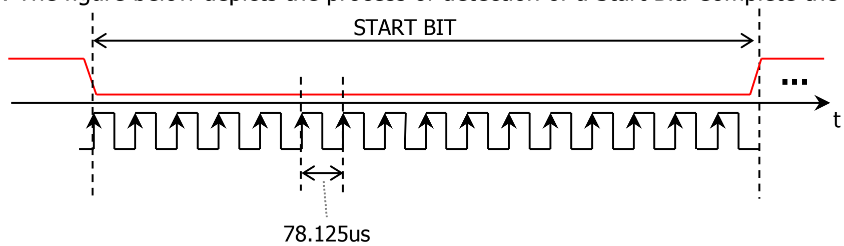
Solutions - Quiz 4

(November 25th @ 5:30 pm)

PROBLEM 1 (20 PTS)

- HCS12D – SCI1: The figure below depicts the process of detection of a Start Bit. Complete the table. E-clock = 24 MHz.



Baud Rate = Tx clock frequency (Hz)	**Rx clock frequency** (Hz)	**SCI1BDH**	**SCI1BDL**
800	12800	07	53

$$Rx\ clock = \frac{1}{78.125 \times 10^{-6}} = 12800 \rightarrow Tx\ clock = \frac{12800}{16} = 800$$

$$12800 = \frac{24 \times 10^{6}}{SBR} \rightarrow SBR = 1875 = 0x0753$$

PROBLEM 2 (50 PTS)

- Analog to Digital Conversion: Using the successive approximation algorithm, compute the $n-bit$ codes and their corresponding quantized voltages V_k for the input voltage Vin = 1.80v. V_{DD} = 5v.
  Formula for Quantized voltage: $V_k = \left(\frac{k}{2^n}\right)V_{DD}$

Vin =1.80v	**n-bit code**	**V_k (v)**
n = 4	0101	1.5625
n = 5	01011	1.71875

- If we want the <u>maximum quantization error</u> to be lower than 0.01v, what is the minimum number of bits that achieves this?

Vin = 1.80v, n = 4:

$b_3 = 1 \rightarrow Code = 1000 \rightarrow k = 8 \rightarrow V_k = \left(\frac{8}{2^4}\right)5 = 2.5v > Vin \rightarrow b_3 = 0$

$b_2 = 1 \rightarrow Code = 0100 \rightarrow k = 4 \rightarrow V_k = \left(\frac{4}{2^4}\right)5 = 1.25v \leq Vin \rightarrow b_2 = 1$

$b_1 = 1 \rightarrow Code = 0110 \rightarrow k = 6 \rightarrow V_k = \left(\frac{6}{2^4}\right)5 = 1.875v > Vin \rightarrow b_1 = 0$

$b_0 = 1 \rightarrow Code = 0101 \rightarrow k = 5 \rightarrow V_k = \left(\frac{5}{2^4}\right)5 = 1.5625v \leq Vin \rightarrow b_0 = 1$

$\Rightarrow Code = 0101, V_k = \left(\frac{5}{2^4}\right)5 = 1.5625v$

Vin = 1.80v, n = 5:

$b_4 = 1 \rightarrow Code = 10000 \rightarrow k = 16 \rightarrow V_k = \left(\frac{16}{2^5}\right)5 = 2.5v > Vin \rightarrow b_4 = 0$

$b_3 = 1 \rightarrow Code = 01000 \rightarrow k = 8 \rightarrow V_k = \left(\frac{8}{2^5}\right)5 = 1.25v \leq Vin \rightarrow b_3 = 1$

$b_2 = 1 \rightarrow Code = 01100 \rightarrow k = 12 \rightarrow V_k = \left(\frac{12}{2^5}\right)5 = 1.875v > Vin \rightarrow b_2 = 0$

$b_1 = 1 \rightarrow Code = 01010 \rightarrow k = 10 \rightarrow V_k = \left(\frac{10}{2^5}\right)5 = 1.5625v \leq Vin \rightarrow b_1 = 1$

$b_0 = 1 \rightarrow Code = 01011 \rightarrow k = 11 \rightarrow V_k = \left(\frac{11}{2^5}\right)5 = 1.71875v \leq Vin \rightarrow b_0 = 1$

$\Rightarrow Code = 01011, V_k = \left(\frac{11}{2^5}\right)5 = 1.71875v$

<u>Maximum Quantization error</u>: This is the equivalent voltage of 1 LSB: $\frac{1}{2^n} \times 5 < 0.01v \rightarrow 2^n > 500 \rightarrow n > 8.965$

$\Rightarrow$ Minimum **n = 9**

PROBLEM 3 (30 PTS)

Given the following CAN system requirements, calculate: i) Time Quantum, ii) CAN Bit Time (in units of time and in time quanta), and iii) Time segments (in time quanta).

sync_seg	prop_seg	phase_seg1	phase_seg2

E-clock= 24 MHz Bit rate = 200 kbps
Bus length = 40 m Bus propagation delay = $4 \times 10^{-9}\, {}^{s}/_{m}$
Transmitter (MCP2551 Transceiver) plus receiver propagation delay = 150 ns at 85 ºC

- $CAN\ Bit\ Time = t_{NBT} = \frac{1}{200\ kbps} = 5us$
- $Bus\ delay = 40m \times (4 \times 10^{-9}\, {}^{s}/_{m}) = 160ns \rightarrow t_{PROP\_SEG} = 2 \times (160 + 150) = 620ns$
- Pre-scaler: let's start with $M = 12$: $t_Q = 12 \times \frac{1}{24MHz} = 500ns$. Then: $CAN\ Bit\ Time = NBT = \frac{5us}{500ns} = 10$
  $\rightarrow prop\_seg = \left\lceil \frac{t_{PROP\_SEG}}{t_Q} \right\rceil = \left\lceil \frac{620}{500} \right\rceil = 2$. $\rightarrow sync\_seg + prop\_seg + phase\_seg1 + phase\_seg2\ = Bit\ Time = 10$
  $\rightarrow phase\_seg1 + phase\_seg2\ = 10 - 2 - 1 = 7$. Then, we add 1 to $prop\_seg$
  $\rightarrow phase\_seg2 = phase\_seg2 = 3,\ prop\_seg = 2 + 1 = 3$
- In summary: $M = 12,\ NBT = 10,\ sync\_seg = 1,\ prop\_seg1 = 3,\ phase\_seg1 = 3,\ phase\_seg2 = 3$