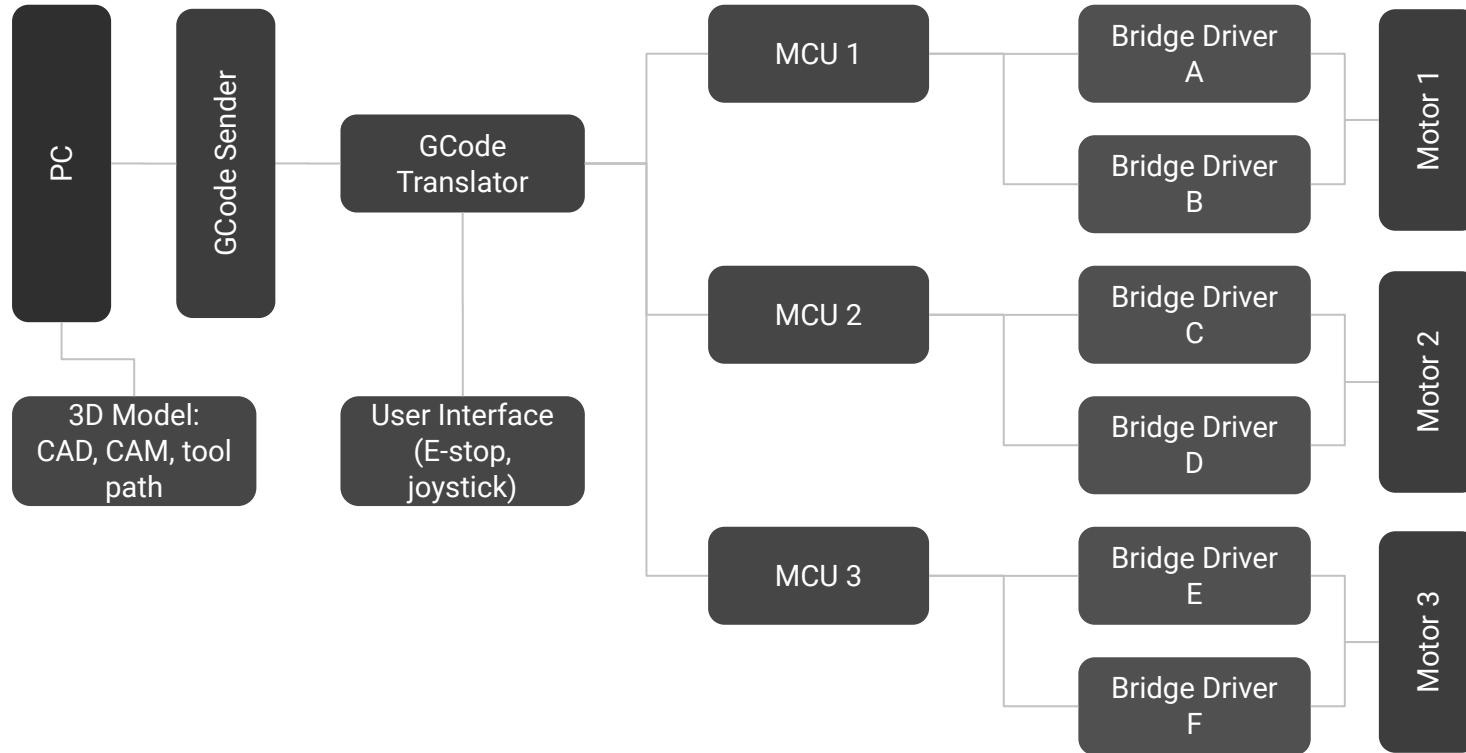
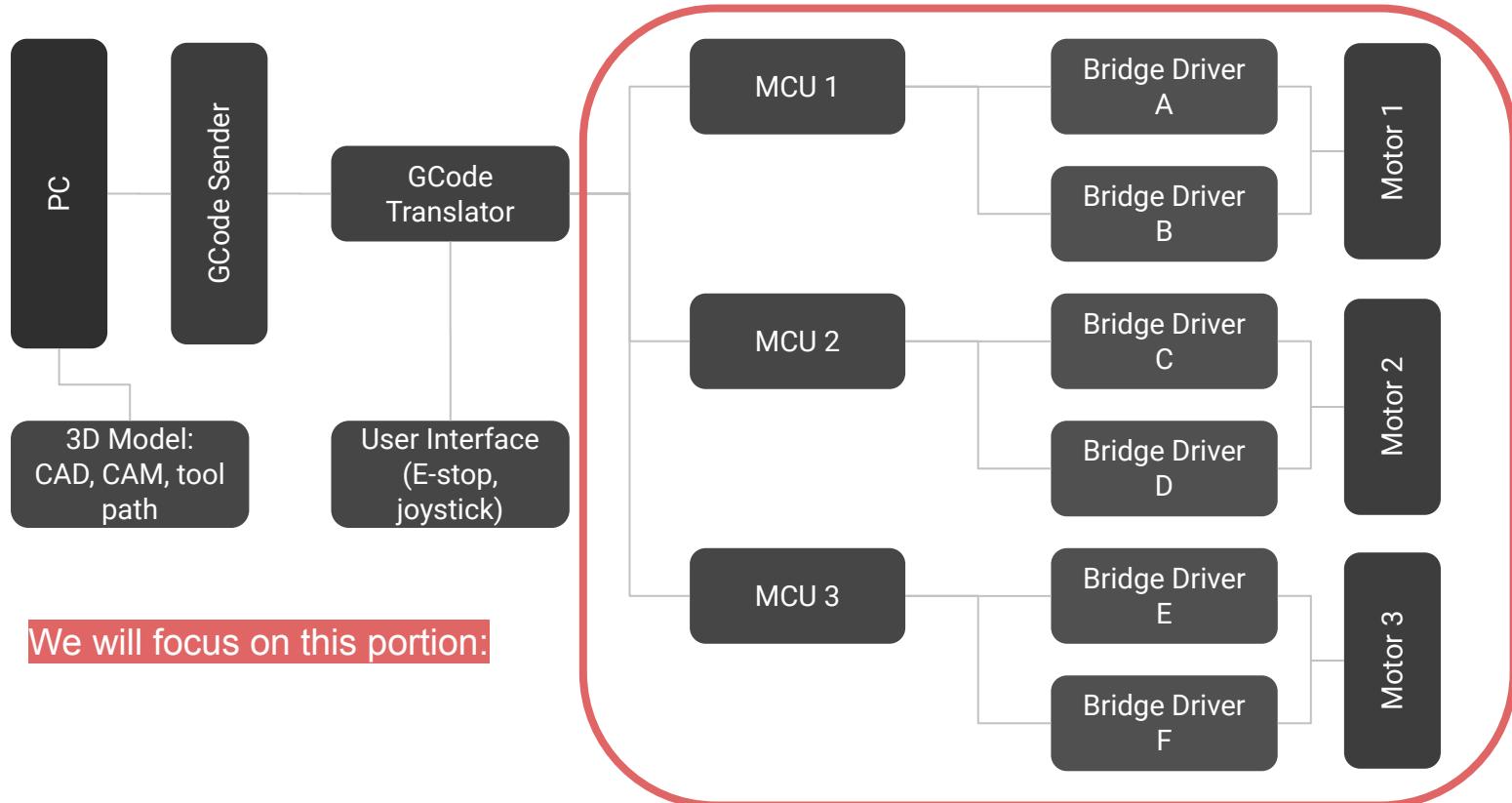


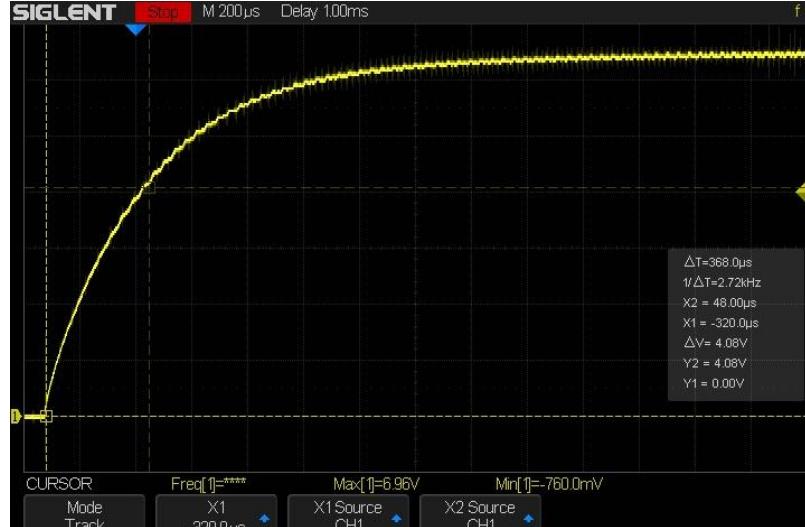
Cheap  
motor!

$\frac{1}{4}$ "-20 lead  
screw!

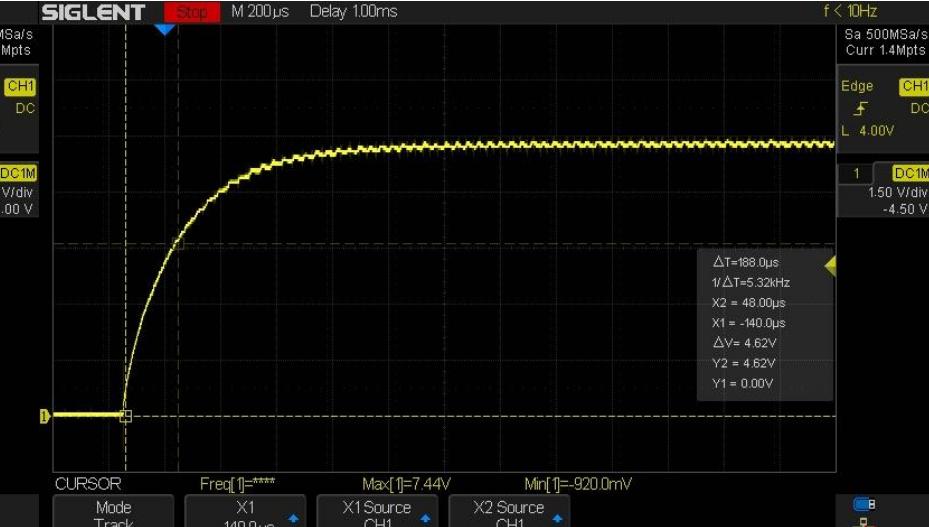
$\frac{1}{4}$ "-20 lead  
screw!







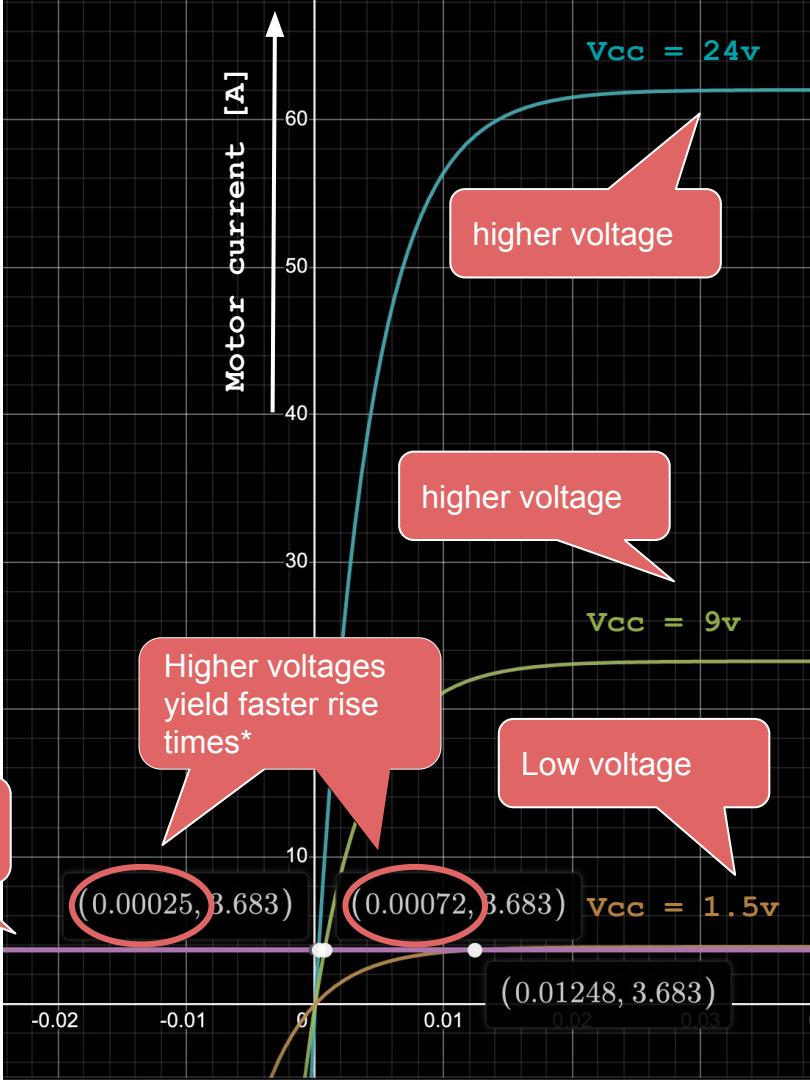
```
>> tau=368E-6s, R_ext=8.2ohm
```

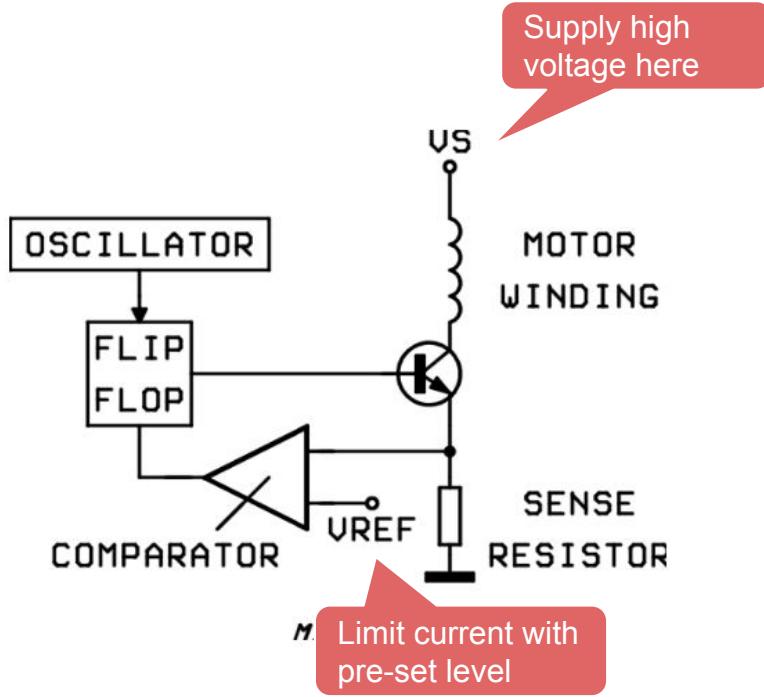


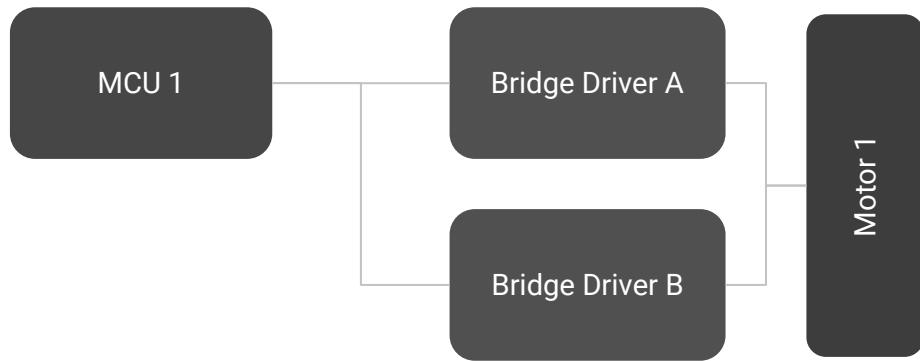
```
>> tau=168E-6s, R_ext=4ohm
```

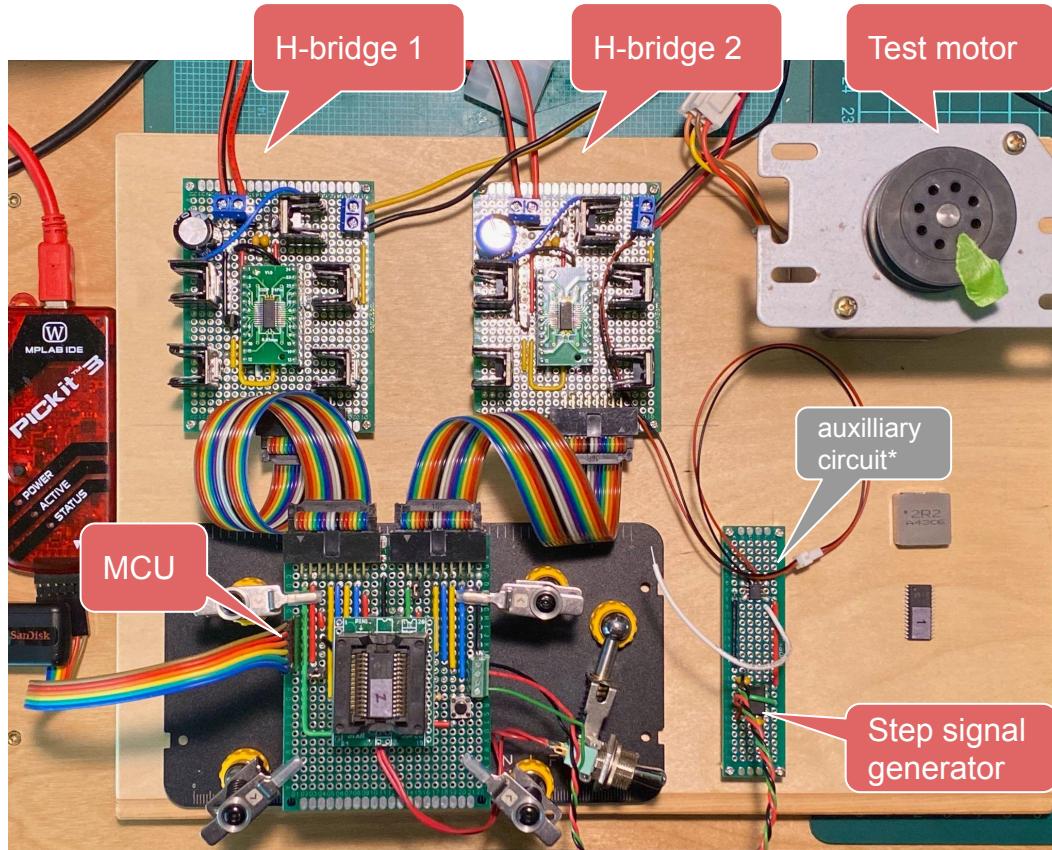
Assume first-order approx.  
>>Motor: tau=L\_0/(R\_0+R\_ext)  
>> L\_0=1.61E-3H, R\_0=0.387ohm

Large time constant!!  
Tau = L0/R0 = 4.2ms

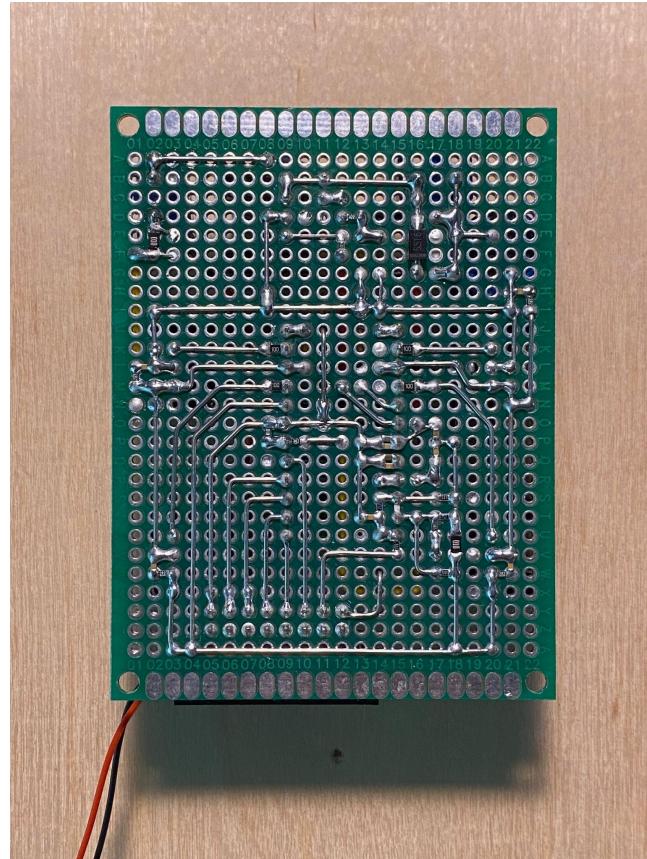
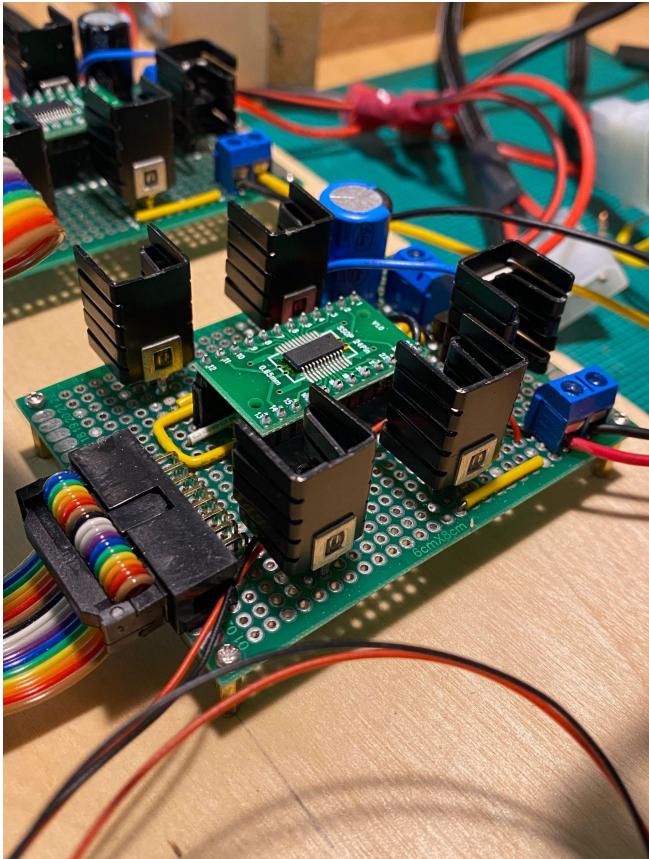


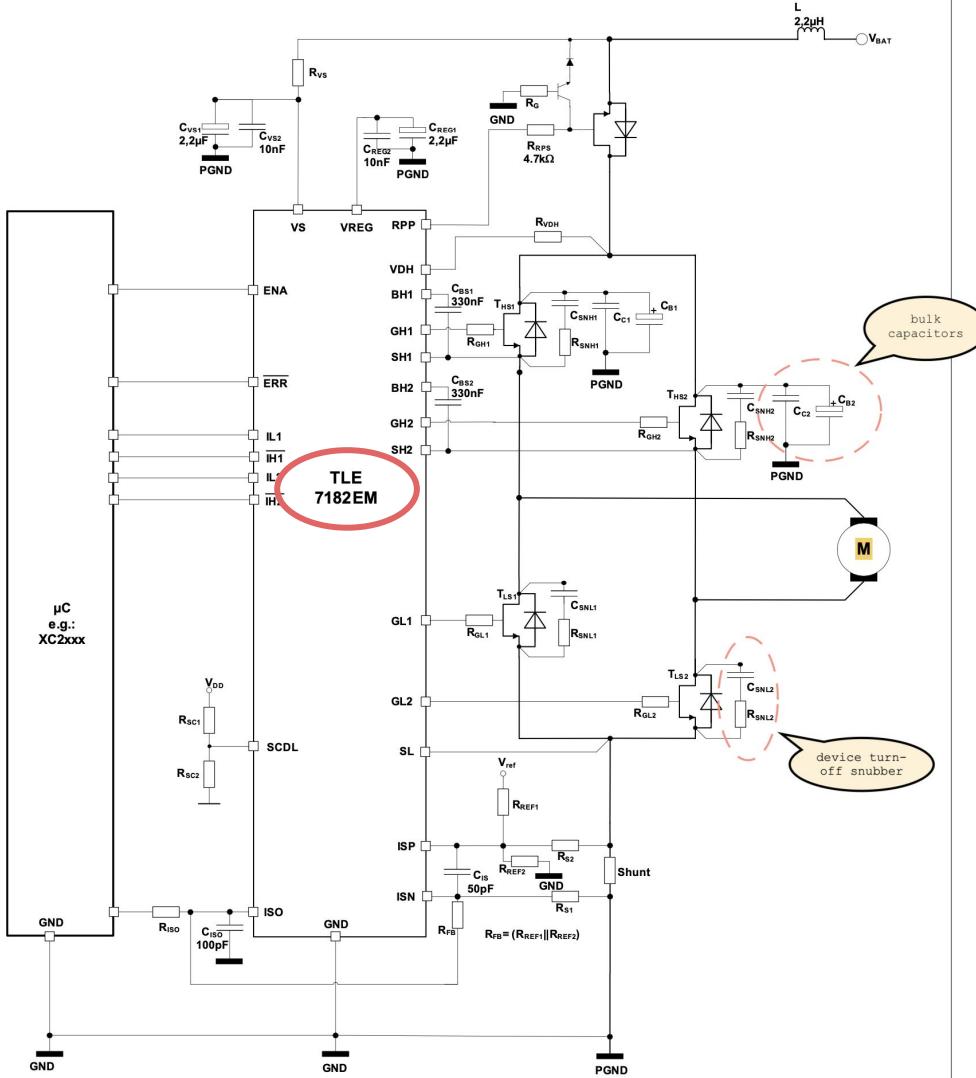


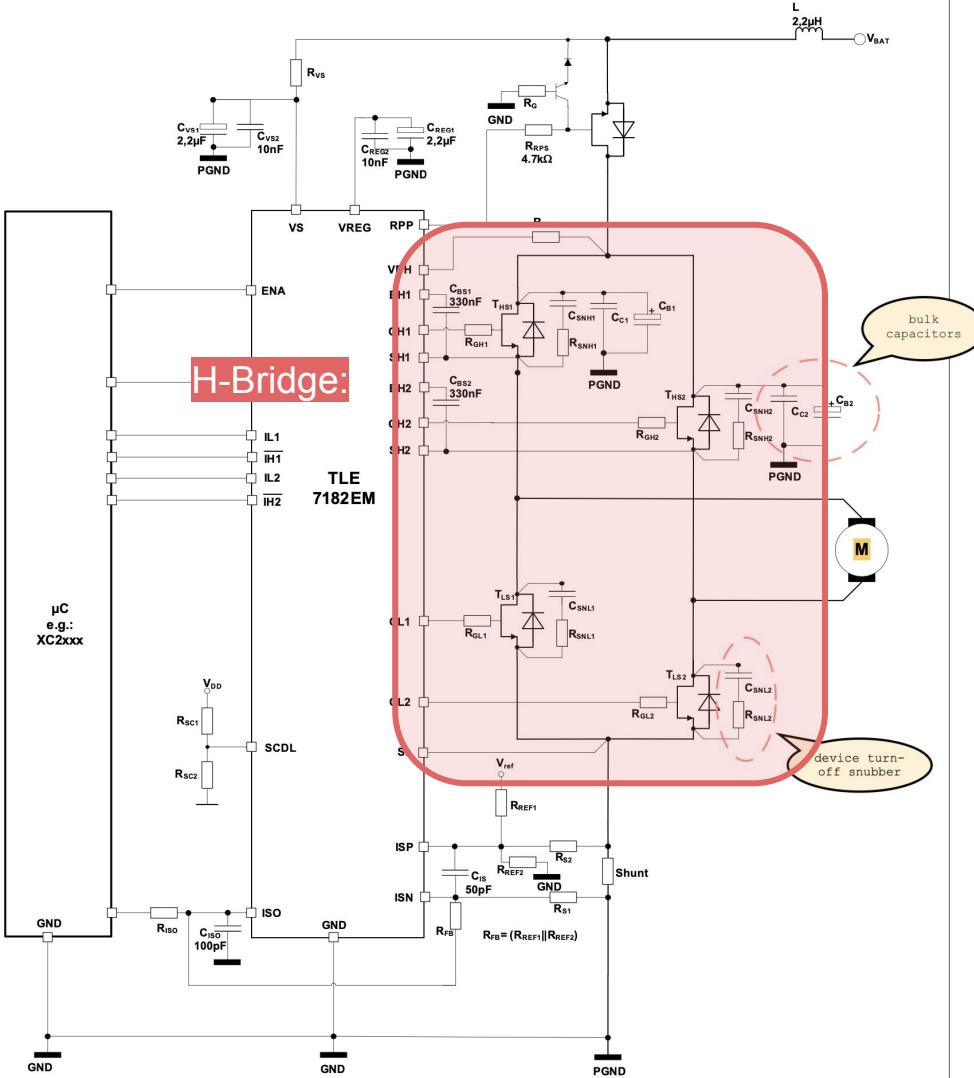




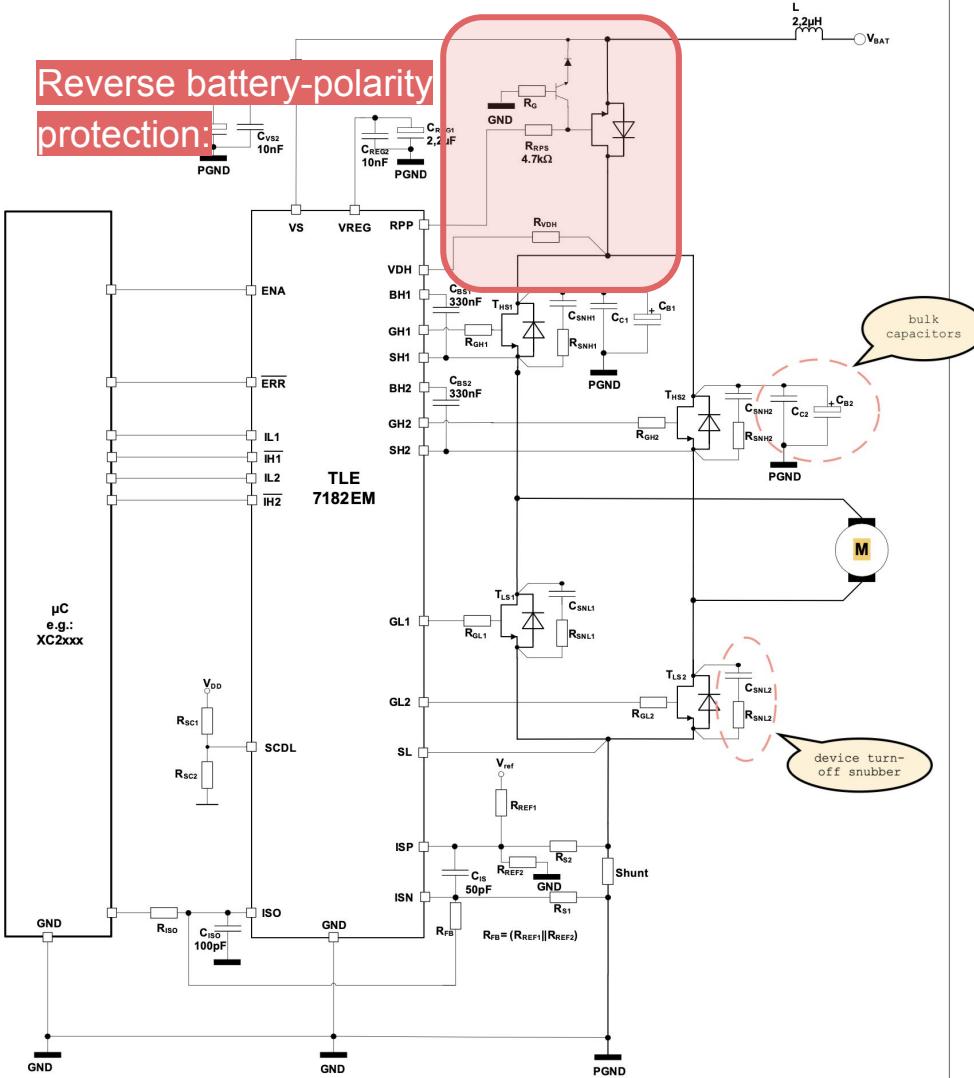
**\*Discussed later**

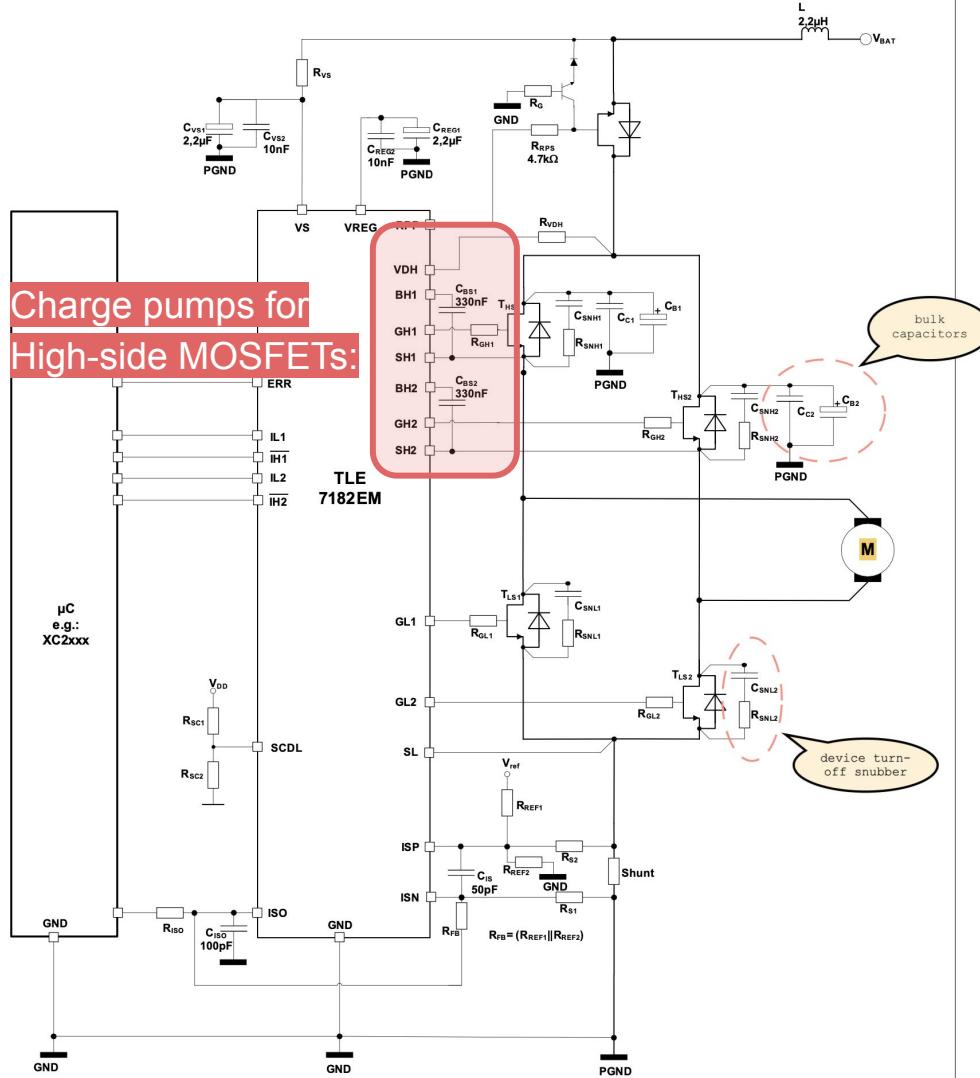


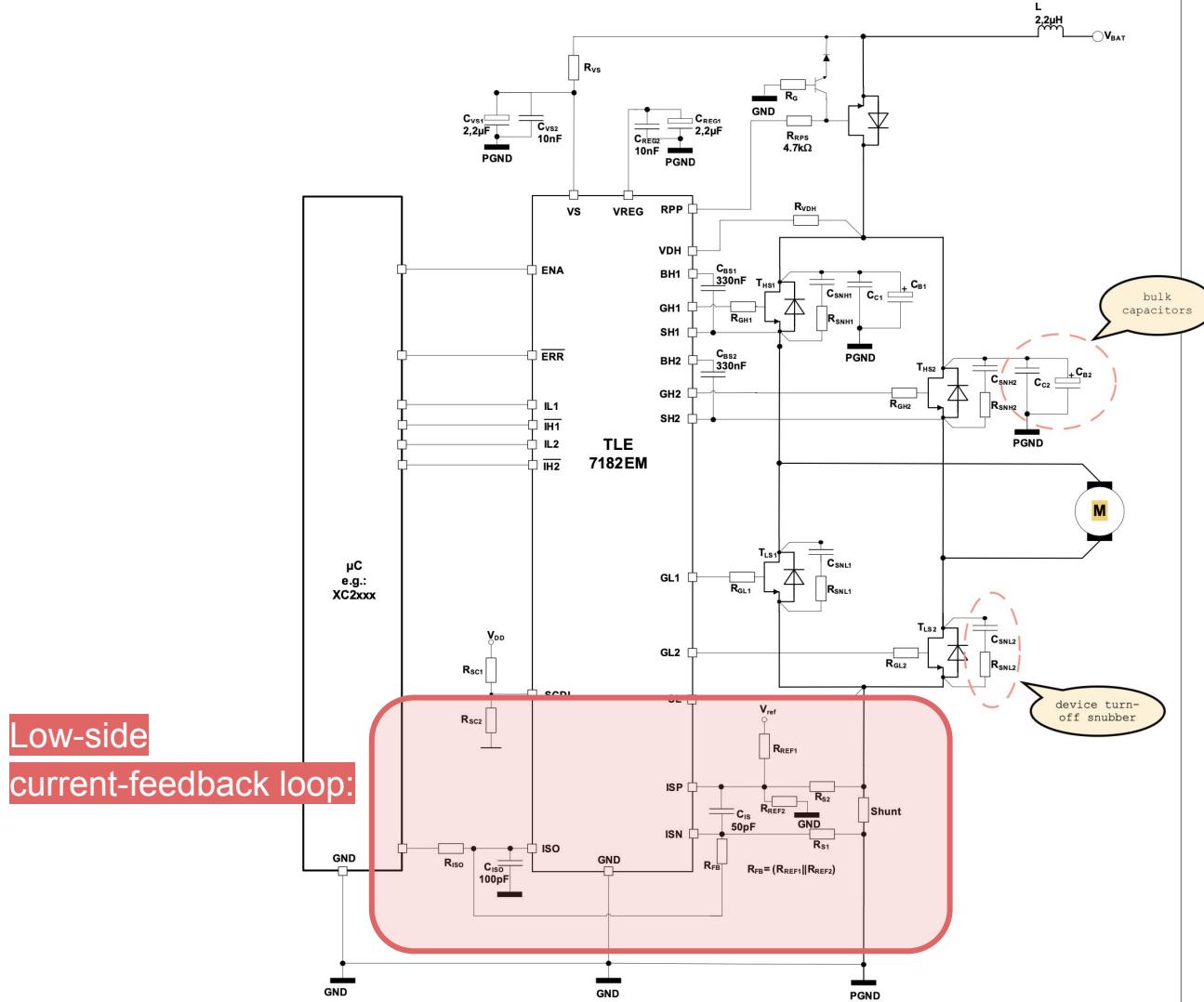


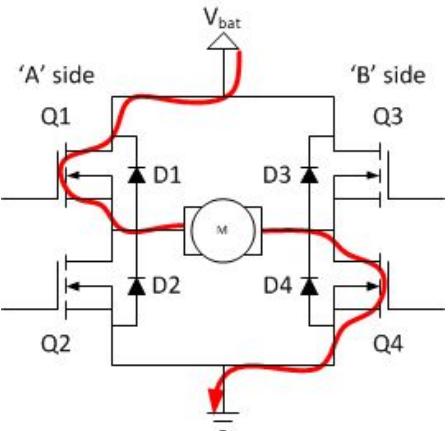


## Reverse battery-polarity protection:

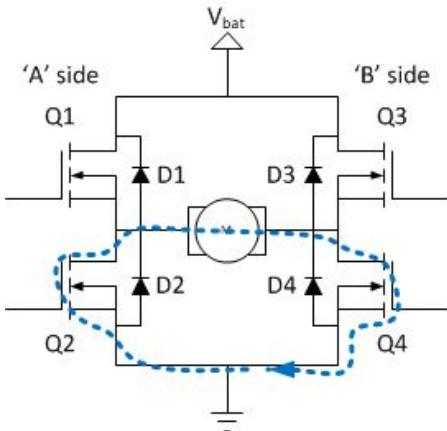






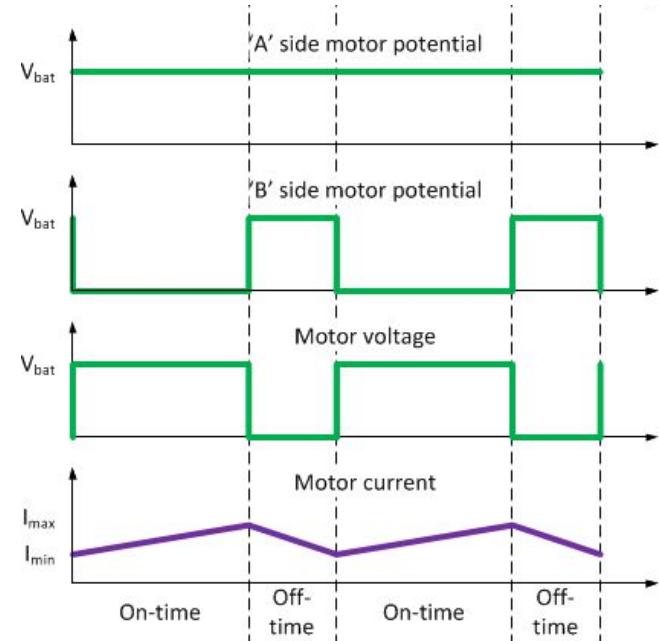


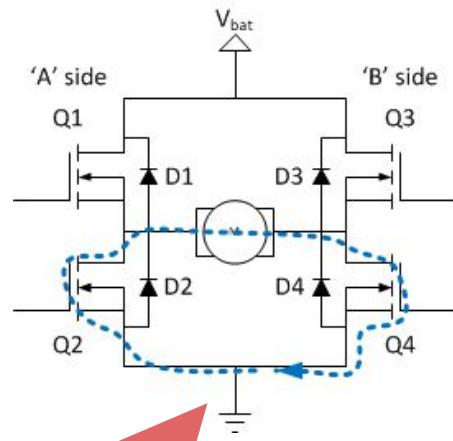
Above: "ON"/forward



Above: "slow-decay"

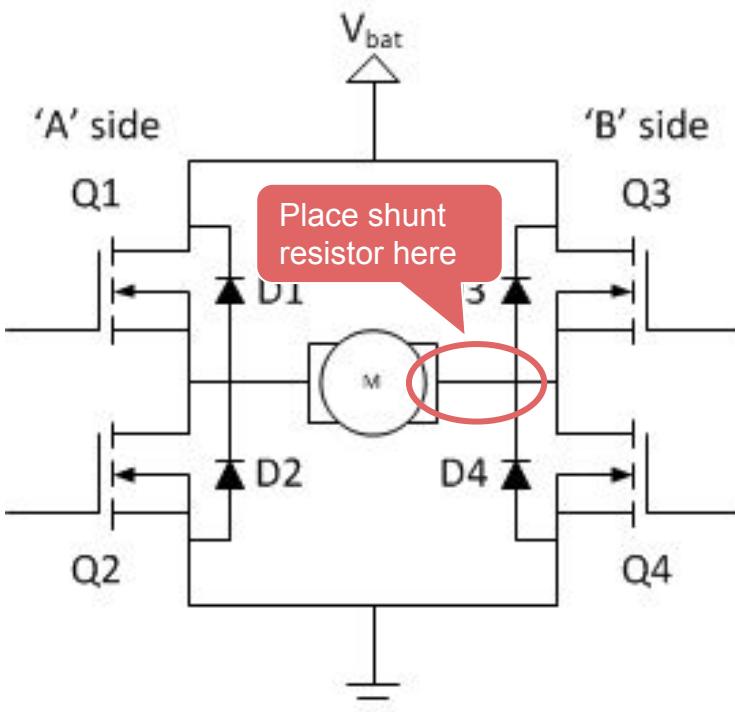
- "ON" period
- "OFF" period

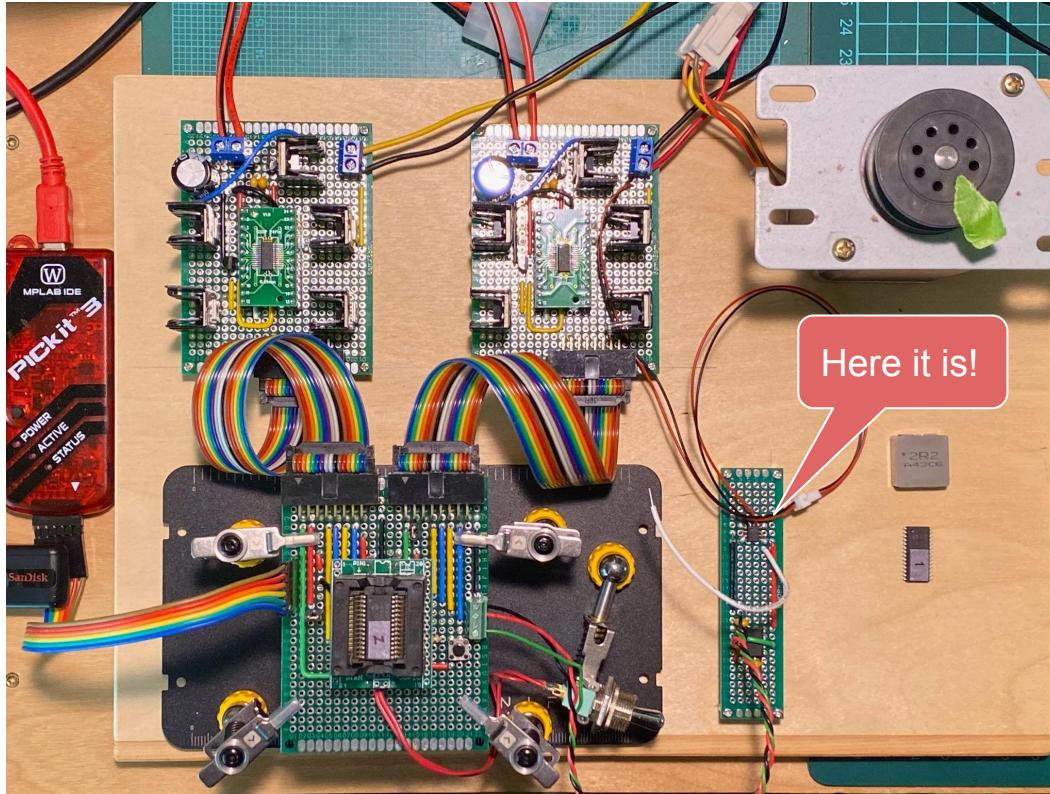




Current does not flow through low-side shunt during off cycle

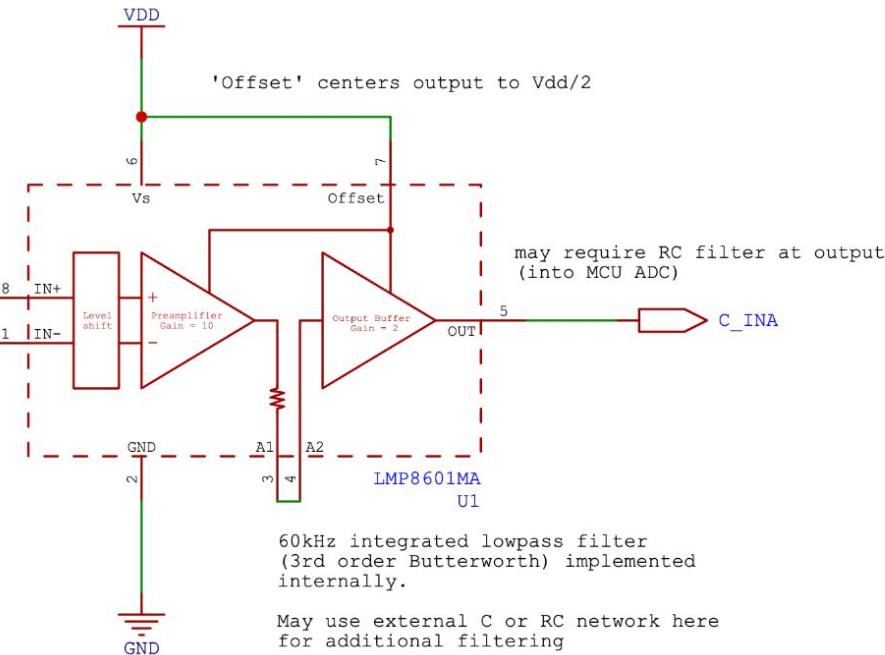
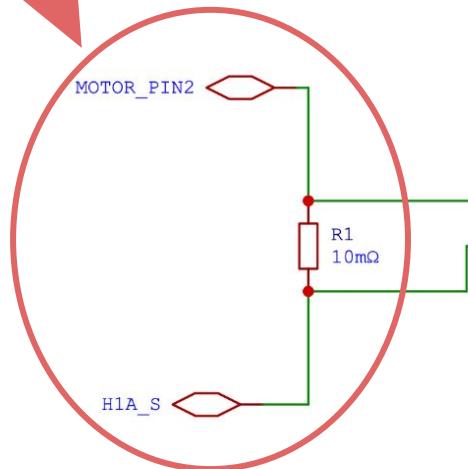


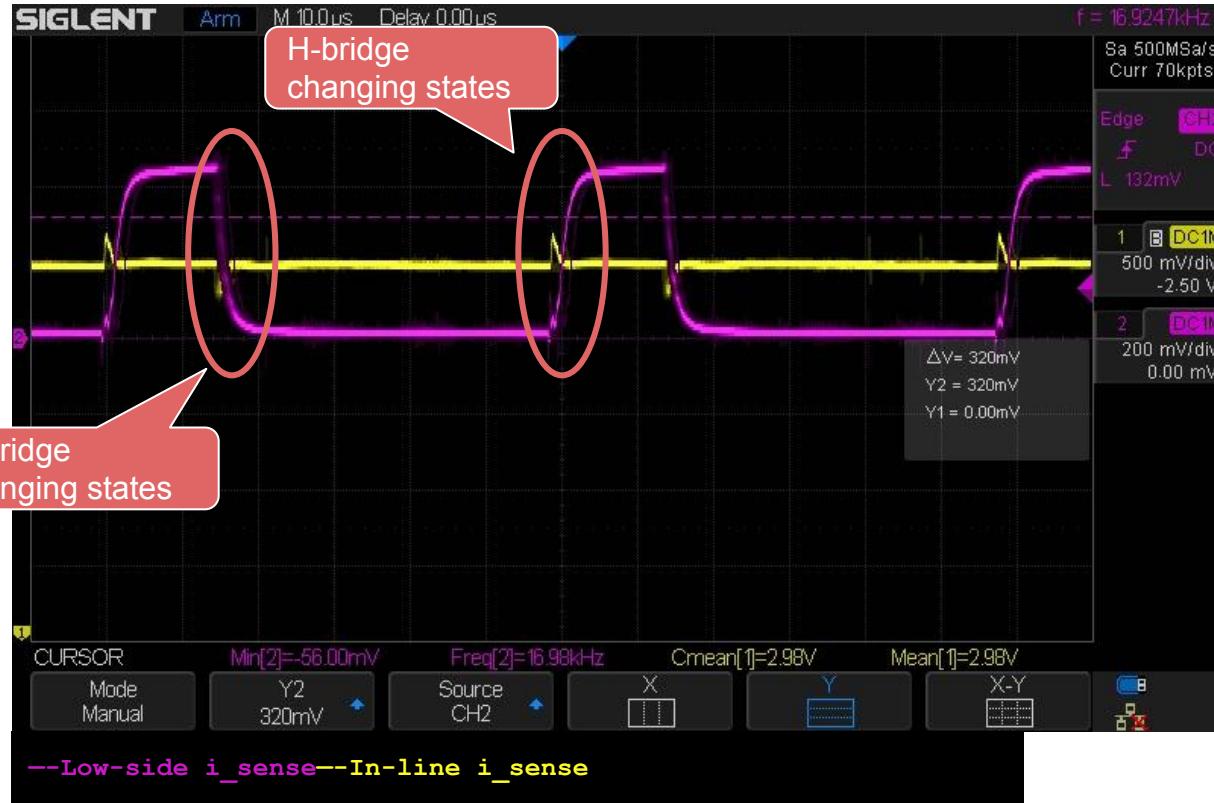


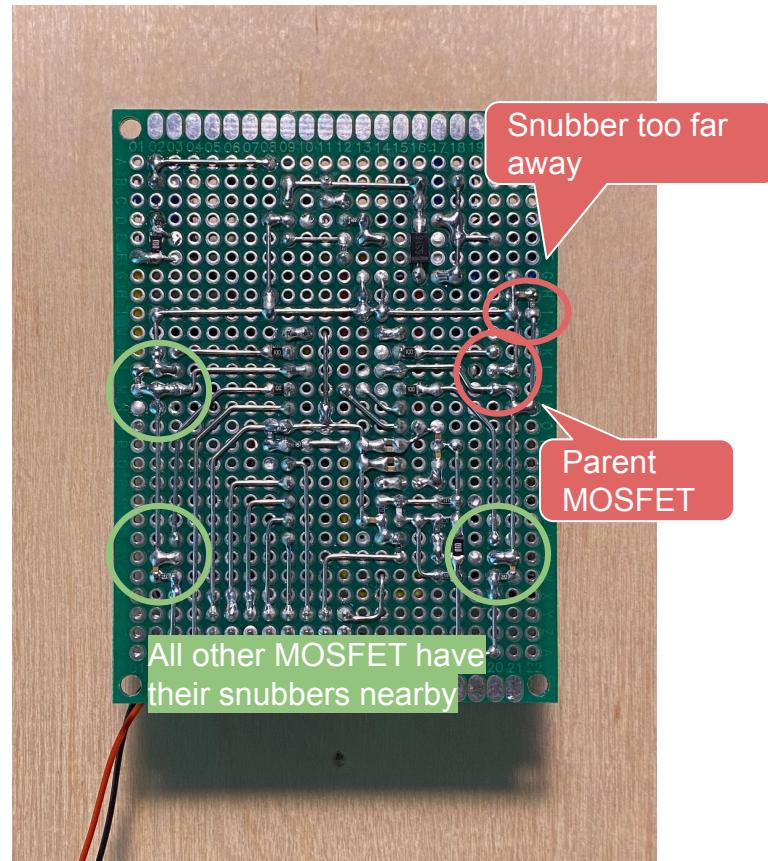
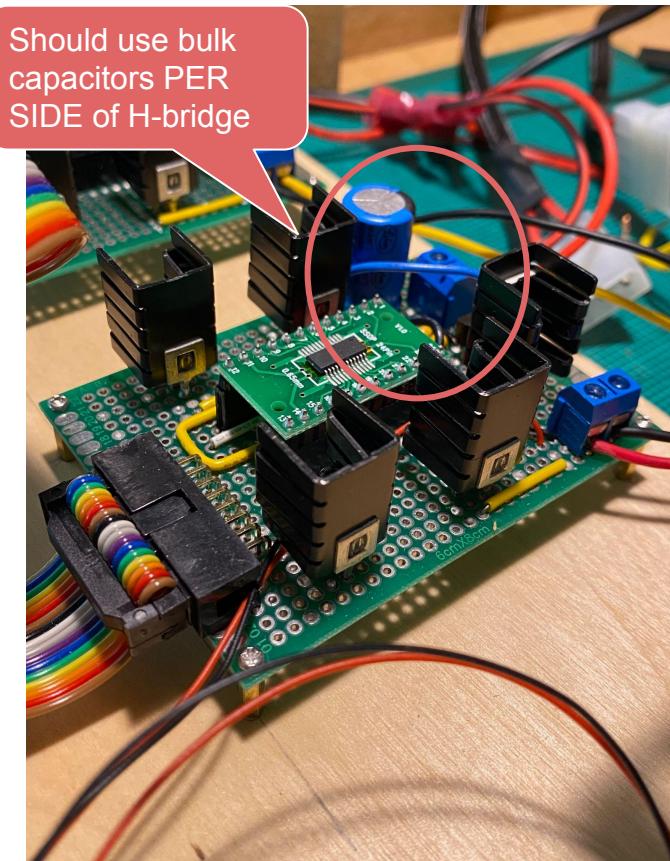


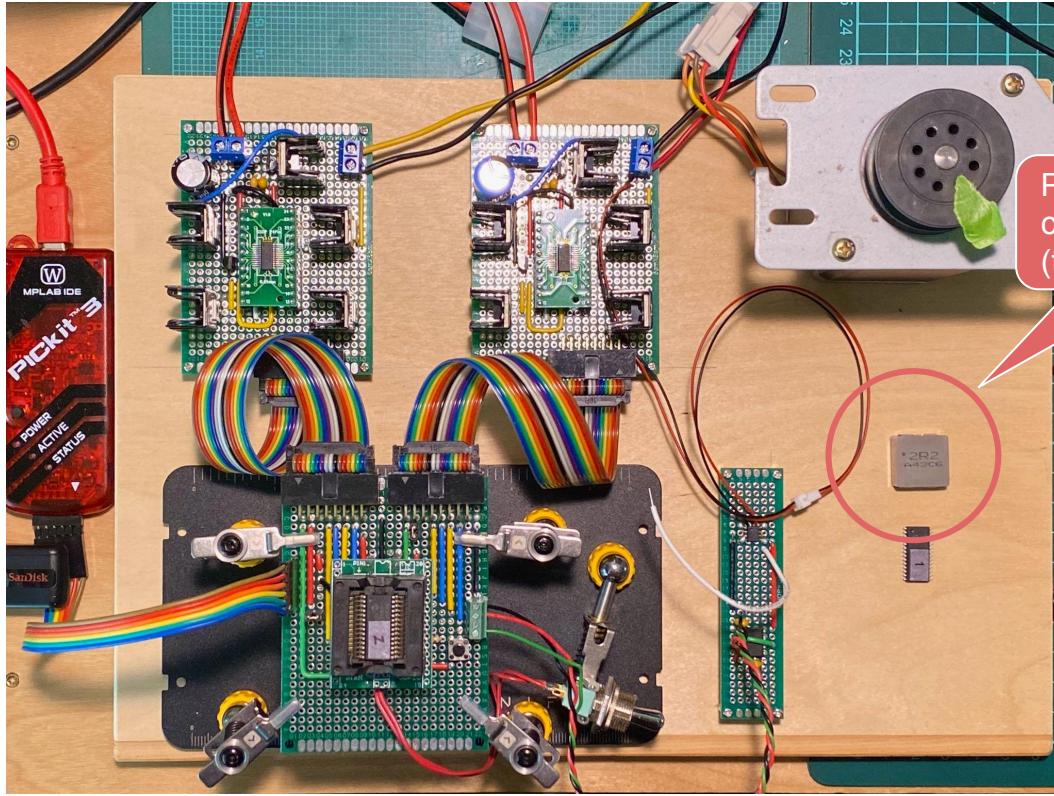
Here it is!

In-line shunt placement





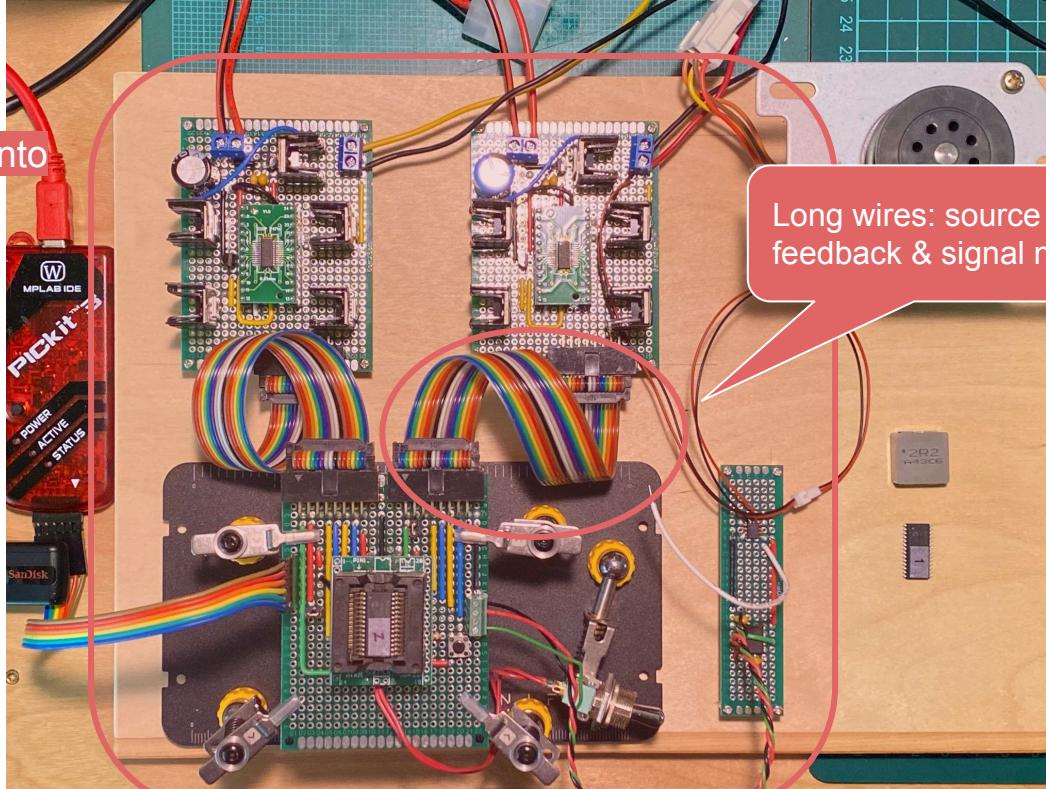


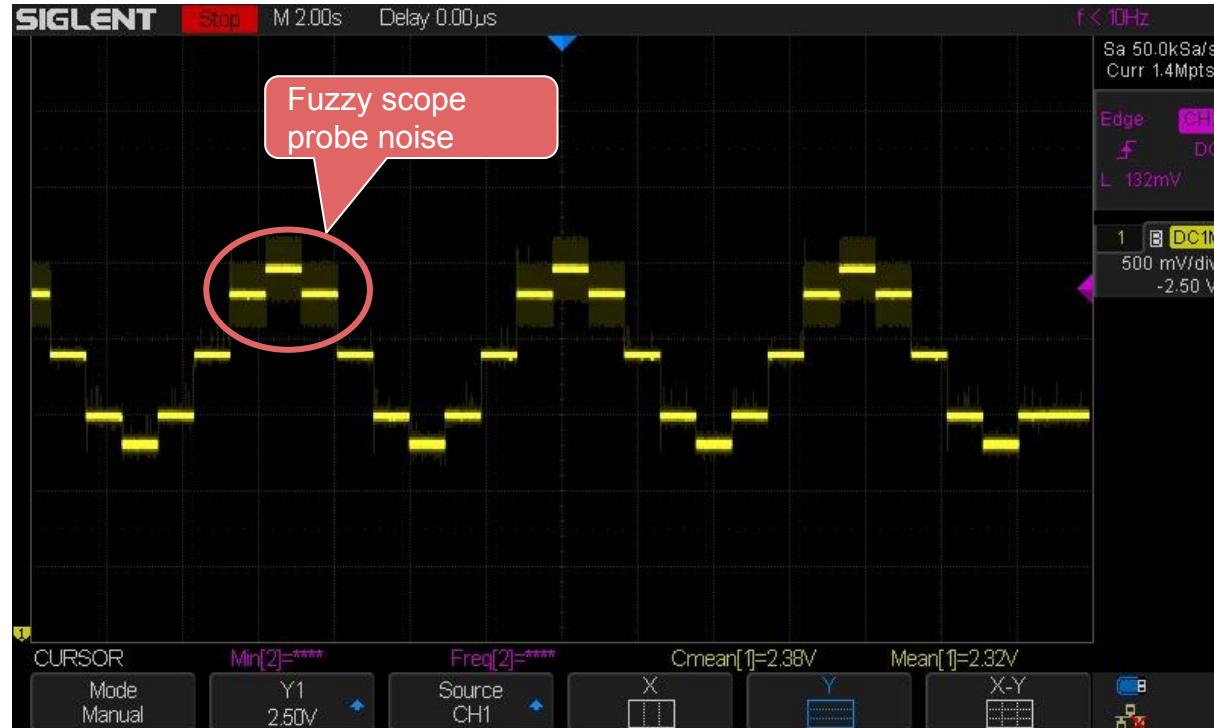


Power inductor not  
currently in-use  
(too large)

Consolidate into  
one board!

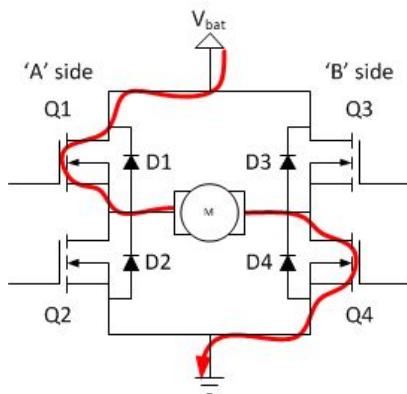
Long wires: source of  
feedback & signal noise!



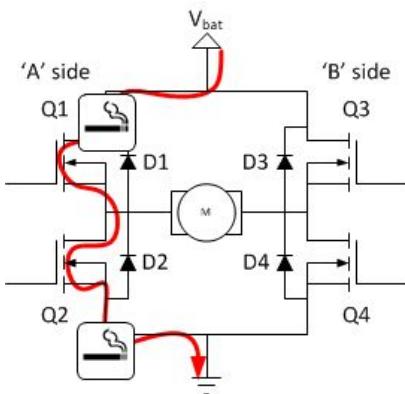


--Imotor



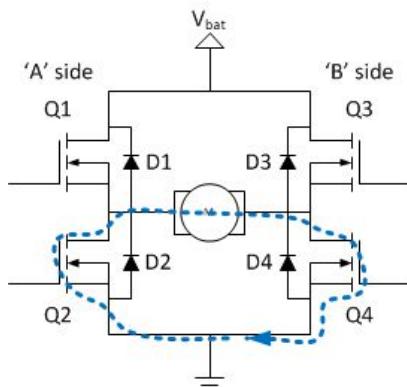


Above: "ON"/forward

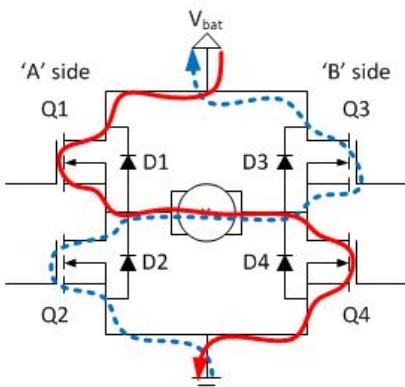


→ "ON" period  
→ "OFF" period

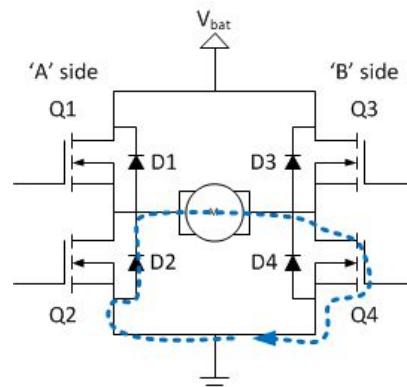
Above: "shoot-through"  
-PROHIBITED



Above: "slow-decay"



Above: "fast-decay"



Above: discontinuous  
current\*

# H-bridge: MOSFET selection

- ⑤ Calculated continuous current based on maximum allowable junction temperature. Package limitation current is 75A.

$t_{gd}$	Gate-to-Drain (Miller) Charge	—	—	ns	$V_{GS} = 10V, S_6$
$t_{d(on)}$	Turn-On Delay Time	—	14	—	$V_{DD} = 28V$
$t_r$	Rise Time	—	101	—	$I_D = 62A$
$t_{d(off)}$	Turn-Off Delay Time	—	50	—	$R_G = 4.5\Omega$
$t_f$	Fall Time	—	65	—	$V_{GS} = 10V, S_6$

Source: IRF3205 datasheet

Note: switching time << motor tau

## MOSFET driver output

5.1.11	Output source resistance	$R_{Sou}$	2	—	13.5	$\Omega$	$I_{Load} = -20mA$
5.1.12	Output sink resistance	$R_{Sink}$	2	—	9.0	$\Omega$	$I_{Load} = 20mA$

Source: TLE7182EM datasheet

Remark: MOSFET switch time dominated by driver limitations

# Design Deep Dive: MOSFET selection

- Given  $V_{DD} = 24V$ ,  $Motor\_R = 0.387\Omega$ 
  - $I_{max}$  (steady state) = **62A**
- Operating at such high voltages reduces rise time  $T_{rise}$  from **12.4ms** → **0.2ms**
  - However, faulty operation could lead to very high currents!

⑤ Calculated continuous current based on maximum allowable junction temperature. Package limitation current is 75A.

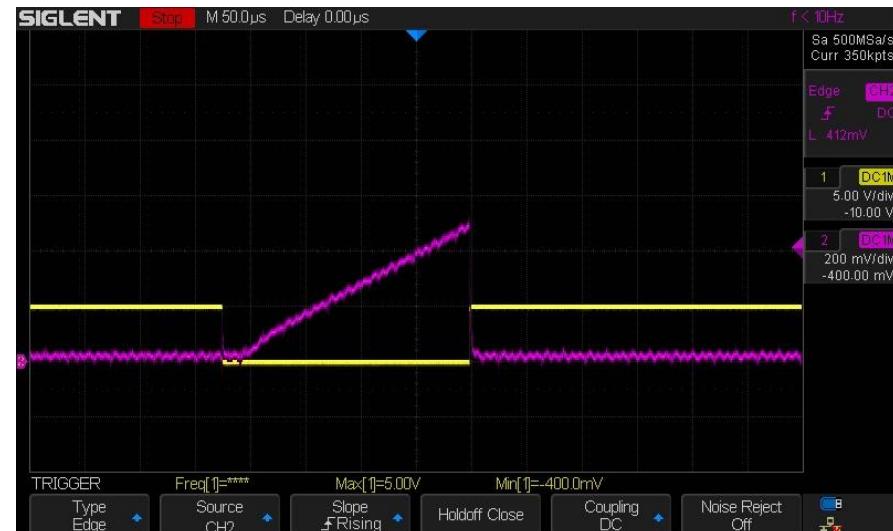
$t_{gd}$	Gate-to-Drain (Miller) Charge	—	—	ns	$V_{GS} = 10V$ , $St$
$t_{d(on)}$	Turn-On Delay Time	—	14	—	$V_{DD} = 28V$
$t_r$	Rise Time	—	101	—	$I_D = 62A$
$t_{d(off)}$	Turn-Off Delay Time	—	50	—	$R_G = 4.5\Omega$
$t_f$	Fall Time	—	65	—	$V_{GS} = 10V$ , $St$

Above: from IRF3205 datasheet

Note: switching time << motor tau

## MOSFET driver output

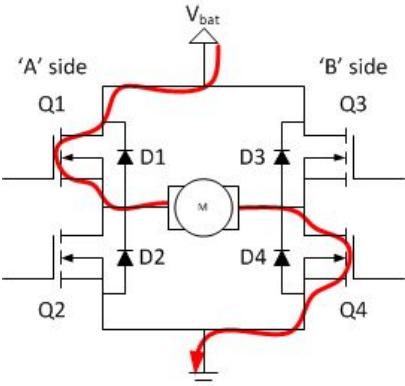
5.1.11	Output source resistance	$R_{Sou}$	2	—	13.5	$\Omega$	$I_{Load} = -20mA$
5.1.12	Output sink resistance	$R_{Sink}$	2	—	9.0	$\Omega$	$I_{Load} = 20mA$



--Motor current,  $V_{DD} = 24V$

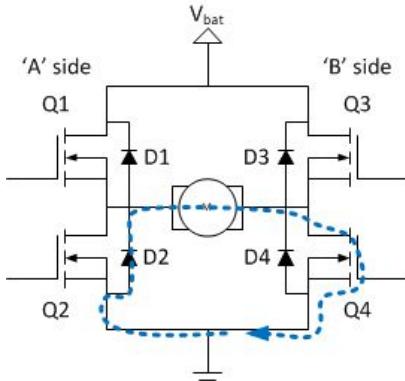
Left: from TLE7182EM datasheet

Remark: MOSFET switch time dominated by driver limitations

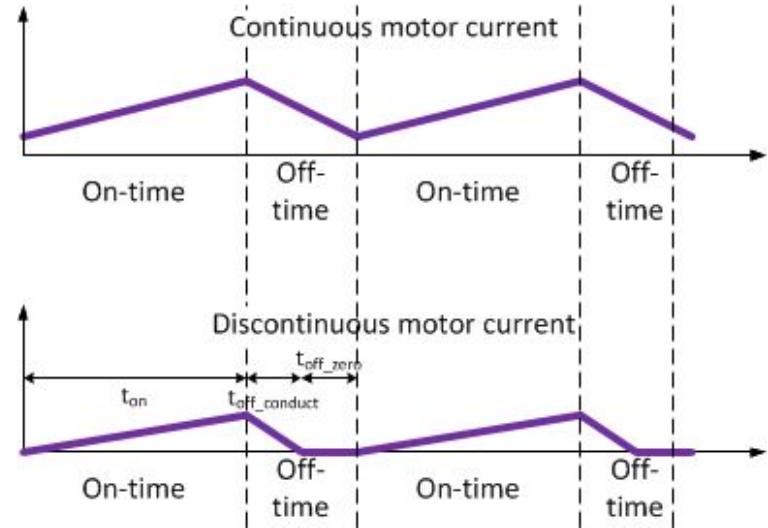


Above: "ON"/forward

- "ON" period
- "OFF" period



Above: discontinuous current flow



Above: because of the body diode, motor current is prevented from reversing