EECS192 Lecture 4
Feb. 12, 2019

Notes:
Check off-
• 2/15: Motor drive/stall, steering servo
• Quiz 2: power MOSFET/motor drive Tues 2/19

Topics
• Quiz 1
• Polarized capacitor
• Project proposal feedback
• Driving MOSFETs and motor (conclusion)
  – MC33883 MOSFET driver
  – H bridge
• PWM and motor drive (conclusion)
• RC servo notes
• Power supplies and Wiring
• Linear Regulator
• Buck Converter

47uF, 16V electrolytic, polarized
Not all same- ESR…
Project proposal feedback: Motor Driver

Schematic

- Estop: what to switch?
- G_EN = 5V not 3.3V.
- Snubbing capacitors and diode
- Drive/brake/enable/dir- shoot through protection
- Need accel/coast/brake to avoid burning out motor/transistors
- Connectors- battery, motor, IO connections+ground
- Make sure capacitors on MC33883 are connected (needed for charge pump) and appropriate Vcc.
- Watch out for RC time constant on gate.
  Ciss Input Capacitance =8970pF.

Circuit Layout

- Mounting holes
- Big wires, short distances
- QFN vs SOIC package, SMD vs through hole
- Heat sinks- horizontal transistor is more robust
- Estop switch
- Signal connectors- include ground
- Power connectors
Project proposal feedback:

2.2 Mechanical Mount
- Encoder location: find easily accessible location, not in suspension
- Materials: 3D printed parts, and acrylic: heavy and brittle. Consider Styrofoam or thin-wall tube

3.1 IO Lines
- PWM? GPIO line won’t be real time. Need PWM hardware, or PRU. PWM0 is available on ``GPS” connector through librobotcontrol.

- Encoder? GPIO line is not setup to count edges and may miss fast samples. QEP avail if using quadrature (maybe hack with delay for using single detector). Could also use PRU and a GPIO input line. (PRU0 already setup for Chan 4 quad encoding).
  - Maybe use timer 7 to latch event of rising edge of signal (ch 20)
  - Maybe use eCAP to catch rising edge (Ch 15)
H-Bridge Gate Driver IC

The 33883 is an H-bridge gate driver (also known as a full-bridge pre-driver) IC with integrated charge pump and independent high and low side gate driver channels. The gate driver channels are independently controlled by four separate input pins, thus allowing the device to be optionally configured as two independent high side gate drivers and two independent low side gate drivers. The low side channels are referenced to ground. The high side channels are floating.

The gate driver outputs can source and sink up to 1.0 A peak current pulses, permitting large gate-charge MOSFETs to be driven and/or high pulse-width modulation (PWM) frequencies to be utilized. A linear regulator is incorporated, providing a 15 V typical gate supply to the low side gate drivers.

This device powered by SMARTMOS technology.

Features
- $V_{CC}$ operating voltage range from 5.5 V up to 55 V
- $V_{CC2}$ operating voltage range from 5.5 V up to 28 V
- CMOS/LSTTL compatible I/O
- 1.0 A peak gate driver current
- Built-in high side charge pump
- Under-voltage lockout (UVLO)
- Over-voltage lockout (OVLO)
- Global enable with <10 µA Sleep mode
- Supports PWM up to 100 kHz

[Diagram of 33883 Simplified Application Diagram]

**ORDERING INFORMATION**

<table>
<thead>
<tr>
<th>Device (Add R2 Suffix for Tape and Reel)</th>
<th>Temperature Range ($T_A$)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC33883HEG</td>
<td>-40 °C to 125 °C</td>
<td>20 SOICW</td>
</tr>
</tbody>
</table>
MC33883 + H bridge

!!!!CAUTION!!!!
Software fries hardware....
Need protection logic- 74HCxxx
Estop?

Figure 14. Application Schematic with External Protection Circuit
PWM and Motor Drive

PWM on BeagleBone Blue

Manual with details: inst.eecs.berkeley.edu/~ee192/sp19/files/am3359-pwm.pdf

Figure 15-27. Up-Down-Count Mode Symmetrical Waveform

Mode: Up-Down Count
TBPRD = 4
CAU = SET, CAD = CLEAR
0% - 100% Duty

TBCNT

TBCTR Direction

UP

DOWN

EPWMxA/EPWMxB

Case 1:
CMPA = 4, 0% Duty

Case 2:
CMPA = 3, 25% Duty

Case 3:
CMPA = 2, 50% Duty

Case 3:
CMPA = 1, 75% Duty

Case 4:
CMPA = 0, 100% Duty

EPWMxA/EPWMxB
PWM for Main Motor control

\[ i_m = \frac{T}{T_0} i_{\text{max}} \]

Is \( i_{\text{max}} \) constant?
Motor Electrical Model

Back EMF
Motor electromechanical behavior

Also- see motor worksheet……

\[ i_m = \frac{V_{BAT} - k_e \dot{\theta}_m}{R_m} \]

Conclusion:
\[ <i_m >=? \]
PWM for Steering Servo

Gotchas:
- 4.8 or 6V, (Not 7.2V! or 11V!!!!!!)
- max current 2A
- May be sensitive to noise on supply line
- Performance depends on voltage
On board: what does this look like electrically (as a schematic)?
Power supplies and Wiring

Power supply wiring - Star is better!

+11.1V

Voltage regulator

Voltage regulator

Low power ground

On board: what does this look like electrically (as a schematic)?
Ohms/square

For some given depth, resistance is directly in proportion to length and inversely proportional to width.

Therefore, we can rate the resistive material of constant depth in terms of ohms per square.

<table>
<thead>
<tr>
<th>Cu Weight oz.</th>
<th>Thickness mm(mils)</th>
<th>mΩ/Square 25°C</th>
<th>mΩ/Square 100°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2</td>
<td>0.02 (0.7)</td>
<td>1.0</td>
<td>1.3</td>
</tr>
<tr>
<td>1</td>
<td>0.04 (1.4)</td>
<td>0.5</td>
<td>0.65</td>
</tr>
<tr>
<td>2</td>
<td>0.07 (2.8)</td>
<td>0.25</td>
<td>0.36</td>
</tr>
<tr>
<td>4</td>
<td>0.13 (5.3)</td>
<td>0.13</td>
<td>0.18</td>
</tr>
</tbody>
</table>

Driving MOSFETs and motor

MC33883 burn out protection

Figure 2. 33883 Simplified Internal Block Diagram

Figure 12. Gate Protection and Flyback Voltage Clamp

Caution: don’t run motor current through here
Power supplies and Wiring
Linear Voltage Regulator

$V_{IN}$  \rightarrow \text{regulator}  \rightarrow V_{REG} = 5.0V$

0.5 \text{ ohm}  
\text{(equiv. for 1 amp load)}$

$V_{REG} = 5.0V$

Diagram: A linear regulator circuit with $V_{IN}$ connected to the input, a regulator module, and $V_{REG}$ outputting a fixed 5.0V. The circuit includes protection and reference components.
Linear Regulator for RC servo power

- Power limit? Heat….  
  Caution: caps required for stability for some voltage regulators

\[ V_{\text{REG}} = 5.0 \text{V} \]

0.5 ohm (equiv. for 1 amp load)

\[ P_{\text{diss}} = ? \]
Buck Converter- DC-DC

Why? Efficiency ~90%

Waveforms on board (also see buck converter notes.)
Buck: high to low. Boost: low-to-high)
Buck Converter
LM2678
Buck Converter

On-State

Off-State

https://en.wikipedia.org/wiki/Buck_converter
Summary

• Wiring to prevent high Vgs
• Wiring to prevent high current through low power devices
• Linear regulator
• Buck converter