EE 391 (All Sections)

Midterm Examination

Friday, October 24, 2008

Time Allowed: 1.5 Hours

Materials allowed: Laboratory Notebooks, Design Reports, Calculators

Instructions:

- **Answer all questions in the space provided (use page backs for rough work if necessary)**
- **State your assumptions; show all relevant work. Box, circle or otherwise highlight your answers where appropriate. For multiple choice, circle the correct answer.**
- ***Put your name and student number on each page; (we may separate them for marking purposes)***
- **Refer to the last page for relevant product data when required**
- **Weighting for each question is indicated in the left margin (Total marks: 120)**

(Marker's use only.)

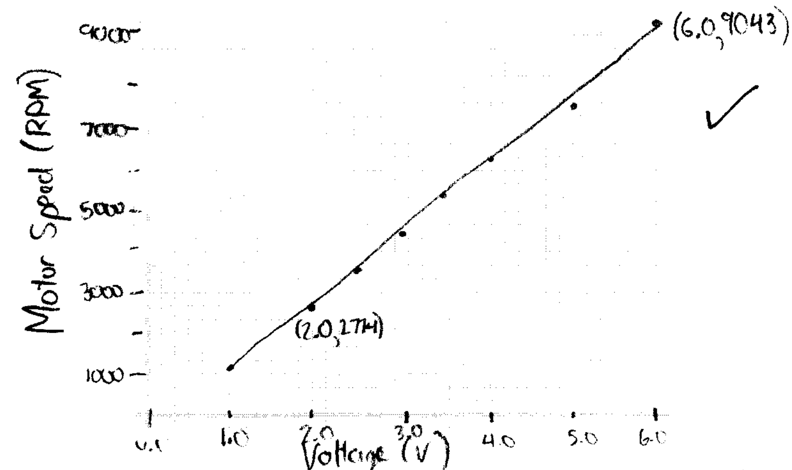
Governor	SPMS	Total
32 /40	15 /40	47 /80

EE 391 **Midterm Examination** Oct. 24, 2008

Design Lab II – Electronic Governor

Q1.1) Draw the speed vs. voltage curve for the DC motor you used in the electronic governor design. Label two points in the graph with your actually measurements, indicating their values (velocity/RPM, voltage).

5/[5]

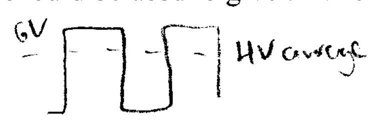


✓

Q1.2) If a person wants to use 6 V PWM running at 5KHz to power the motor, what duty cycle (%) should be used to give an average DC voltage of 4 V?

[5]

3/5



$\frac{4V}{6V} = .666$ duty cycle = 66.6% ✓

What duty cycle (%) would be required for the same *power* (i.e. Effective or RMS value) as 4VDC?

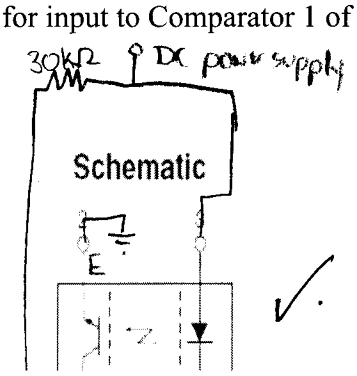
$\frac{4V/\sqrt{2}}{6V} = .471 \rightarrow 47.1\%$ ✗

5
3
4
4
5
5
3
3
22/4

Q1.3) The QRD1113 Reflective Object Sensor was used to measure the speed of the motor. QRD1113 consists of an infra red LED and a photo transistor, which are optically coupled. The sensor characteristics are described by a line of specifications, that is, sensor current Ic(ON) is min. 0.3mA when the forward LED current is 20mA and the reflector is placed at 0.05".

[4] Complete the schematic diagram (below) for using the sensor by showing all the connections you made to get a sensor output for input to Comparator 1 of the PIC16F668.

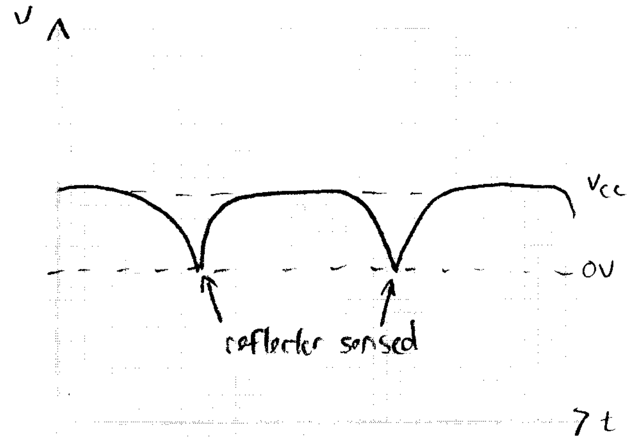
4



✓

Sketch a graph of the output signal showing the change when the reflector passes in front of the sensor. Be sure to label all relevant points.

[4]



4 ✓

Q1.4) You can use Comparator 1 of the PIC to "shape up" the sensor signal to be a rectangular pulse with sharp rising and falling edges. The threshold voltage (reference voltage) can be internally set with the register called VRCON. (The PIC reference manual describes VRCON – see extract in Appendix.)
Assume the sensor signal swings between 1.5 V to V_{DD} which is 5V, and a reference voltage of 3.5 V is desired. Determine the last four bits of VRCON (VR3,VR2,VR1,VR0) which will give a comparator reference voltage closest to 3.5V. Assume the rest of the bits are set as 1100, or VRCON= 0b1100nnnn (i.e. you must determine 'nnnn' to get a reference closest to 3.5V).

[5] 5

$3.5V = \frac{x}{32}(5V) + \frac{5V}{4}$

bit 5 : 0 → $+\frac{V_{DD}}{4} + \frac{x}{32}$

$x = 14.4 \sim 14 = 0b1110$

VRCON= 0b11001110 ✓

Q1.6) The following C-program shows the skeleton of the program (1) to perform measurement of motor speed by means of Comparator 1 interrupts and (2) to regulate the motor speed by varying the duty cycle of PWM. Only those statements related to the Comparator 1 interrupt are shown:

[7]

```
interrupt void isr(void)
{     C1IF = 0;             // turn comparator1 interrupt flag OFF
- Interrupt Service Routine -
}                           //end of interrupt service routine

void main()
{     //Set up comparators
      CM1CON0 = 0b10100100;
      //Comparator 1 on (bit7=1), C1 output present on C1OUT pin 6
(bit5=1)
      //C1 Reference C1Vin connected to C1Vref (bit2=1)
      //C1 Voltage Reference enabled (bit7=1), CVref voltage output
on C2IN+ (pin4)
      VRCON = 0b11001111;
      //Set up VREF For comparator at about 1.25 volt + 2.5 volts =
3.25 V
      C1RSEL = 1;           //this is bit 5 in CM2CON1
      // route C1REF to C1VREF input of Comparator 1
      TRISA &= 0b11101111;
      //C1OUT should be output pin 6, RA4/T0CKI/C1OUT
```

List the *functionalities* to be included in the Interrupt Service Routine to accomplish this, and any related function in the Main Program. Describe the functions required concisely in plain language. Do not write C-code.

[5]

ISR → should reload timer 0, stop timer 1, assign a variable to the higher and lower registers of timer 1

Then, assign count, the 16-bit variable, to have the upper 8 bits of timer 1, and the lower 8 bits to have the lower 8 bits of timer 1. Then, clear timer 1, and turn it back on. Main → Set go done to 1, and wait until its conversion is finished. Then, decrement CCPR1L if count < target frequency, and increment CCPR1L if count > target frequency

5/7 — combine L + H, no reset count ✗ — what conversion?

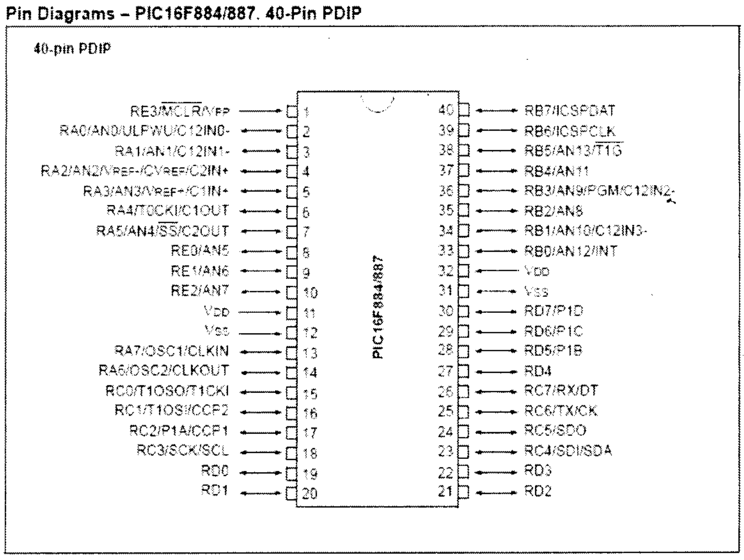
Q1.7) Which pin of PIC16F866:

do you feed the input signal to Comparator 1?	5 ✓
can you observe the reference signal for Comparator 1?	C1VREF ✗
can you observe the Comparator 1 output?	6 ✓
do you feed analog input, if analog channel 4 is selected?	1 ✓
do you get PWM output from Capture/Compare/PWM 1 (CCP1)?	8 ✗

3/5 — using the PIC 16F8…

[5]

Pin Diagrams – PIC16F884/887. 40-Pin PDIP



[1]

Q1.8) Timer 1 is a 16 bit counter incremented every instruction cycle (8 μs). The upper 8 bits (High byte) is stored in TMR1H, and the lower 8 bits (Low byte) is stored in TMR1L. Write code in C-language to combine those two bytes to make a 16 bit integer number of the total count. Including define statements for all variables used.

5

[4]

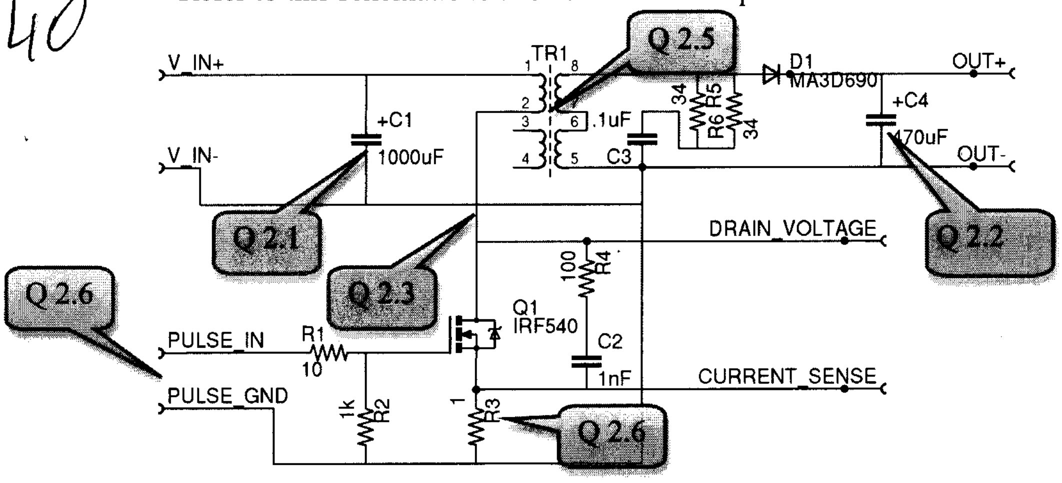
```
Volatile unsigned int count;
count = (countH << 8) + (countL);
```

3/

Design Lab I – Switch Mode Power Supply

15/40

Refer to this schematic to answer the related questions that follow.



Q2.1) Assume you are designing for the input (V_{in}) of your SMPS to come from a direct, full-wave bridge rectified off-line source (i.e. $v(t) = 170\sin(377t)VAC$), and you are willing to accommodate a ripple in this supply of up to 30VDC. Your *average* current draw (i.e. into the transformer) will be 1.25A at maximum load.

[3]

What minimum value of filter capacitor should you specify? 694µF –

What working voltage specification should this capacitor have? 100V –

1/3

$C = \frac{1.25A}{(60Hz)(30V)} = 694\mu F$

60×2 – because full-wave bridge

$\frac{170}{2} = 85V$ → use 100V to be safe

Q2.2) Assume that you have decided on a variable frequency method of regulation, and that the maximum frequency can be up to 60KkHz depending on the load current. The maximum design load current is 15A, and the output voltage is to be 12VDC with a maximum ripple of 2%

[3]

What is the minimum value of capacitance required for the output filter capacitor? 1042µF +

3/3

.02 × 12V = .24V

$C = \frac{15A}{(60kHz)(.24V)}$

$C = 1042\mu F$

Q2.3) Assuming the design specifications as given in 2.1 and 2.2 above ($I_{Avg\text{-}in}$=1.25A, frequency regulated, up to 60kHz), and a fixed pulse width of 7.5µs, what is the *peak* current in the transformer primary (and FET switch)?

[5]

$I_{avg\text{-}in} = 1.25A$

4.55A

Q2.4) Again assume the design specifications as given above, and that the peak current you determined in the last question was 5A. If the transformer primary has an inductance of 0.25mH, what is the maximum power that can be delivered by this supply? (Assume 100% efficiency.)

[4]

0/4

$I_o = \frac{5A(1-.45)}{2} = 1.375A$

$V_o = 12V\,DC$

$P = (12V)(1.375A)$

$P = 16.5W$

16.5W

Q2.5) Continuing with the design specifications as given above, what is the turns ratio of the transformer?

[5]

$n = \frac{V_s}{V_p} = \frac{12V}{30V} = .4$

.4

0/5

If the secondary consists of 4 turns, how many turns are needed in the primary? 10

$.4 = N_s/N_p$ $N_p = \frac{4}{.4} =$

Q2.6) The "pulse" input shown in the partial design above is now to be replaced by the UC3845B regulator chip you used in your SMPS design. (We have now abandoned the frequency method of regulation in favour of pulse-width regulation.) Determine the value of the current sense resistor, R_1, required to allow the system to operate with the maximum transformer primary current assumed in 2.4 (5A).

[3]

0/3

$I_o =$ Vcutoff : $5A \cdot R = 1V$

$R = \frac{V}{R} = \frac{1}{5} = 0.2\Omega$

Describe *how* the current sense input must be connected to the UC3845B (from where in the circuit to what pin on the chip) and briefly describe the purpose and basic operation of this function on the regulator chip.

[3]

The current sense input should be tied through a resistor R_1 to the source of the FET. The I_{sense} will "breakdown" the output voltage signal if the output power gets too big for the SMPS to deliver. Choosing R_1 determines when this breakdown will

Q2.7) How is the operating frequency for the regulator chip set? Briefly describe the process you went through to determine values, and show the values you used and your resulting frequency.

[4]

Frequency is set using R_T and C_T. The general formula is $f \simeq \frac{1}{R_T C_T}$. we chose $C_T = .001\mu F$ since it was available, and tried different values of R_T until we got 40 kHz. A 27kΩ resistor yielded a frequency of about 39 kHz, after trying values of 37kΩ and 20kΩ.

2/4

Q2.8) Calculate the feedback resistors required for a target output of 12VDC and again describe the basic connection in the circuit for this feature to operate, and then briefly describe how the regulator uses this input to control the output voltage.

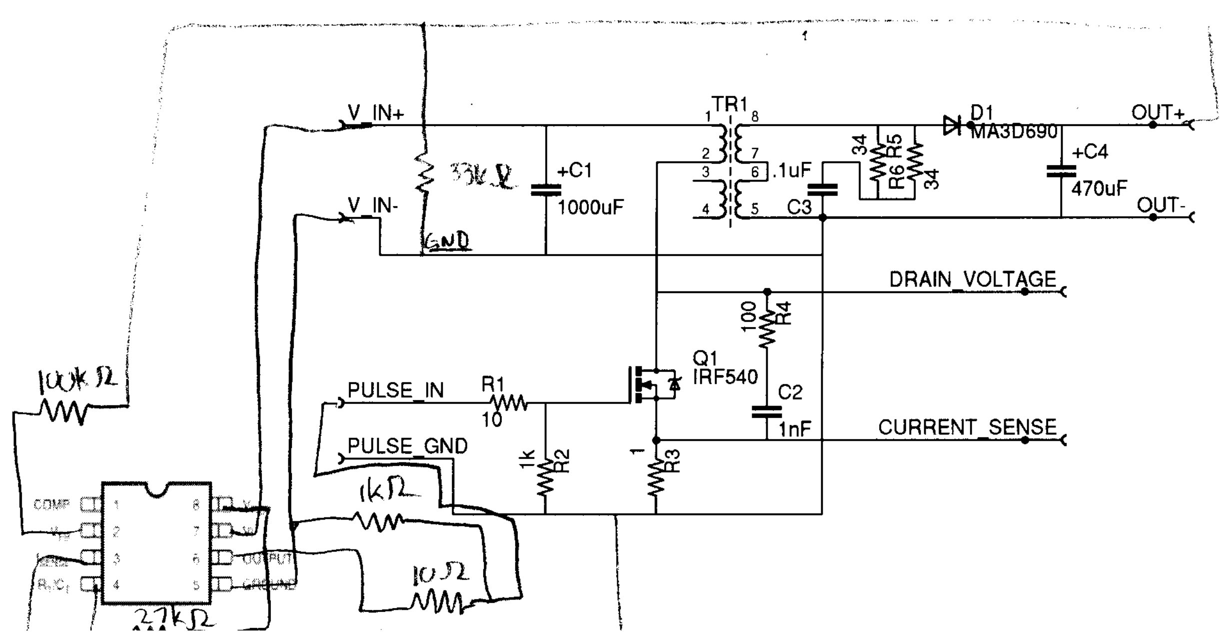
[3]

The feedback works as a basic voltage divider, since pin 2 is 2.5V with a very high output impedance. A resistor put between V_{FB} and ground sets the current I and 2.5V+(I)(R) sets the output voltage. It uses this voltage divider to maintain the output voltage, by measuring the V/I at the pin, and adjusting the PW accordingly.

1/3

Q2.9) Using the partial schematic below and the design calculations you performed in previous questions, show the connections required to integrate the regulator chip. Be sure to provide for the chip's power requirements! (Note: only basic connections for operating – you need not include any special filtering or snubbing for circuit noise.)

[7]



3/7

APPENDIX

From: **PIC16F882/883/884/886/887** manual:

REGISTER 8-5: VRCON: VOLTAGE REFERENCE CONTROL REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
VREN	VROE	VRR	VRSS	VR3	VR2	VR1	VR0
bit 7							bit 0

Legend:			
R = Readable bit	W = Writable bit	U = Unimplemented bit, read as '0'	
-n = Value at POR	'1' = Bit is set	'0' = Bit is cleared	x = Bit is unknown

bit 7 **VREN:** Comparator C1 Voltage Reference Enable bit
1 = CVREF circuit powered on
0 = CVREF circuit powered down

bit 6 **VROE:** Comparator C2 Voltage Reference Enable bit
1 = CVREF voltage level is also output on the RA2/AN2/VREF-/CVREF/C2IN+ pin
0 = CVREF voltage is disconnected from the RA2/AN2/VREF-/CVREF/C2IN+ pin

bit 5 **VRR:** CVREF Range Selection bit
1 = Low range
0 = High range

bit 4 **VRSS:** Comparator VREF Range Selection bit
1 = Comparator Reference Source, CVRSRC = (VREF+) - (VREF-)
0 = Comparator Reference Source, CVRSRC = VDD - VSS

bit 3-0 **VR<3:0>:** CVREF Value Selection $0 \le VR<3:0> \le 15$
When VRR = 1: CVREF = (VR<3:0>/24) * VDD
When VRR = 0: CVREF = VDD/4 + (VR<3:0>/32) * VDD

UC2842B/3B/4B/5B - UC3842B/3B/4B/5B

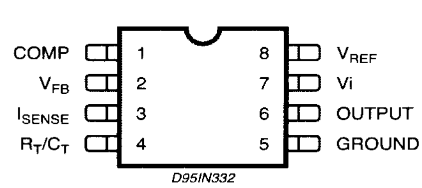
ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_i	Supply Voltage (low impedance source)	30	V
V_i	Supply Voltage (Ii < 30mA)	Self Limiting	
I_O	Output Current	±1	A
E_O	Output Energy (capacitive load)	5	μJ
	Analog Inputs (pins 2, 3)	– 0.3 to 5.5	V
	Error Amplifier Output Sink Current	10	mA
P_{tot}	Power Dissipation at $T_{amb} \le 25$ °C (Minidip)	1.25	W
P_{tot}	Power Dissipation at Tamb ≤ 25 °C (SO8)	800	mW
T_{stg}	Storage Temperature Range	– 65 to 150	°C
T_J	Junction Operating Temperature	– 40 to 150	°C
T_L	Lead Temperature (soldering 10s)	300	°C

* All voltages are with respect to pin 5, all currents are positive into the specified terminal.

PIN CONNECTION (top view)

Minidip/SO8



PIN FUNCTIONS

No	Function	Description
1	COMP	This pin is the Error Amplifier output and is made available for loop compensation.
2	V_{FB}	This is the inverting input of the Error Amplifier. It is normally connected to the switching power supply output through a resistor divider.