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August 16, 1999, 7pm-10pm

This is an open book, open notes exam. You may put answers on the backs of the pages, but please don't turn in any extra sheets. Due Monday, August 16, 10 pm.

(50) Question 1. The objective of this problem is to control the rotational speed of a DC motor. The +5v DC motor has a resistance of 10 Ω. Your control system will apply a variable power to the motor by varying the duty-cycle of a 50 Hz signal. For example:

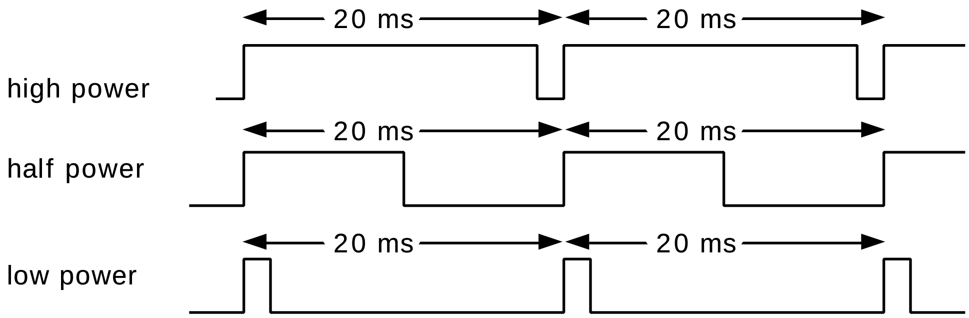


Figure 1. PWM output to actuator.

The rotation speed, **R**, of the motor is measured by a tachometer. You should measure **R** every 20 ms with a resolution of 1 rps. The rotational speed will vary from 0 to 250 rps (0≤**R**≤250rps.) The output of the tachometer is an ugly-looking digital wave with a frequency 100 times the motor speed. Thus, 0 ≤ **f** ≤ 25 KHz.

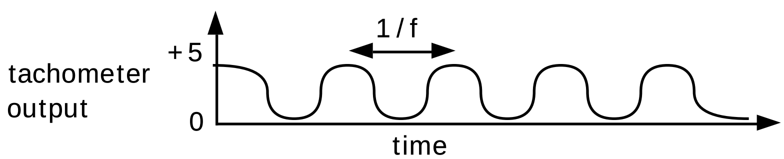


Figure 2. Tachometer frequency is a function of the motor rotation speed.

The desired rotational speed (**R*** also in rps) comes from an 8 bit parallel input port. A new value is available on the rise of Ready. The fall of Done is an acknowledge signal back to the input device signifying the 6812 no longer needs the data. The timing is as follows:

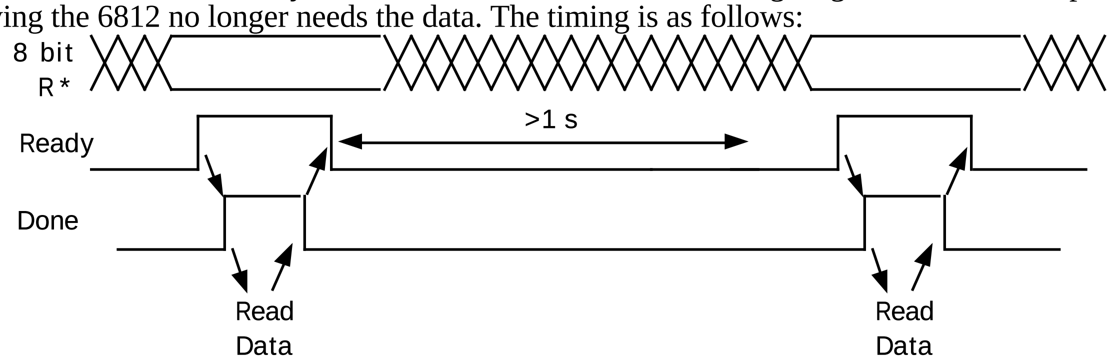


Figure 3. Sensor timing.

The interrupt-driven control algorithm should be implemented at 50 Hz (**U(t)** is the duty cycle in %)

$$\mathbf{U(t)} = \int_0^{\mathbf{t}} (\mathbf{R^*} - \mathbf{R(t)})\, d\mathbf{t}$$

where **R*** and **R(t)** are in rps and t is in seconds

Part a) Let **u(n)** equal the cycle count (500ns each) that controls the duty cycle of the output compare variable-duty cycle 50 Hz square wave. If the range of duty cycle is 0 < **U(t)** < 100, what is the relationship between **u(n)** and **U(t)**?

Part b) Let **R(n)** be the sampled sequence of measured rotational speed in rps. Convert the above integral control equation into discrete form. I.e., determine the relationship that calculates **u(n)** from **u(n-1)**, **u(n-2)**, …, **R(n)**, **R(n-1)**, **R(n-2)**,…, and **R***.

Part c) Show the interface from the input device, the motor, and the tachometer to the microcomputer. Label chip numbers, resistors and capacitor values.

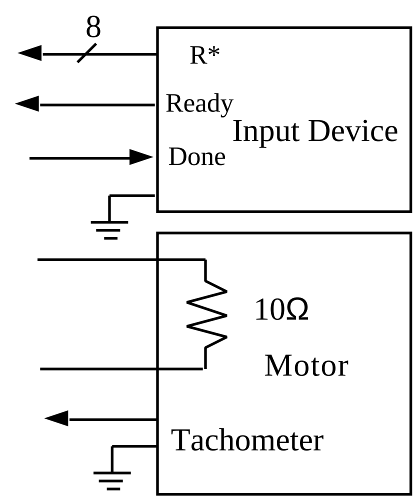
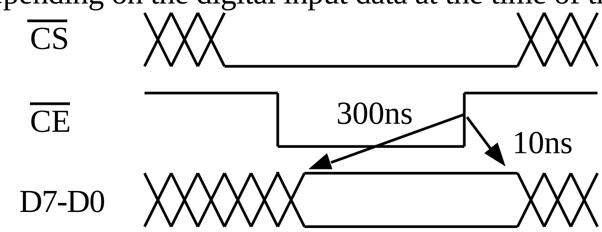


Figure 4. Sensor and motor interface.

Part d) Ritual software including data structures. The main program executes the ritual, then performs other unrelated tasks. I.e., all processing occurs under interrupt control.

Part e) Show the interrupt software. You may poll any way you wish.

(30) Question 2. Interface an AD557 8-bit D/A directly to the MC68HC812A4 bus (not to an output port). Assume an 8 MHz E clock. You will use one of the built-in address decoders and choose the proper number of cycle stretches. Assume a 10ns gate delay through each digital gate. Place the 8-bit D/A at $0200. When both $\overline{CE}$ and $\overline{CS}$ are zero, the D/A analog output follows the 8 bit digital input (transparent mode). If $\overline{CE}$ rises while $\overline{CS}$ equals zero (or if $\overline{CS}$ rises while $\overline{CE}$ equals zero), the 8 bit digital inputs are latched into the chip. The setup time is 300ns and the hold time is 10 ns. When either $\overline{CE}$ or $\overline{CS}$ is one, the D/A ignores the input digital data and the analog output remains constant depending on the digital input data at the time of the last rising edge.



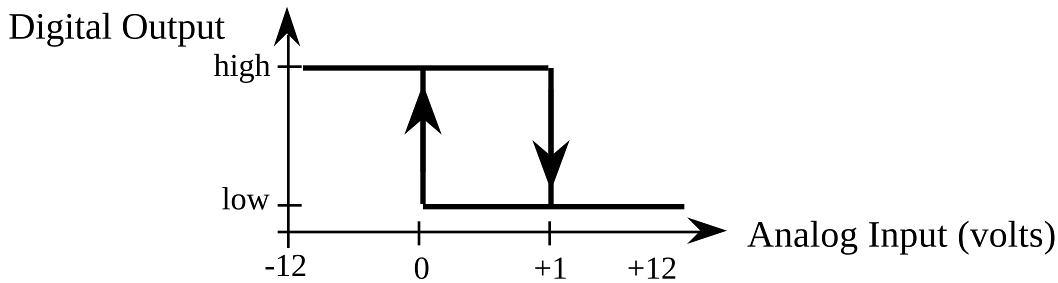
Part a) What is the write data available interval? Express your answer as a function of the E clock period. Let t_{cyc} be the E clock period.

Part b) What is the write data required interval? Express your answer as an equation using only the terms like $\downarrow\overline{CS}$ and $\uparrow\overline{CE}$. Don't calculate (yet) the actual interval in ns.

Part c) Show digital circuit for the interface between the expanded mode 6812 and the AD557 8-bit D/A. Please label TTL chip numbers but not pin numbers.

Part d) What is the smallest possible number of cycle stretches for this interface? SHOW YOUR WORK.

(20) Question 3. Design an analog to digital converter with the following transfer function. The analog input range is between -10 and +10 V.



Label all chip numbers (but not pin numbers). Specify the +12, -12, and +5 power supply connections, resistor values and capacitor values. Offset null potentiometers are not required.