t) \rightarrow |V_{in}|_{max} = 5V$

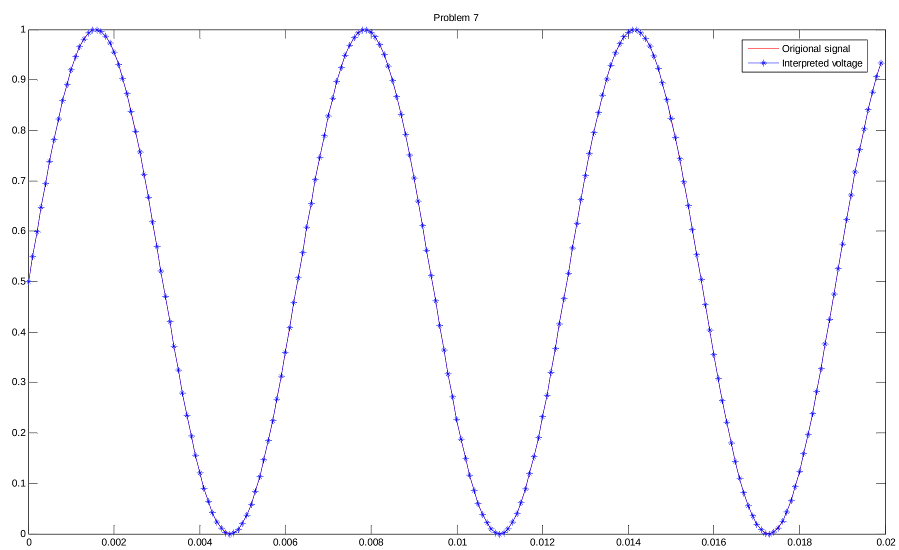
$\text{output} = \left\lfloor \frac{5V}{V_{LSB}} \right\rfloor = 2^{10} = 1024$

$\text{error} = \frac{5 - 1024 \cdot V_{LSB}}{5} = 0$

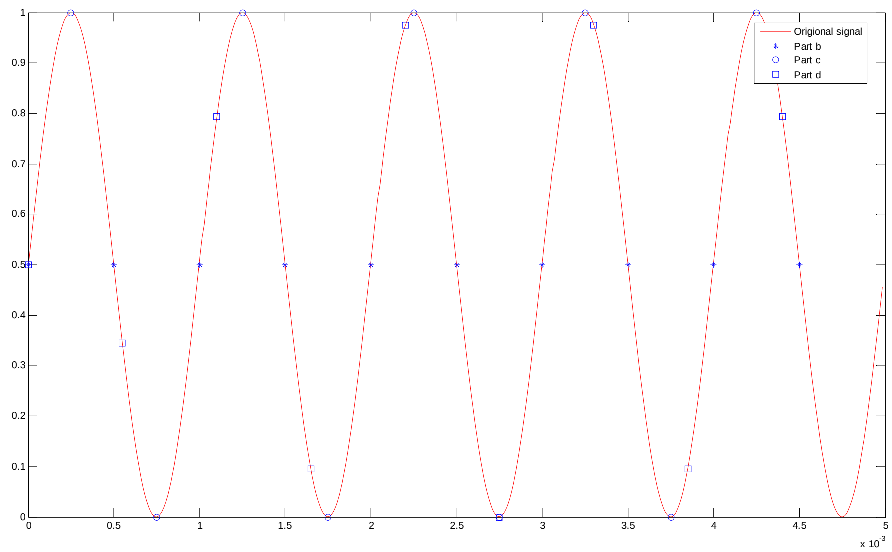
```
%%%%%%% hw 12 matlab code of problem 7 %%%%%%

n=12;
VREF=1;
VLSB=VREF/2^n;
Ts=100*10^(-6);
T=0:Ts:Ts*(200-1);
%    origional signal
S=0.5+0.5*sin(1000.*T);
%    Interpreted voltage
Vout=floor((0.5+0.5*sin(1000.*T))./VLSB).*VLSB;
%    Boolean output
Boolean=dec2bin(floor((0.5+0.5*sin(1000.*T))./VLSB));

plot(T,S,'-r')
hold on
plot(T,Vout,'-*')
legend('Origional signal','Interpreted voltage')
```



Problem 8



(a) See figure above

(b) We can not reconstruct the original signal from the sampling results without any prior information. For example, if the input signal is a sine wave having twice the frequency or a triangular waveform having same time period. Even if we know the sampling frequency is larger than or equal to the input frequency, we still can not tell whether the input is a sine wave (We would not be able to find the amplitude.) or a zero input (no input).

(c) If we know the sampling frequency is larger than or equal to the input frequency, we can recover the input signal.

(d) It is impossible to reconstruct the signal as the sampling frequency is not large enough.

(e) See comments above.

P9. (a) $W_{max} = 60\text{ tons} + \underset{\text{scale}}{20\text{ tons}} = 80\text{ tons}$

maximum error $= (\pm 0.001) \cdot 60\text{ tons} = \pm 0.06\text{ tons}$

which is the $\frac{LSB}{2}$ $\Rightarrow LSB = 0.12$

hence $\frac{80\text{ tons}}{2^n} = 0.12\text{ tons} \Rightarrow n = 9.38 \rightarrow$ 10 bits ADC

(b) 56 lbs per bushel, so the weight is

$750 \cdot 56 = 42.000\text{ lbs}$ if fully loaded

$= 21\text{ tons}$

accuracy $= \frac{\pm 0.06}{21} = \pm 0.286\%$

(c) If the load were only 50 bushel

the weight is 2800 lbs or 1.4 tons

accuracy $= \frac{\pm 0.06}{1.4t} = \pm 4.28\%$

(d) if the weight of scale is calibrated out

$W_{max} = 60\text{ tons}$

$\frac{60}{2^n} = 8.965 \Rightarrow$ 9 bits ADC

P10 (a) $e_{max} = \frac{\pm 0.06\text{ tons}}{16 \cdot 40\text{ lbs}} = \frac{\pm 120\text{ lbs}}{640\text{ lbs}} = \pm 18.8\%$

(b) dollar error $(\pm 0.188)(\$120/\text{ton})(640\text{ lbs}) \cdot \left(\frac{1\text{ ton}}{2000\text{ lbs}}\right)$

$= \$7.20$