

# EECS192 Lecture 3

Feb. 2, 2016

## Notes:

RSF no office hour Thurs Feb 4, 2 pm (this week only)

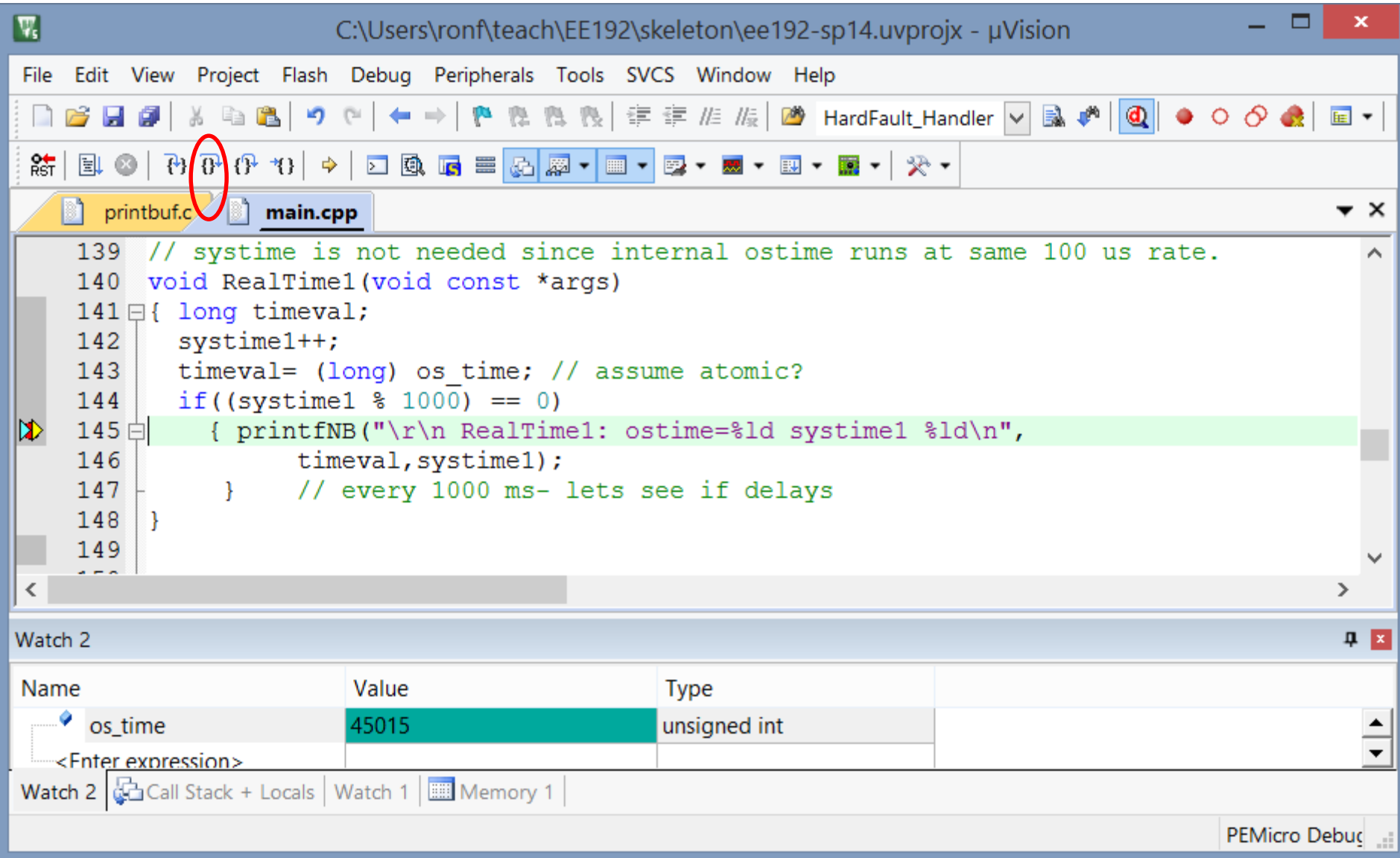
Check off-

- 2/5 project proposal – upload bcourses 5 pm
- 2/12: Motor drive/stall, steering servo
- Office hours – Thursday too late?
- Quiz 1: motor behavior Tues 2/9

## Topics

- Keil hint: timing using *os\_time*
- Motor Electrical Model
- Back EMF
- Motor electromechanical behavior
- MOSFETs and motor drive
- H bridge
- PWM
- Back EMF measurement

# Timing from Keil Tools



The screenshot displays the Keil uVision IDE interface. The main window shows a C source file named `main.cpp` with the following code:

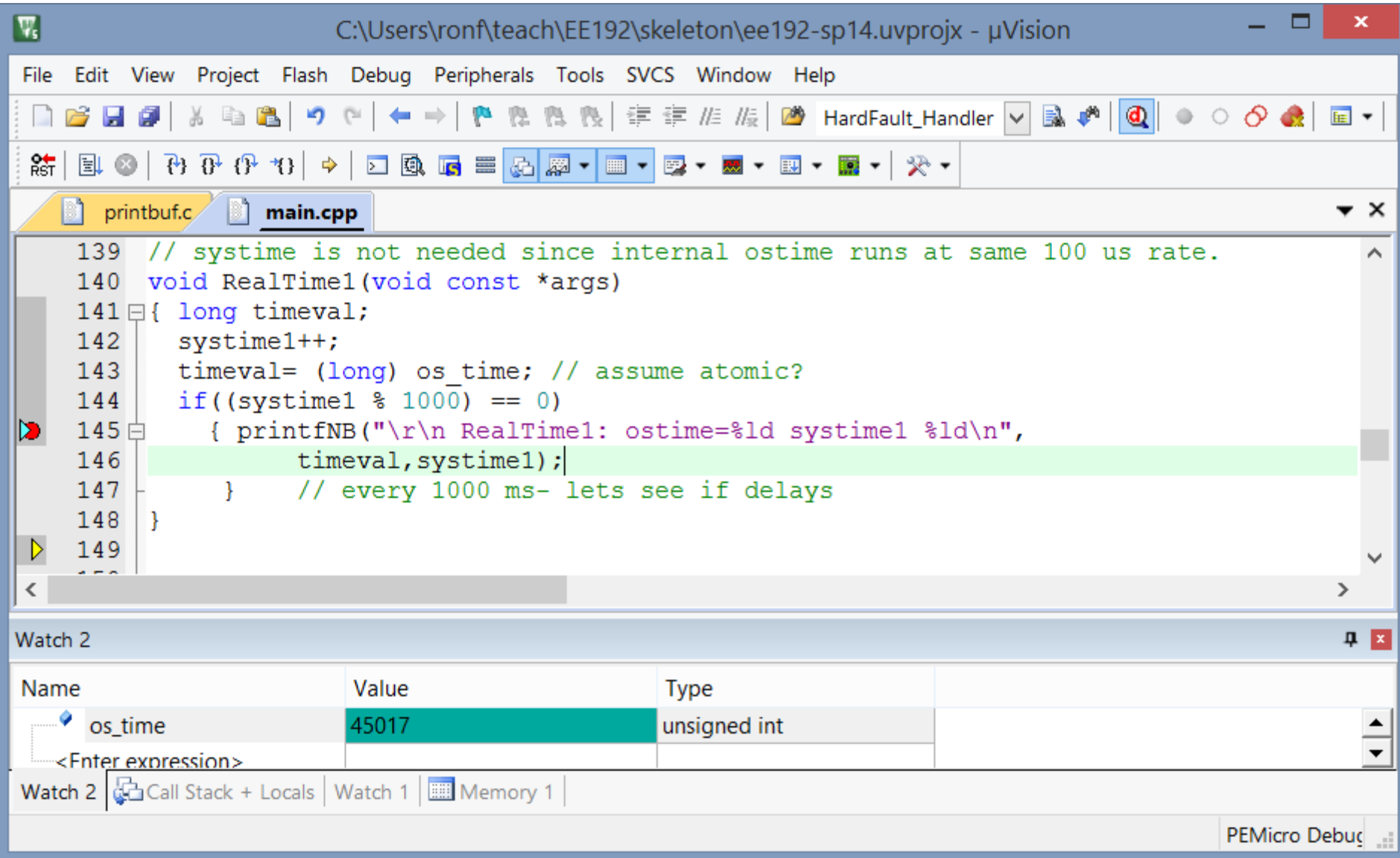
```
139 // systime is not needed since internal ostime runs at same 100 us rate.
140 void RealTime1(void const *args)
141 { long timeval;
142   systime1++;
143   timeval= (long) os_time; // assume atomic?
144   if((systime1 % 1000) == 0)
145   { printfNB("\r\n RealTime1: ostime=%ld systime1 %ld\n",
146             timeval, systime1);
147     } // every 1000 ms- lets see if delays
148 }
149
```

The line 145 is highlighted in green. The Watch window at the bottom shows the following data:

Name	Value	Type
os_time	45015	unsigned int
<Enter expression>		

The Watch window also includes tabs for "Call Stack + Locals", "Watch 1", and "Memory 1". The status bar at the bottom right indicates "PEMicro Debug".

# Timing from Keil Tools



The screenshot shows the Keil uVision IDE interface. The main window displays a C code snippet from `main.cpp`. The code is as follows:

```
139 // systime is not needed since internal ostime runs at same 100 us rate.
140 void RealTime1(void const *args)
141 { long timeval;
142   systime1++;
143   timeval= (long) os_time; // assume atomic?
144   if((systime1 % 1000) == 0)
145   { printfNB("\r\n RealTime1: ostime=%ld systime1 %ld\n",
146             timeval, systime1);
147   } // every 1000 ms- lets see if delays
148 }
149
```

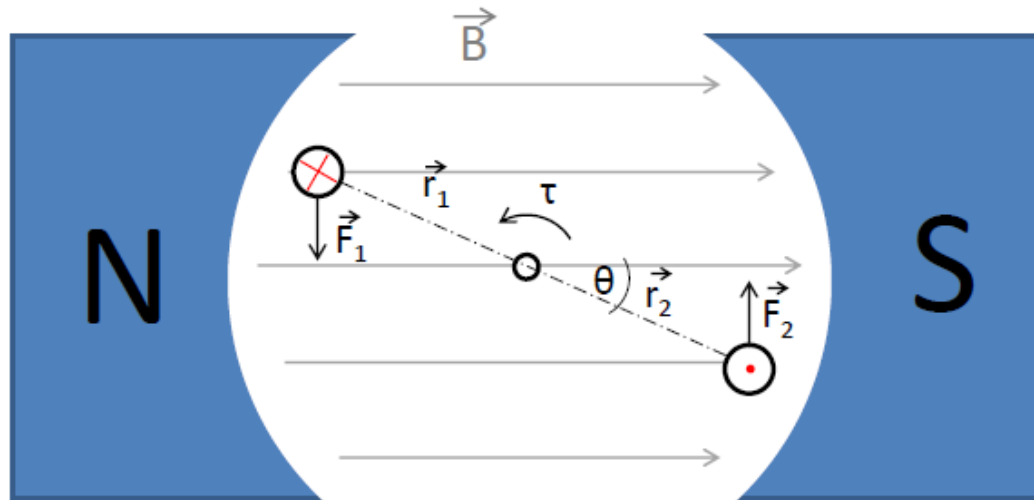
The Watch window at the bottom shows the following data:

Name	Value	Type
os_time	45017	unsigned int
<Enter expression>		

Additional UI elements include the menu bar (File, Edit, View, Project, Flash, Debug, Peripherals, Tools, SVCS, Window, Help), a toolbar with various icons, and a status bar at the bottom right indicating "PEMicro Debug".

~200 us

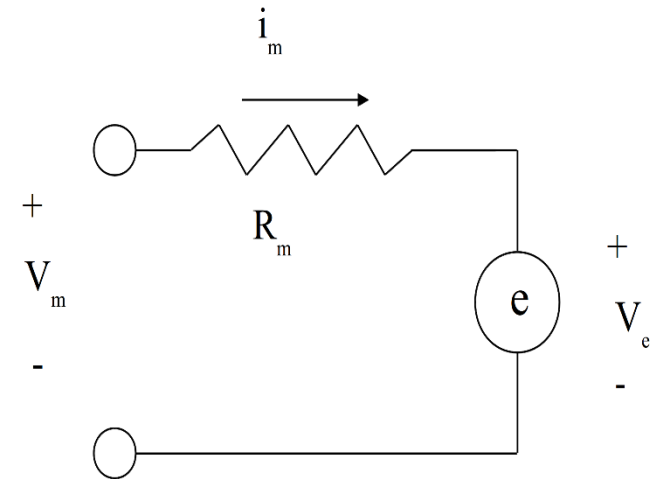
# DC Motor Physical Model



$$\vec{F} = i\vec{l} \times \vec{B}$$
$$\tau = \vec{r}_1 \times \vec{F}_1 + \vec{r}_2 \times \vec{F}_2$$

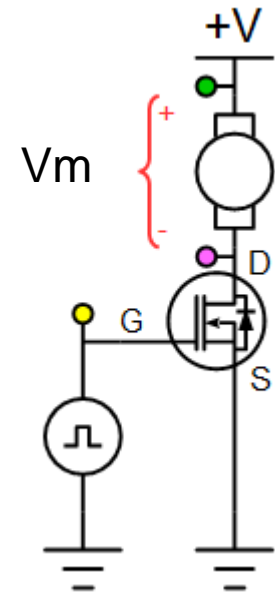
# Motor Electrical Model

Motor Electrical Model  
Back EMF  
Motor electromechanical behavior



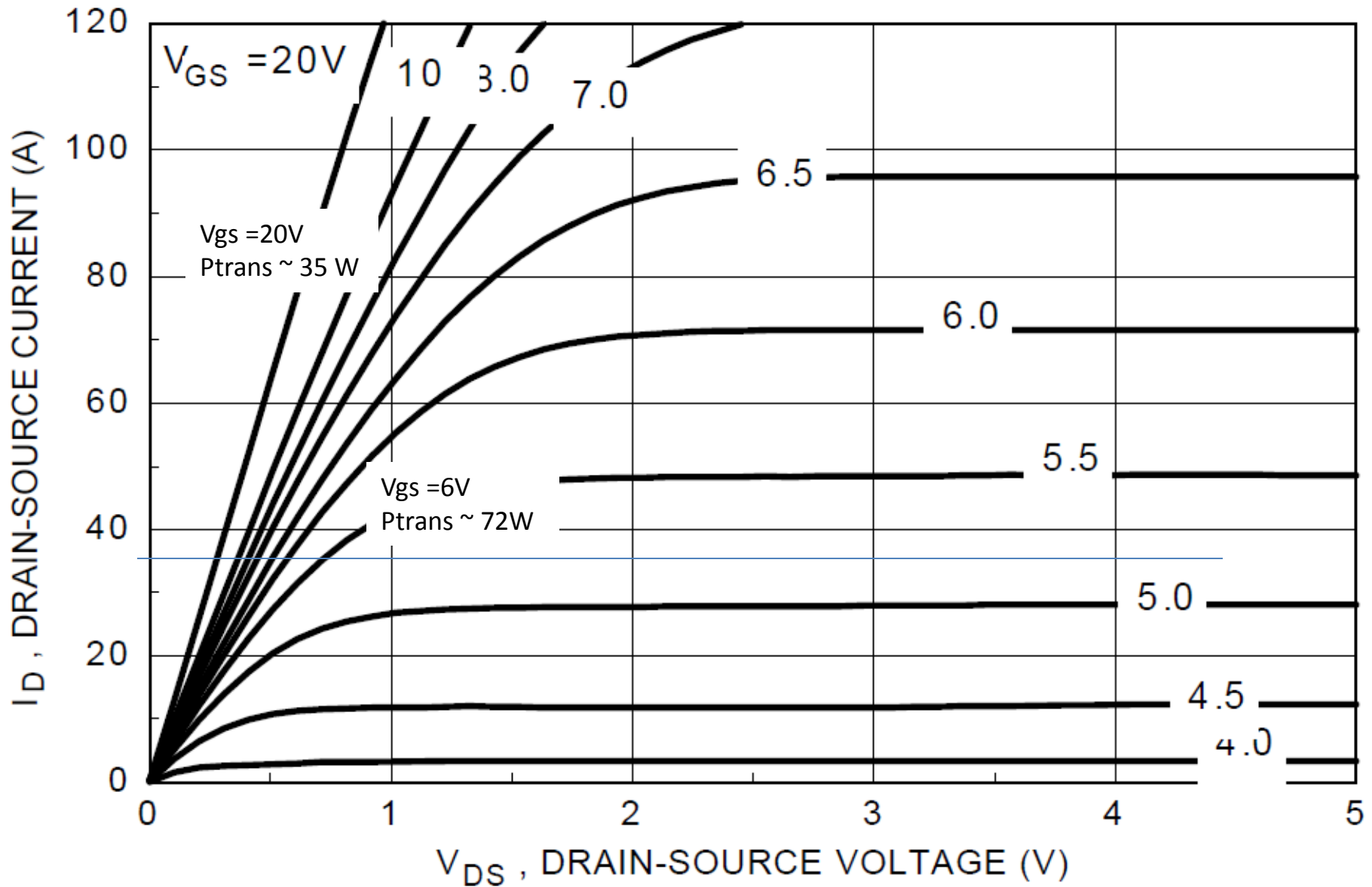
Continued on board  
Also- see motor worksheet.....

Note: missing e-stop!



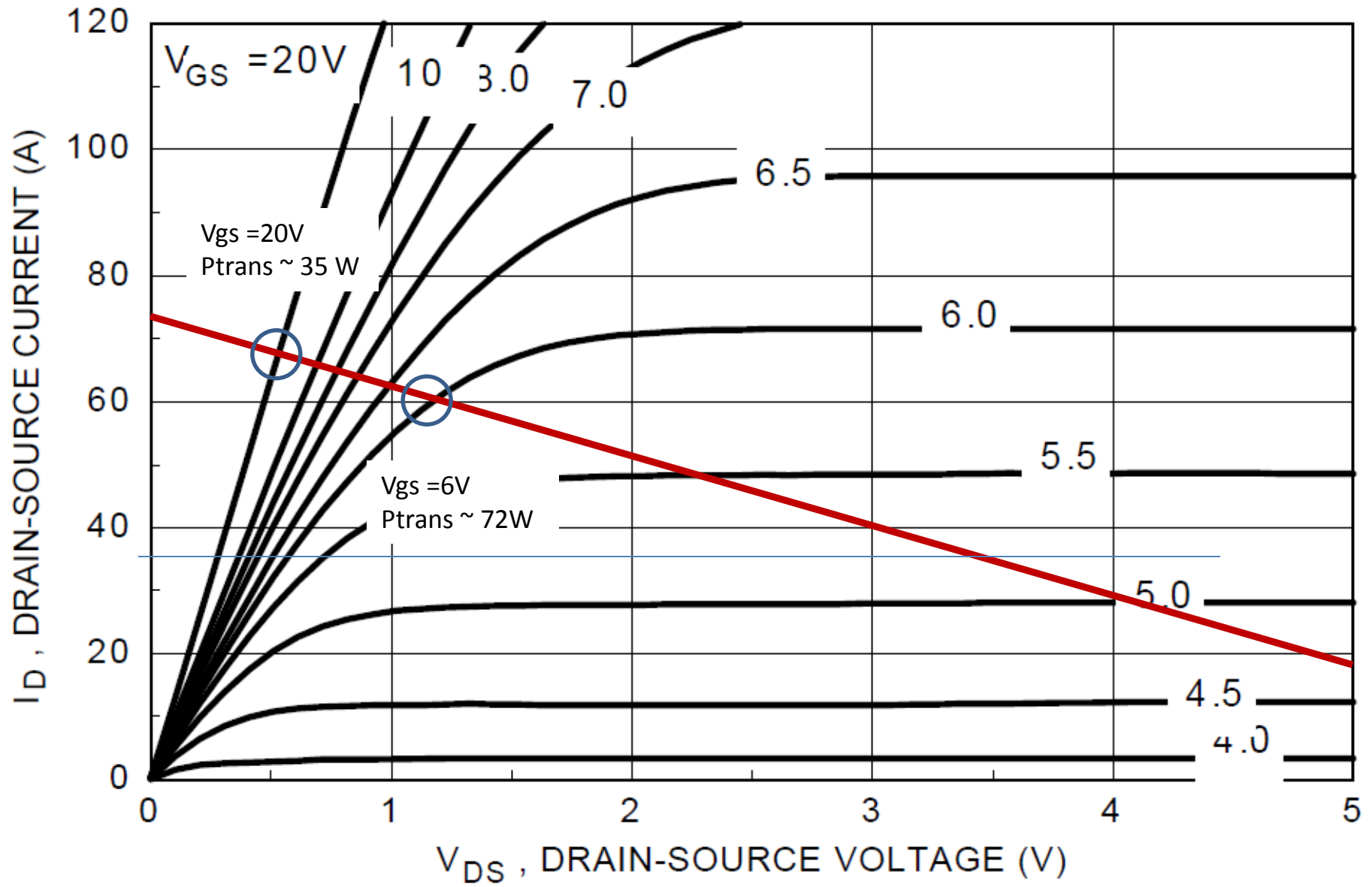
Given:  $R_m = 0.1$  ohms,  $V_{batt} = 7.2$  V,  $R_{bat} = 0$ .

$V_{ds} = ? \rightarrow I_{ds} = ?$  amps



$R_m = 0.1 \text{ ohms}$ ,  $V_{batt} = 7.2 \text{ V}$ ,  $R_{bat} = 0$ .

$V_{ds} = 3.6\text{V} \rightarrow I_{ds} = (7.2 - 3.6\text{V}) / (0.1 \text{ ohm}) = 36 \text{ amps}$



# H bridge gate driver devices



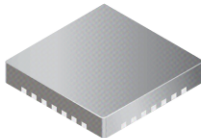
A4931

## 3-Phase Brushless DC Motor Pre-Driver

### Features and Benefits

- Drives 6 N-channel MOSFETs
- Synchronous rectification for low power dissipation
- Internal UVLO and thermal shutdown circuitry
- Hall element inputs
- PWM current limiting
- Dead time protection
- FG outputs
- Standby mode
- Lock detect protection
- Overvoltage protection

Package: 28-contact QFN (ET package)



Approximate Scale 1:1



### Description

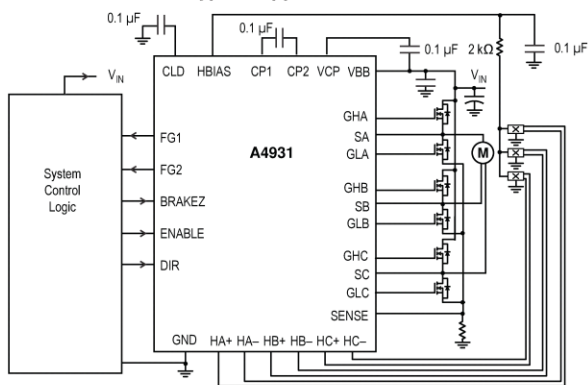
The A4931 is a complete 3-phase brushless DC motor pre-driver. The device is capable of driving a wide range of N-channel power MOSFETs and can support motor supply voltages up to 30 V. Commutation logic is determined by three Hall-element inputs spaced at 120°.

Other features include fixed off-time pulse width modulation (PWM) current control for limiting inrush current, locked-rotor protection with adjustable delay, thermal shutdown, overvoltage monitor, and synchronous rectification. Internal synchronous rectification reduces power dissipation by turning on the appropriate MOSFETs during current decay, thus shorting the body diode with the low  $R_{DS(on)}$  MOSFET. Overvoltage protection disables synchronous rectification when the motor pumps the supply voltage beyond the overvoltage threshold during current recirculation.

The A4931 offers enable, direction, and brake inputs that can control current using either phase or enable chopping. Logic outputs FG1 and FG2 can be used to accurately measure motor rotation. Output signals toggle state during Hall transitions, providing an accurate speed output to a microcontroller or speed control circuit.

Operating temperature range is -20°C to 105°C. The A4931 is supplied in a 5 mm × 5 mm, 28-terminal QFN package with exposed thermal pad. This small footprint package is lead (Pb) free with 100% matte tin leadframe plating.

### Typical Application



Freescale Semiconductor  
Technical Data

Document Number: MC33883  
Rev 10.0, 10/2012

## 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  $\mu$ A Sleep mode
- Supports PWM up to 100 kHz

33883

H-BRIDGE GATE DRIVER IC



EG SUFFIX (Pb-FREE)  
98ASB42343B  
20-PIN SOICW

### ORDERING INFORMATION

Device (Add R2 Suffix for Tape and Reel)	Temperature Range (T <sub>A</sub> )	Package
MC33883HEG	-40 °C to 125 °C	20 SOICW

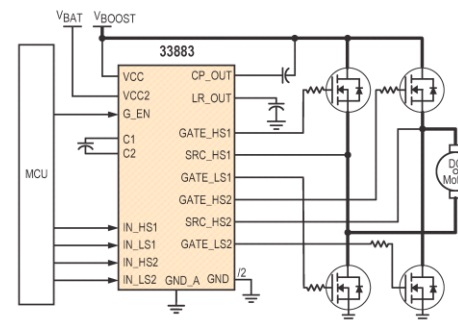


Figure 1. 33883 Simplified Application Diagram



# PWM

<https://developer.mbed.org/handbook/PwmOut>

	<b>PwmOut</b> (PinName pin) Create a <b>PwmOut</b> connected to the specified pin.
void	<b>write</b> (float value) Set the output duty-cycle, specified as a percentage (float)
float	<b>read</b> () Return the current output duty-cycle setting, measured as a percentage (float)
void	<b>period</b> (float seconds) Set the PWM period, specified in seconds (float), keeping the duty cycle the same.
void	<b>period_ms</b> (int ms) Set the PWM period, specified in milli-seconds (int), keeping the duty cycle the same.
void	<b>period_us</b> (int us) Set the PWM period, specified in micro-seconds (int), keeping the duty cycle the same.
void	<b>pulsewidth</b> (float seconds) Set the PWM pulsewidth, specified in seconds (float), keeping the period the same.
void	<b>pulsewidth_ms</b> (int ms) Set the PWM pulsewidth, specified in milli-seconds (int), keeping the period the same.
void	<b>pulsewidth_us</b> (int us) Set the PWM pulsewidth, specified in micro-seconds (int), keeping the period the same.
<b>PwmOut</b> &	<b>operator=</b> (float value) A operator shorthand for <b>write()</b>
	<b>operator float</b> () An operator shorthand for <b>read()</b>