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May 14, 2009, 2-5pm

Open book, open notes, calculator (no laptops, phones, devices with screens larger than a TI-89 calculator, devices with wireless communication). Please don't turn in any extra sheets.

(6) Question 1. Consider how the ACK bit is used in a CAN network.

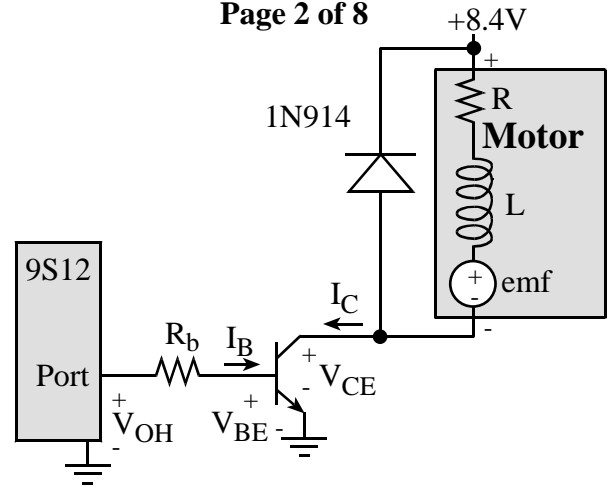
Part a) What do the receivers do during the ACK bit?

Part b) What does it mean if the ACK bit is high?

Part c) What does it mean if the ACK bit is low?

(4) Question 2. When designing a low power system, give the equation that defines **power budget**. Explain (define) each of the terms in the equation.

(15) **Question 3.** Consider the following motor interface. A series-wound DC motor, like the ones in the robot kit, can be modeled by a series combination of a resistor (the ohmic contribution of the long thin wires used to wrap the electromagnets), an inductor (physically resulting from the cylindrical manner in which the electromagnets are wound), and an emf (a voltage caused by the load torque applied from the shaft back into the electromagnet). The resistance is what you get when you measure the resistance of the motor with an ohmmeter (a stopped motor, disconnected from power). In this motor, $R = 100 \Omega$ and $L = 100 \mu\text{H}$. Hint: L/R is $1 \mu\text{sec}$.



Part a) Under maximum load, V_{CE} is 0.75V , the emf becomes -12.35V , and 0.2A flows through the motor. What transistor do you choose for this interface (specify part number)? Why?

Part b) What value do you choose for R_b ? Show your work using the labels from the picture.

Part c) Initially the motor is on (0.2A current to the motor). At time $t=0$, the digital port goes from $+5$ to 0 and transistor turns off. At time $t=0^+$, the emf is -12.35V (motor has external torque applied to the shaft) and the transistor turns off instantaneously. First, assuming there is no 1N914, graph the collector voltage (V_{CE}) as a function of time. Second, graph V_{CE} with the 1N914.

(10) Question 4. Design a two-pole analog low-pass filter with a cutoff frequency of 10 Hz. Show the design steps, and specify resistor/capacitor values, choosing standard values. Standard values for 5% resistors range from 10 Ω to 22 M Ω . We can multiply a number in Table 1 by powers of 10 to select a standard value 5% resistor. For example, if we need a 25 k Ω 5% resistor, the closest number is 24*1000, or 24 k Ω . Table 2 shows standard capacitor values.

10	11	12	13	15	16	18	20	22	24	27	30
33	36	39	43	47	51	56	62	68	75	82	91

Table 1. Standard resistor values for 5% tolerance

10pF	100pF	1000pF	0.010 μ F	0.10 μ F	1.0 μ F	10 μ F
12pF	120pF	1200pF	0.012 μ F	0.12 μ F	1.2 μ F	
15pF	150pF	1500pF	0.015 μ F	0.15 μ F	1.5 μ F	
18pF	180pF	1800pF	0.018 μ F	0.18 μ F	1.8 μ F	
22pF	220pF	2200pF	0.022 μ F	0.22 μ F	2.2 μ F	22 μ F
27pF	270pF	2700pF	0.027 μ F	0.27 μ F	2.7 μ F	
33pF	330pF	3300pF	0.033 μ F	0.33 μ F	3.3 μ F	33 μ F
39pF	390pF	3900pF	0.039 μ F	0.39 μ F	3.9 μ F	
47pF	470pF	4700pF	0.047 μ F	0.47 μ F	4.7 μ F	47 μ F
56pF	560pF	5600pF	0.056 μ F	0.56 μ F	5.6 μ F	
68pF	680pF	6800pF	0.068 μ F	0.68 μ F	6.8 μ F	
82pF	820pF	8200pF	0.082 μ F	0.82 μ F	8.2 μ F	

Table 2. Standard capacitor values for 10% tolerance

(25) Question 5. Consider the following implementation of `OS_AddThread`, similar to the one given in the Lab 17 starter file.

```

struct TCB{
    struct TCB *Next;           // Link to Next TCB
    unsigned char *StackPt;    // Stack Pointer
    unsigned char MoreStack[101]; // additional stack
    unsigned char InitialCCR;
    unsigned char InitialRegB;
    unsigned char InitialRegA;
    unsigned short InitialRegX;
    unsigned short InitialRegY;
    void (*InitialPC)(void);
};
typedef struct TCB TCBType;
typedef TCBType * TCBPtr;
TCBType SystemTCB[MAX_THREADS];
unsigned short static NumThread=0; // number of threads
TCBPtr RunPt; // Pointer to thread currently running

//***** OS_AddThread *****
// add a foreground thread to the scheduler
// Inputs: pointer to a void/void foreground function
// Outputs: 1 if successful, 0 if this thread can not be added
short OS_AddThread(void(*fp)(void)){
    if(NumThread >= MAX_THREADS){
        return 0; // structure is full
    }
    if(NumThread){
        SystemTCB[NumThread-1].Next = &SystemTCB[NumThread];
    }
    SystemTCB[NumThread].StackPt = &SystemTCB[NumThread].InitialCCR;
    SystemTCB[NumThread].InitialCCR = 0x40; // I bit clear
    SystemTCB[NumThread].InitialPC = fp; // Initial PC
    SystemTCB[NumThread].Next = &SystemTCB[0]; // link
    NumThread++;
    return 1;
}

```

Redesign the system so that if the user program finishes, the OS will run the user program again. For example, this user function executes `stuff1`, `stuff2` and `stuff3` once and quits.

```
void user(void){ stuff1(); stuff2(); stuff3();}
```

If the user calls this system function to activate `user`,

```
OS_AddThread(&user);
```

then with your updated system `stuff1`, `stuff2` and `stuff3` will be repeated over and over again. You are allowed to make changes to the `struct` and to `OS_AddThread`, but not to `user` or other OS functions. You can however add additional OS functions. In particular, show changes to the `struct` and rewrite `OS_AddThread` in its entirety.

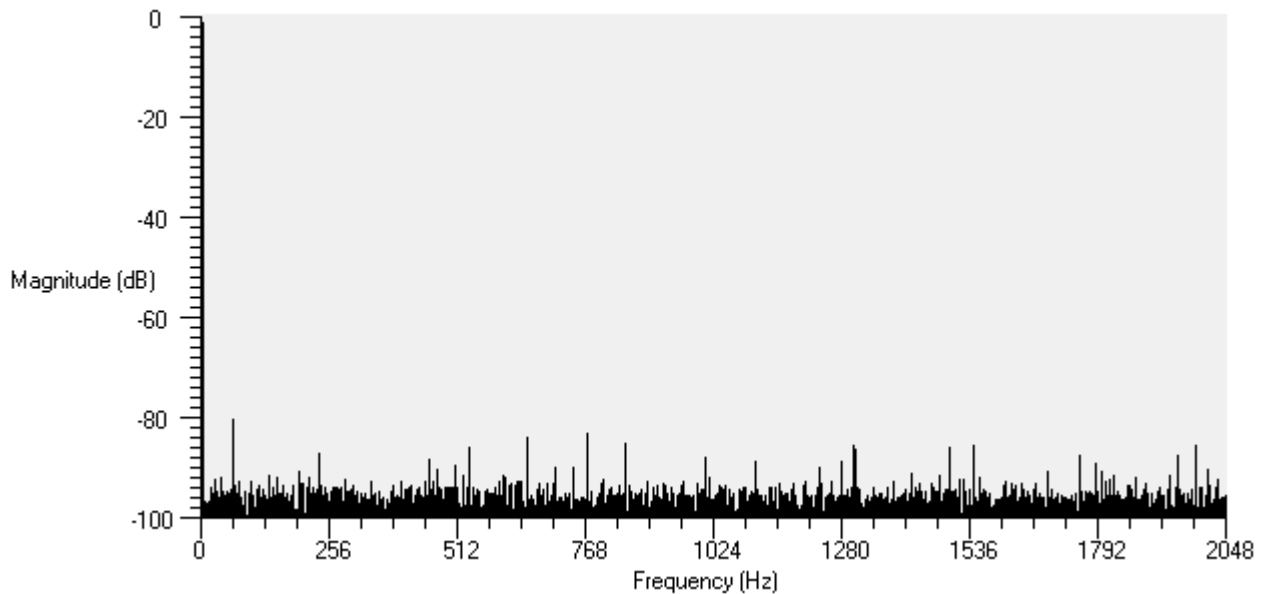
(16) Question 6. List the four design choices one must make when implementing a spectrum analyzer (ADC->FFT->graphics display) like the spectrum analyzer that generated the following figure. For each of the four choices, explain what the consequences are of that choice. I did not mean circuitry in front of the ADC, such as anti-aliasing analog low pass filter, analog circuit gain, analog input impedance,

1) Design choice and what does it mean?

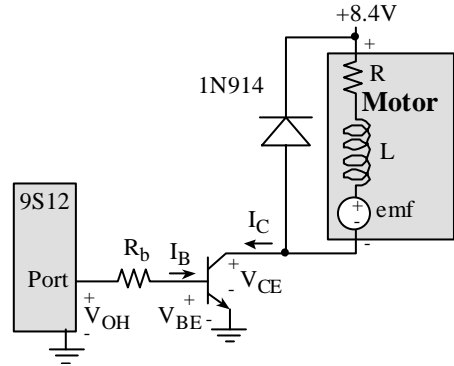
2) Design choice and what does it mean?

3) Design choice and what does it mean?

4) Design choice and what does it mean?



(24) **Question 7.** The overall goal is to design a feedback motor controller based on motor current I_C . The specific goal of this question is to add functionality to the following motor control circuit to allow the microcontroller to measure I_C . You may assume I_C is always positive (0 to +0.2A) according to the arrow in the figure. I.e., it acts like a motor under load, and not a generator. You may assume the same specifications as Problem 3.



(12) **Part a)** Redesign this hardware interface so that the motor current can be measured using the 10-bit ADC on PAD0. Only one ADC channel may be used. You may assume I_B is small compared to I_C . Full credit will be given to designs that limit the lost voltage to 0.1V at 0.2A (i.e., the motor spins like it has a battery voltage of 8.3V.)

(12) Part b) Write one C function that samples the ADC channel 0 and calculates motor current I_C . You may assume the battery voltage is 8.4V, R is 100Ω and V_{CE} is 0.75V. Return the result by value using an unsigned decimal fixed-point system of 0.001A. For example, if I_C is 0.123A, then return a 123. You may assume an **ADC_Init()** function has been previously called, but you may not call any functions in any of the starter files from lab. You should explicitly write/read from the ADC registers to create the 10-bit ADC sample. Please consider overflow, and dropout in your solution.