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October 9, 2009, 2:00pm-2:50pm. This is a closed book exam. You have 50 minutes, so please allocate your time accordingly. ***Please read the entire quiz before starting*.**

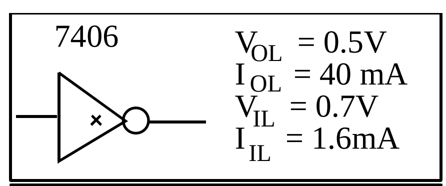
`PTT` is 8-bit bi-directional I/O port
`DDRT` is the associated direction register for Port T (0 means input, 1 means output)
`PTM` is 8-bit bi-directional I/O port
`DDRM` is the associated direction register for Port M (0 means input, 1 means output)
`PTP` is 8-bit bi-directional I/O port
`DDRP` is the associated direction register for Port P (0 means input, 1 means output)
`TSCR1` is the first 8-bit timer control register
  bit 7 **`TEN`**, 1 allows the timer to function normally, 0 means disable timer including **`TCNT`**
`TSCR2` is the second 8-bit timer control register
  bits 2,1,0 are **`PR2`**, **`PR1`**, **`PR0`**, which select the rate, let **n** be the 3-bit number formed by **`PR2`**, **`PR1`**, **`PR0`**
  9S12DP512 without PLL **`TCNT`** is 8MHz/$2^{\mathbf{n}}$, with PLL **`TCNT`** is 24MHz/$2^{\mathbf{n}}$, **n** ranges from 0 to 7
`TCNT` is 16-bit up counter
`TIOS` is the 8-bit output compare select register, one bit for each channel (1 = output compare, 0 = input capture)
`TIE` is the 8-bit output compare arm register, one bit for each channel (1 = armed, 0 = disarmed)
`TC0 TC1 TC2… TC7` are the eight 16-bit output compare registers, one register for each channel
`TFLG1` is the 8-bit flag register, one bit for each channel:
  With input capture, flags are set on the active edge of the input **`TC0 TC1 TC2… TC7`**
  With output compare, flags are set when **`TCNT`** equals **`TC0 TC1 TC2… TC7`**
  Flags become zero when software writes a 1 to it. E.g., **`TFLG1=0x08;`** clears channel 3 flag

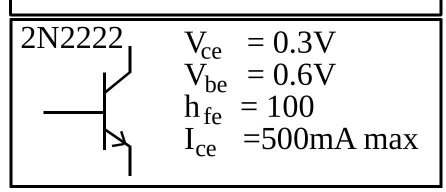
TCTL1	**OM7**	**OL7**	**OM6**	**OL6**	**OM5**	**OL5**	**OM4**	**OL4**
TCTL2	**OM3**	**OL3**	**OM2**	**OL2**	**OM1**	**OL1**	**OM0**	**OL0**
TCTL3	**EDG7B**	**EDG7A**	**EDG6B**	**EDG6A**	**EDG5B**	**EDG5A**	**EDG4B**	**EDG4A**
TCTL4	**EDG3B**	**EDG3A**	**EDG2B**	**EDG2A**	**EDG1B**	**EDG1A**	**EDG0B**	**EDG0A**

If OMn=OLn=0 then an output compare event will not directly affect the output pin. If the pair (OMn,OLn) equals (0,1) then the output pin will toggle on each output compare. If the pair (OMn,OLn) equals (1,0) then the output pin will clear on each output compare. If the pair (OMn,OLn) equals (1,1) then the output pin will set on each output compare.

If EDGnB=EDGnA=0 then no input capture event will occur. If EDGnB=0 and EDGnA=1 then an input capture event will occur on the rising edge of the input. If EDGnB=1 and EDGnA=0 then an input capture event will occur on the falling edge of the input. If EDGnB=1 and EDGnA=1 then an input capture event will occur on both the rising and falling edges of the input.

```
0xFFD6    interrupt 20 SCI
0xFFDE    interrupt 16 timer overflow
0xFFE0    interrupt 15 timer channel 7
0xFFE2    interrupt 14 timer channel 6
0xFFE4    interrupt 13 timer channel 5
0xFFE6    interrupt 12 timer channel 4
0xFFE8    interrupt 11 timer channel 3
0xFFEA    interrupt 10 timer channel 2
0xFFEC    interrupt 9  timer channel 1
0xFFEE    interrupt 8  timer channel 0
0xFFF0    interrupt 7  real time interrupt
```





9S12DP512 parameters

I_{OL} = 10mA, I_{OH} = 10mA, I_{IL} = 1μA, I_{IH} = 1μA,
V_{OL} = 0.8V, V_{OH} = 4.2V, V_{IL} = 1.75V, V_{IH} = 3.25 V

(5) Question 1. Consider a real-time system that employs a battery backup to allow the system to operate when main power is lost. After main power is lost, because of the capacitance in the system, there will be 10 ms before a hardware reset occurs and the software stops executing. There is an input that is true when the main power is available and is false when the main power is unavailable. The software can read this input. There are two outputs that the software can set: Out=01_2 to use the main power and Out=10_2 to disconnect the main power and connect to the battery backup. *For this real time system, define what the term **latency** means.* Be as explicit as possible. *For this system what does it mean to be real time?*

(10) Question 2. The following function is not reentrant. Explain what that means by giving an example execution sequence where data is lost.

```
/*-----------------------RxFifo_Put---------------------------
  Enter one character into the fifo
  Inputs: 8-bit data
  Outputs: true if data is properly saved */
int RxFifo_Put(char data){
char volatile *tempPt;
  tempPt = RxPutPt;
  tempPt++;
  if(tempPt == &RxFifo[RXFIFOSIZE]){ /* need to wrap?*/
    tempPt = &RxFifo[0];
  }
  if(tempPt == RxGetPt){
    return(0);             /* Failed, fifo was full */
  }
  else{
    *(RxPutPt) = data;     /* Put data into fifo */
    RxPutPt = tempPt;      /* Success, so update pointer */
    return(1);
  }
}
```

(10) Question 3. In Lab 10 we will be interfacing an XBee wireless module to the 9S12. The V_{CC} of the XBee is 3.3V. $0.35*V_{CC} = 1.155V$ $0.7*V_{CC} = 2.31V$ $V_{CC}-0.5V = 2.8$ V

Table 1-03. DC Characteristics (VCC = 2.8 - 3.4 VDC)

Symbol	Characteristic	Condition	Min	Typical	Max	Unit
V_{IL}	Input Low Voltage	All Digital Inputs	-	-	0.35 * VCC	V
V_{IH}	Input High Voltage	All Digital Inputs	0.7 * VCC	-	-	V
V_{OL}	Output Low Voltage	I_{OL} = 2 mA, VCC >= 2.7 V	-	-	0.5	V
V_{OH}	Output High Voltage	I_{OH} = -2 mA, VCC >= 2.7 V	VCC - 0.5	-	-	V
II_{IN}	Input Leakage Current	V_{IN} = VCC or GND, all inputs, per pin	-	0.025	1	μA
II_{OZ}	High Impedance Leakage Current	V_{IN} = VCC or GND, all I/O High-Z, per pin	-	0.025	1	μA
TX	Transmit Current	VCC = 3.3 V	-	45 (XBee) 215 (PRO)	-	mA
RX	Receive Current	VCC = 3.3 V	-	50 (XBee) 55 (PRO)	-	mA
PWR-DWN	Power-down Current	SM parameter = 1	-	< 10	-	μA

We can not connect the 9S12 output to an XBee input because the +5V output of the 9S12 will damage the XBee input powered at 3.3V. *However, can we connect the 9S12 input to an XBee output?* If yes, give all inequalities with both symbolic and numerical values to prove it works. If no, give at least one inequality both symbolic and numerical values that is not satisfied.

(5) Question 4. What is the value of a 16-bit signed binary fixed-point number (resolution is 2^{-8}, which equals 1/256) if the integer stored in memory is -384?

(20) Question 5. Draw a Moore FSM graph to solve the switch bounce problem. There is one positive input connected to a switch that bounces when touched. The switch bounce cause 1, 3, 5, 7, or 9 transitions each time the switch is touched or released. The bounce time will be less than 10 ms and the total time the switch is actually touched and released is at least 100 ms. Create a single positive logic output that is a clean representation of the switch state: 1 if the switch is touched and 0 if the switch is released. There can be a delay between the actual touch/release of the switch and the output of the FSM, but this delay should be minimized. For each state give: the state name, the output, the time to wait, and two next states. The FSM controller sequence is output, wait, input, change to next state. Just draw the FSM graph, no software is required. Full credit will be given to the machine with the fewest states.

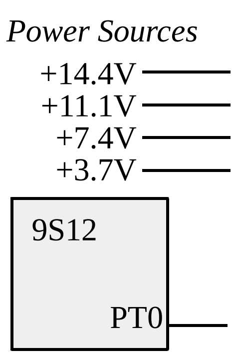
(5) Question 6. Consider a stepper motor with an angle change of $\Delta\theta$ per step in radians, and let $\mathbf{t_1}$, $\mathbf{t_2}$, $\mathbf{t_3}$ be three times between outputs to the motor in seconds. Assume the software output this sequence: output 5 for $\mathbf{t_1}$ seconds, output 6 for $\mathbf{t_2}$ seconds, output 10 for $\mathbf{t_3}$ seconds, output 9.

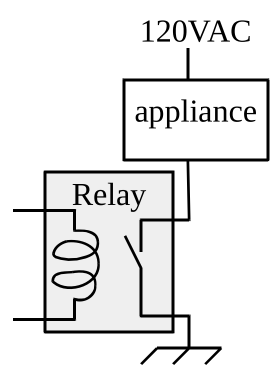
Part a) Define **rotational jerk** for a rotating motor. You can give a general definition, without deriving specific equations.

Part b) What are the units of jerk?

(15) Question 7. The Li-Ion battery cell voltage is 3.7V. Using multiple cells, we can create a power source at integer multiples of 3.7V. Interface an electromagnetic relay to the 9S12. To activate, the relay needs anywhere from 6 to 8 V at 200 mA. Include protection against back EMF. Label part numbers for all interface components and resistor values. You can specify resistor values using an equation, rather than calculating the exact number. You must select which Li-Ion battery to use.

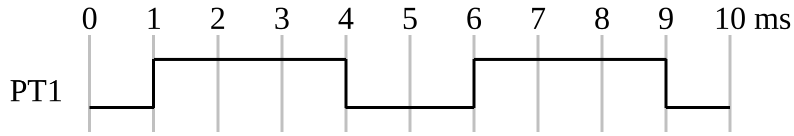
Part a)





Part b) Give an equation that relates current through to the voltage across an ideal inductor, with inductance L.

(30) Question 8. Write software that creates the following output on PT1. The pattern of high for 3 ms, low for 2 ms should repeat over and over. You must use output compare interrupt 1.



Part a) Write the ritual to initialize the system. The main program will call this once at the beginning to start the output. You should not activate the PLL. The 9S12DP512 E clock is 8 MHz.

Part b) Show the output compare interrupt 1 service routine that outputs to PT1. You do need to be friendly. No backward jumps are allowed.