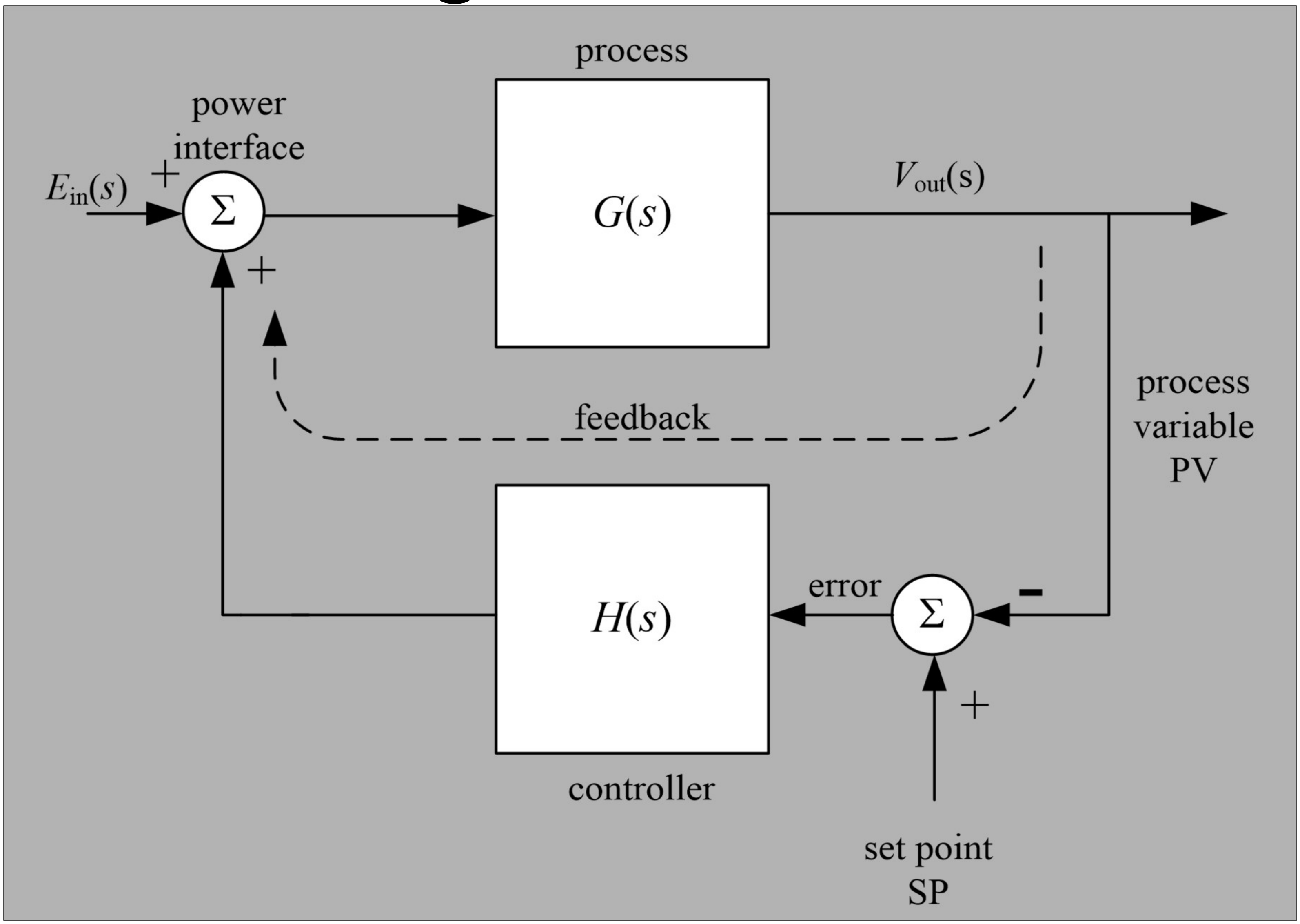
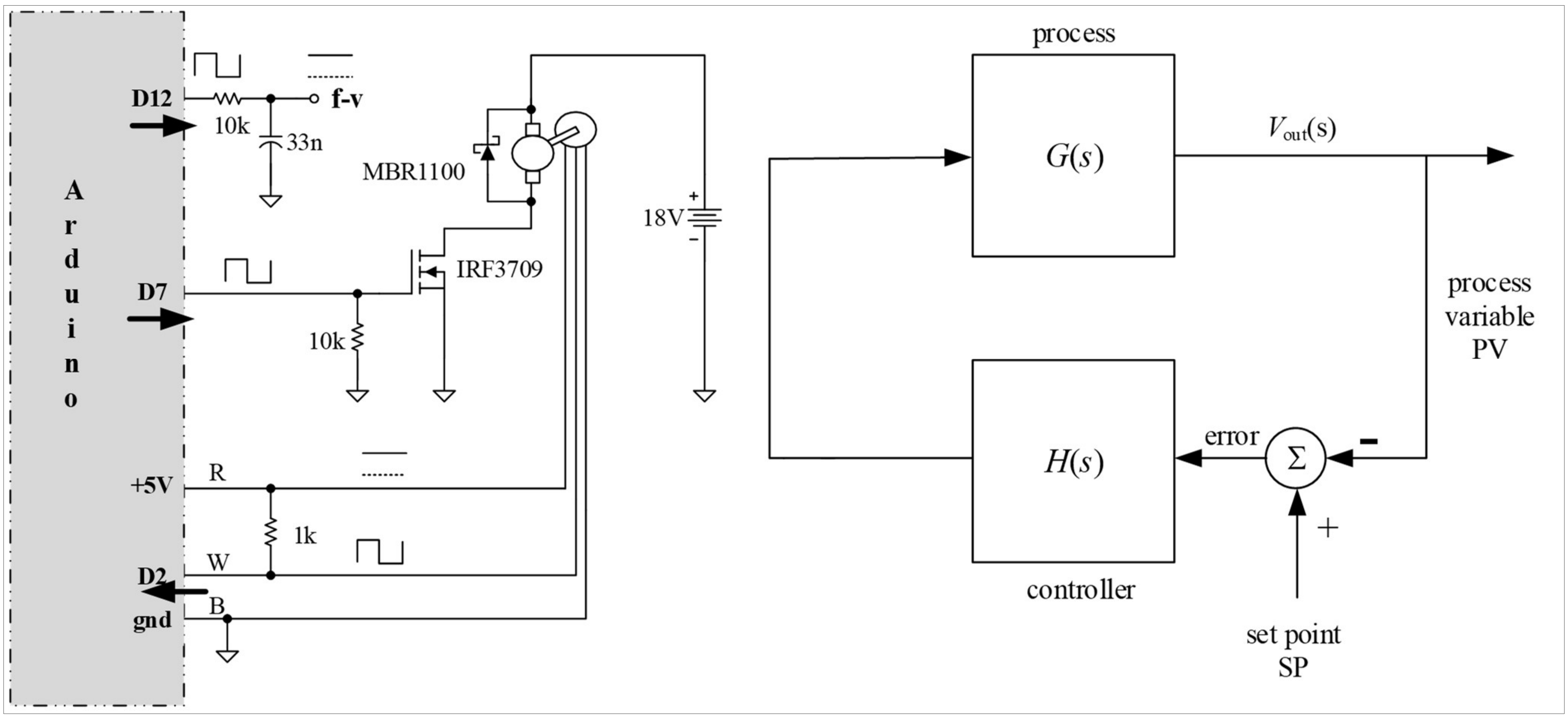
Negative feedback

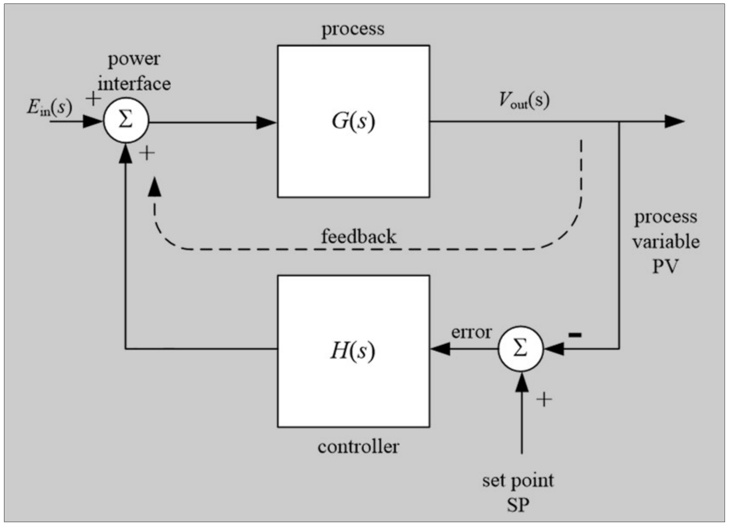


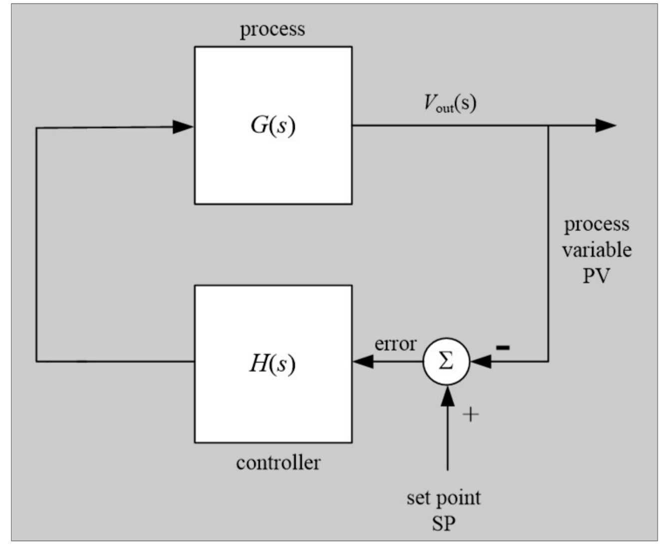
Motor speed Control

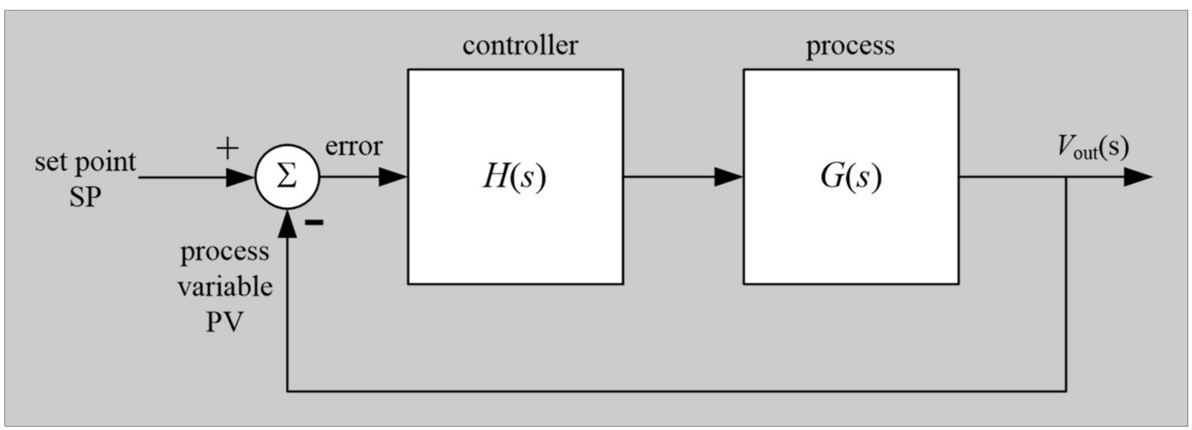


E_{in} G Process Variable Set Point H What's the objective?

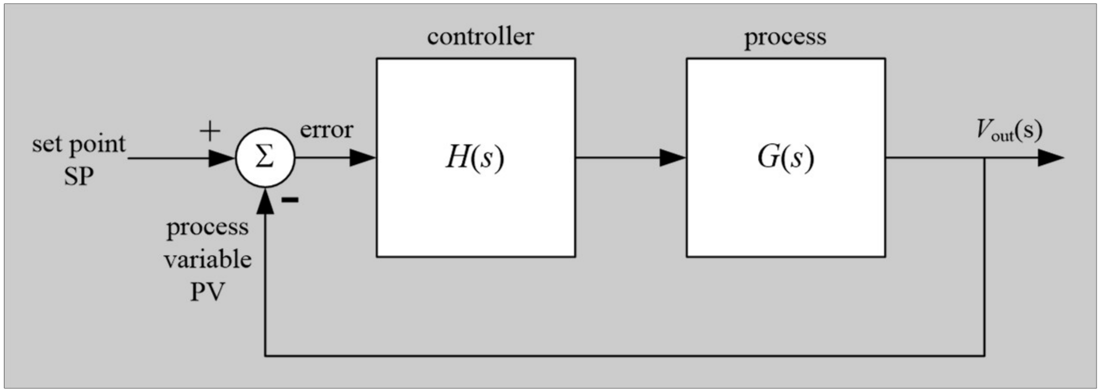
Servo Tracking: ΔSP => ΔPV

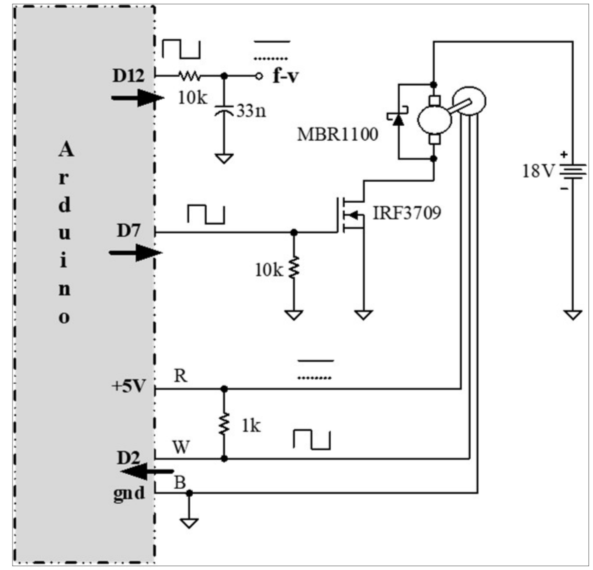






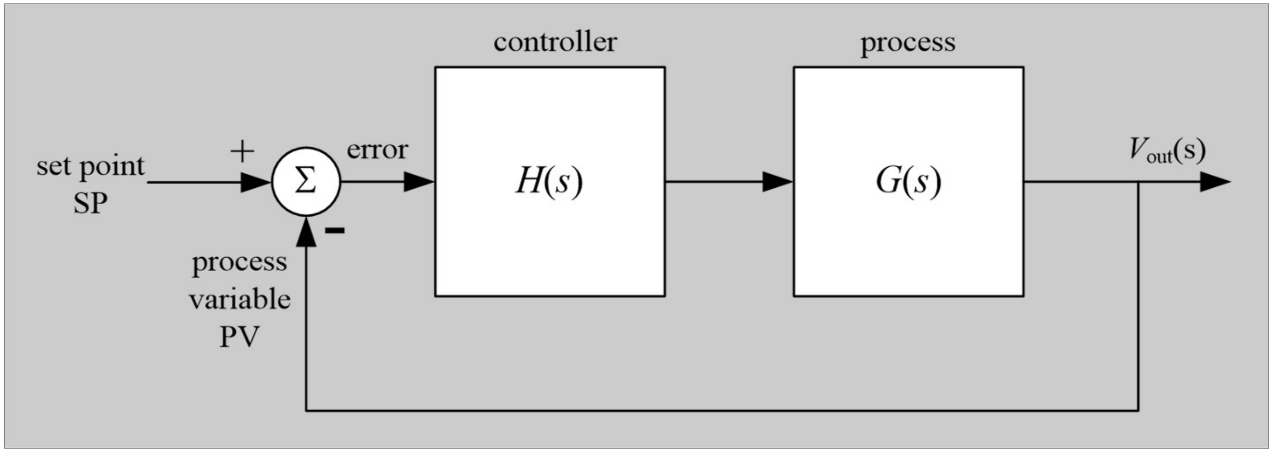
Servo Tracking: Transfer Function

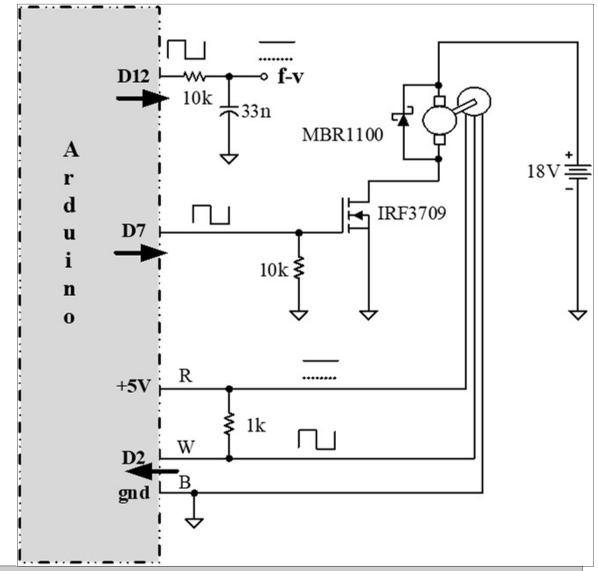


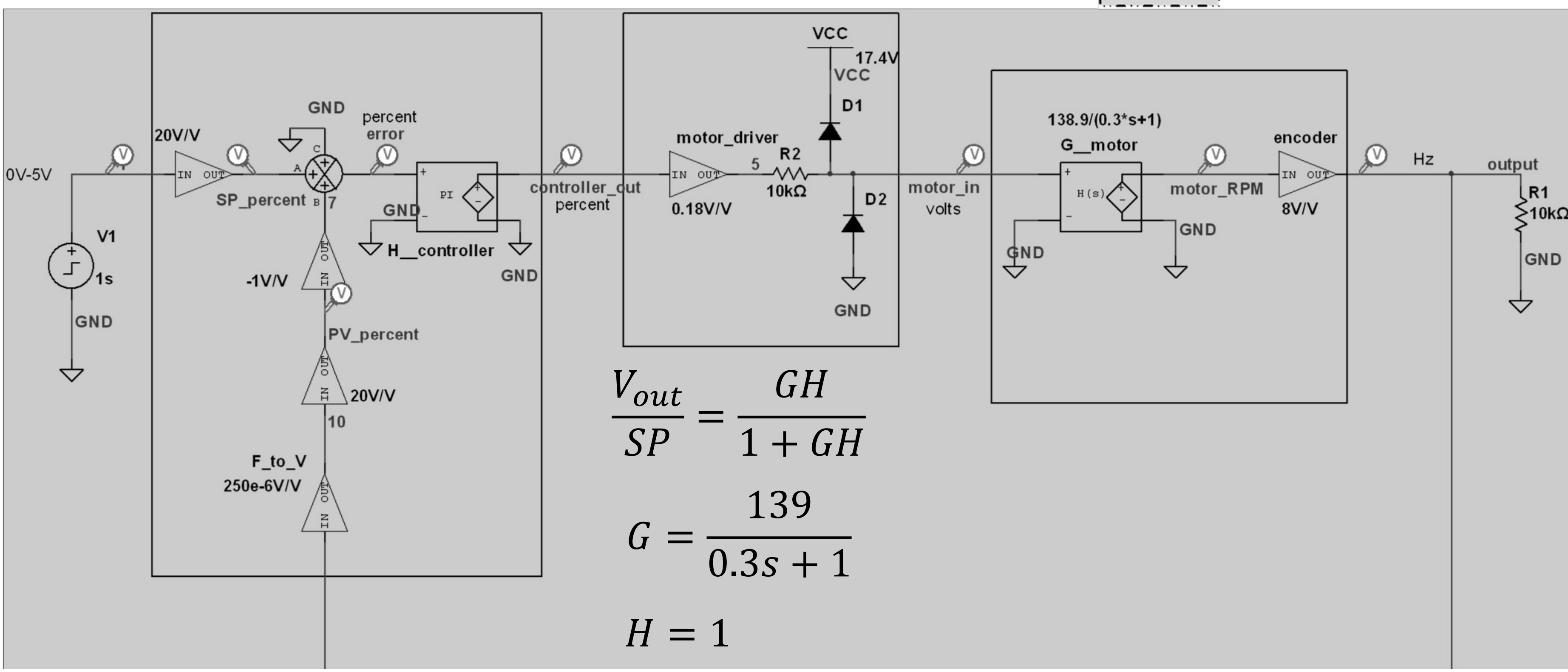


$$\frac{V_{out}}{SP} = \underline{\hspace{4cm}}$$

Motor with Proportional Controller





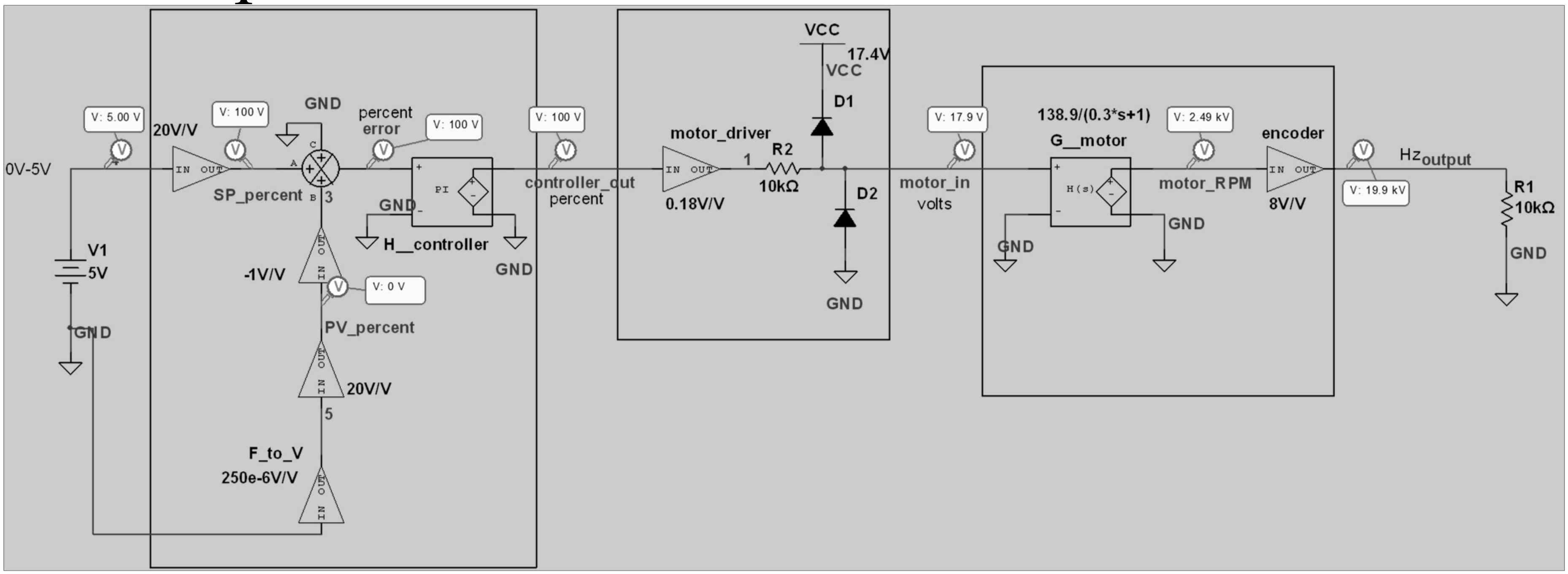


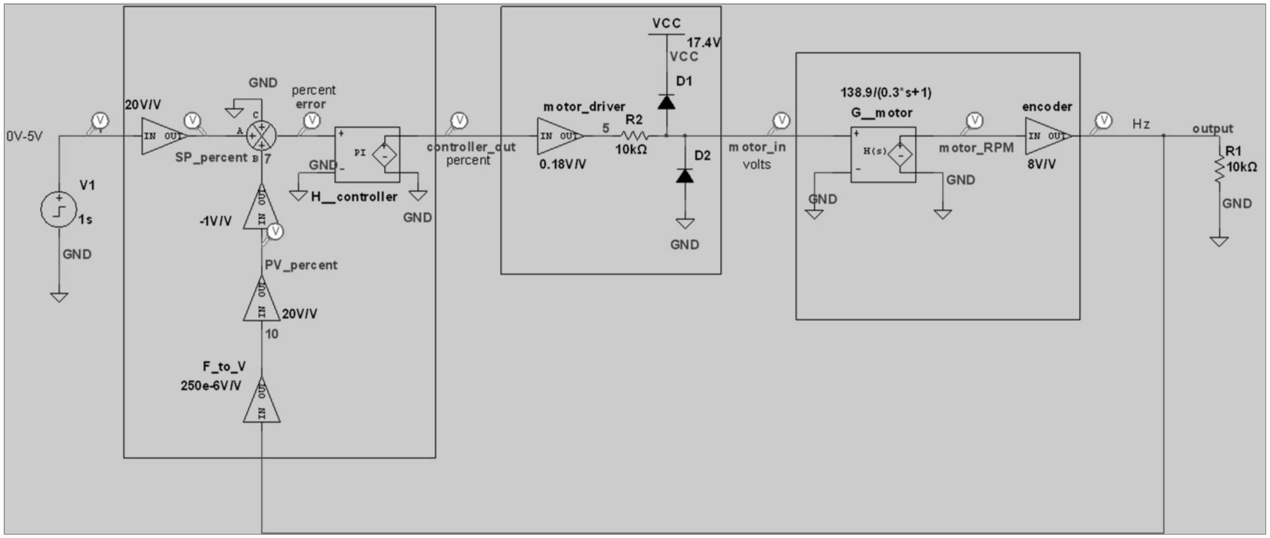
$$\frac{V_{out}}{SP} = \frac{GH}{1 + GH}$$

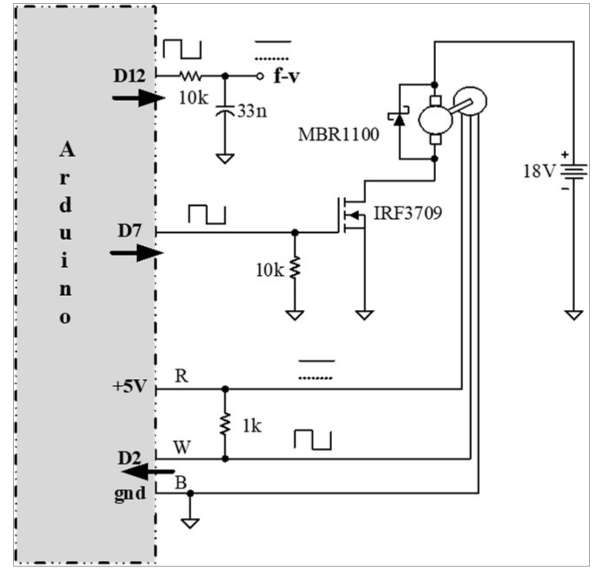
$$G = \frac{139}{0.3s + 1}$$

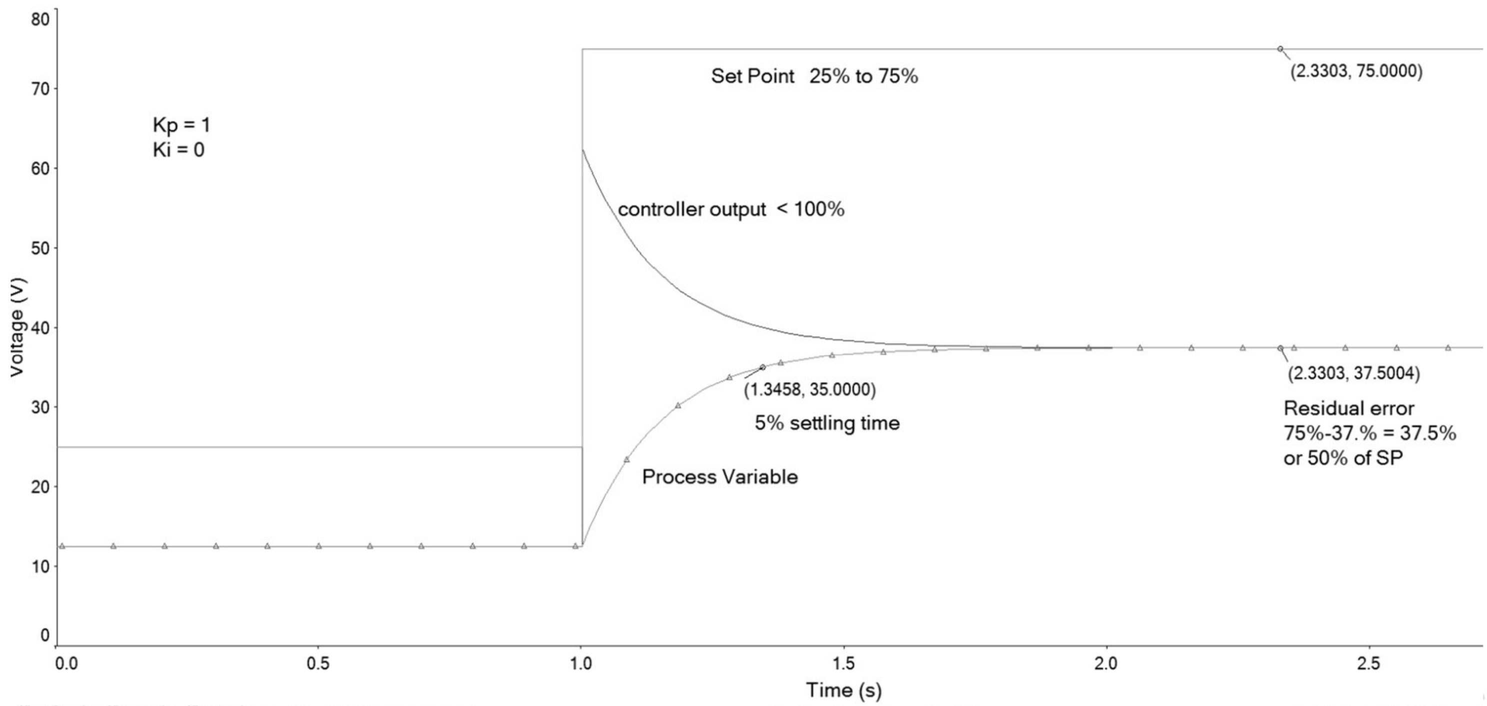
$$H = 1$$

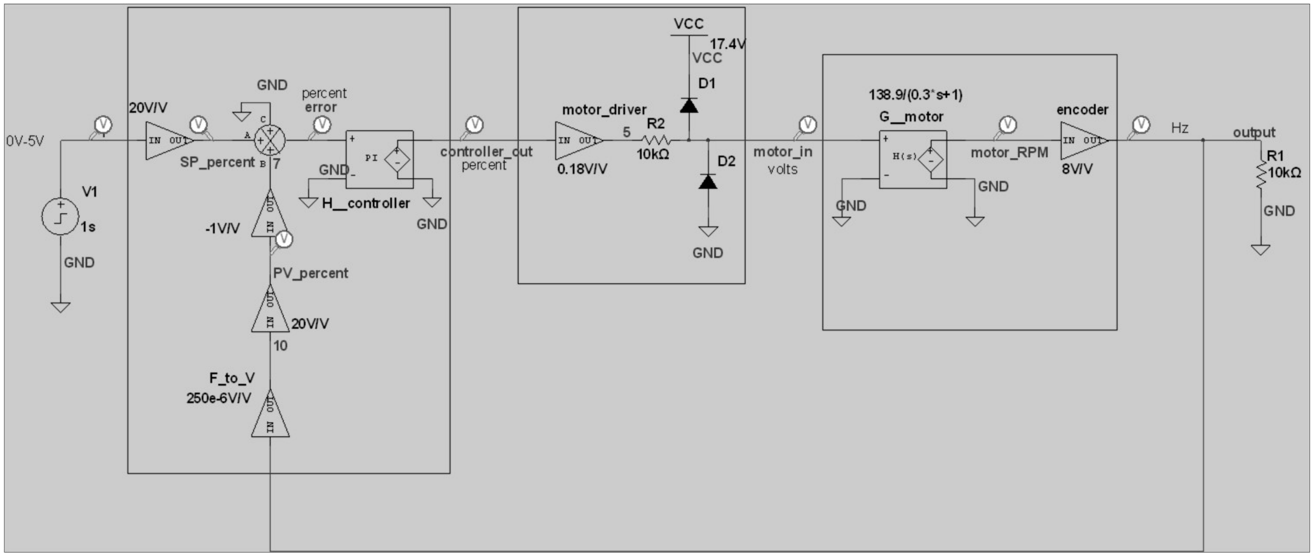
Proportional Controller – Calibration to % FS

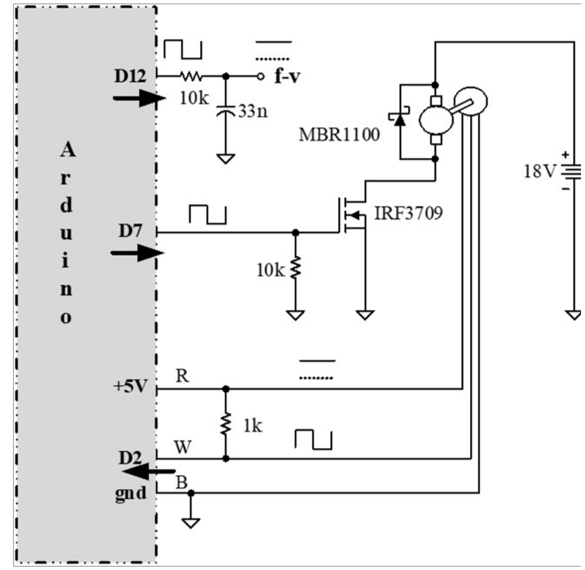


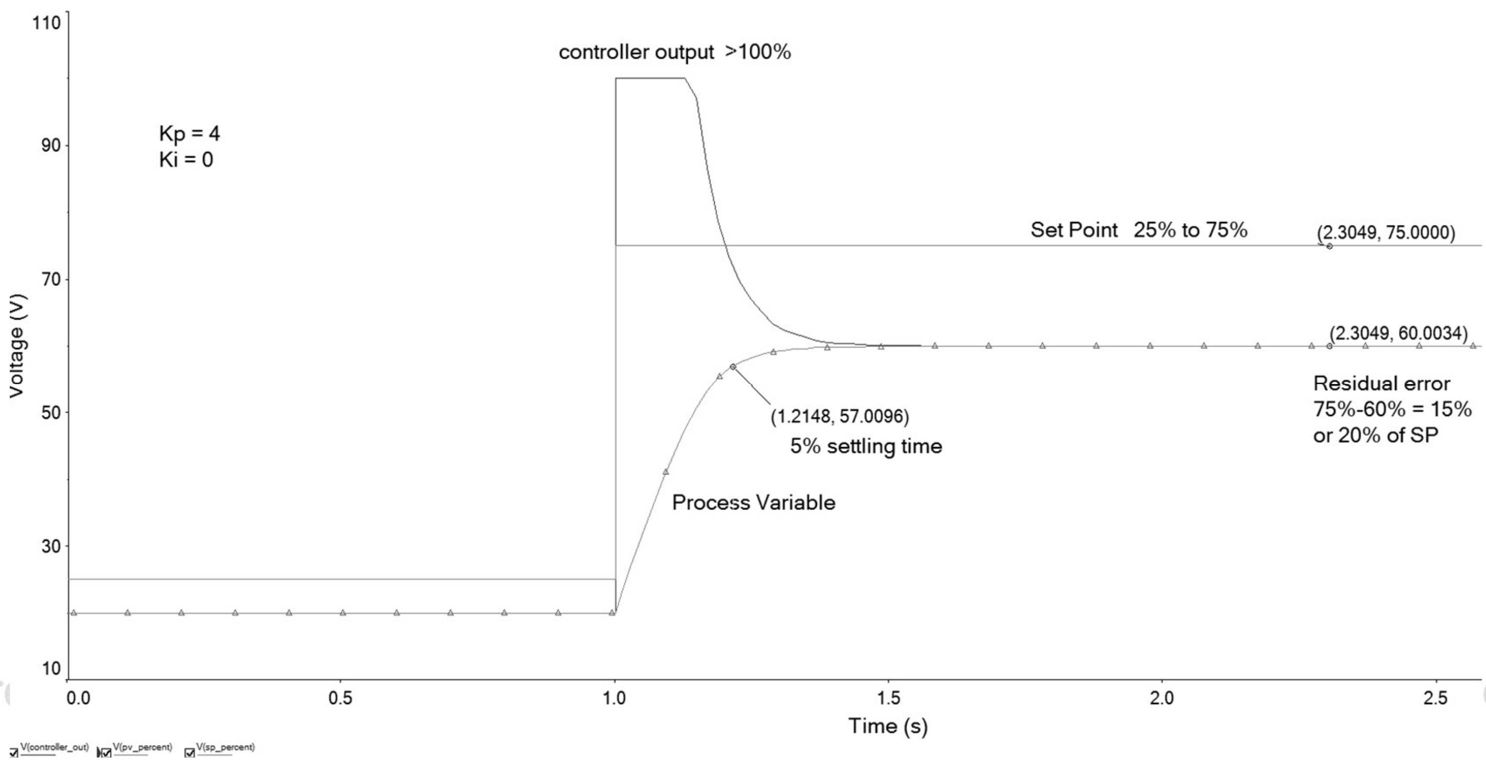

0V-5V
V1
1s
GND
20V/V
SP_percent
GND
percent error
H__controller
-1V/V
PV_percent
20V/V
10
F_to_V
250e-6V/V
controller_out percent
motor_driver
0.18V/V
5
R2
10kΩ
VCC
17.4V
D1
D2
motor_in volts
138.9/(0.3*s+1)
G__motor
motor_RPM
encoder
8V/V
Hz
output
R1
10kΩ
GND


Arduino
D12
10k
33n
f-v
D7
10k
IRF3709
MBR1100
18V
+5V
R
1k
W
D2
B
gnd

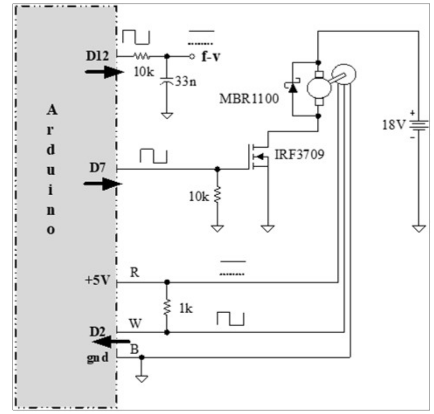

Set Point 25% to 75%
(2.3303, 75.0000)
Kp = 1
Ki = 0
controller output < 100%
(1.3458, 35.0000)
5% settling time
(2.3303, 37.5004)
Residual error
75%-37.% = 37.5%
or 50% of SP
Process Variable
Voltage (V)
Time (s)


0V-5V
V1
1s
GND
20V/V
SP_percent
GND
percent
error
GND_
H__controller
GND
-1V/V
PV_percent
20V/V
10
F_to_V
250e-6V/V
controller_out
percent
motor_driver
0.18V/V
5
R2
10kΩ
VCC
17.4V
VCC
D1
D2
GND
motor_in
volts
138.9/(0.3*s+1)
G__motor
GND
GND
motor_RPM
encoder
8V/V
Hz
output
R1
10kΩ
GND


Arduino
D12
10k
33n
f-v
MBR1100
18V
D7
IRF3709
10k
+5V
R
1k
W
D2
gnd
B


controller output >100%
Kp = 4
Ki = 0
Set Point 25% to 75%
(2.3049, 75.0000)
(2.3049, 60.0034)
(1.2148, 57.0096)
5% settling time
Residual error
75%-60% = 15%
or 20% of SP
Process Variable
Voltage (V)
Time (s)
V(controller_out)
V(pv_percent)
V(sp_percent)

Prop Motor Speed Control



$$H_{\mathrm{prop}} = k_{\mathrm{p}}$$

$$G = \frac{m}{\tau s + 1}$$

m is the *entire* open loop gain; from CO to PV, driver, motor, sensors, …

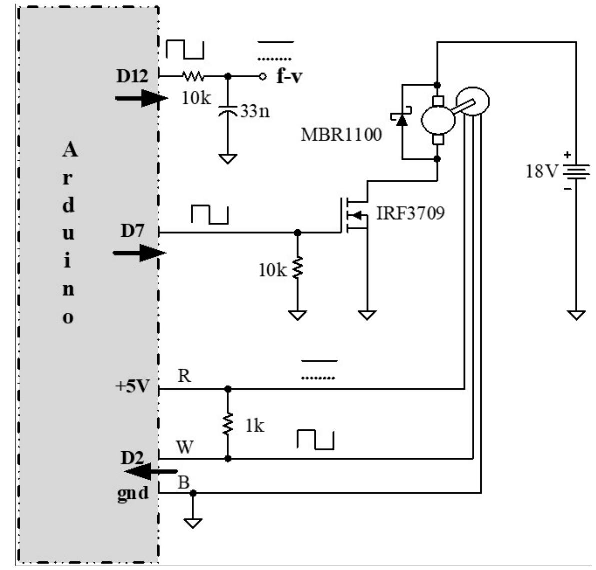
$$\frac{PV}{SP} = \frac{GH}{1 + GH}$$

$$G = \frac{PV}{SP} = \frac{GH}{1 + GH} = \frac{\frac{m}{\tau s + 1} \times k_{\mathrm{p}}}{1 + \frac{m}{\tau s + 1} \times k_{\mathrm{p}}}$$

$$\frac{PV}{SP} = \frac{\frac{mk_{\mathrm{p}}}{\tau s + 1}}{1 + \frac{mk_{\mathrm{p}}}{\tau s + 1}}$$

$$\frac{PV}{SP} = \frac{\frac{mk_{\mathrm{p}}}{\tau s + 1}}{\frac{\tau s + 1}{\tau s + 1} + \frac{mk_{\mathrm{p}}}{\tau s + 1}} = \frac{\frac{mk_{\mathrm{p}}}{\tau s + 1}}{\frac{\tau s + 1 + mk_{\mathrm{p}}}{\tau s + 1}}$$

$$\frac{PV}{SP} = \frac{mk_\mathrm{p}}{\tau s + 1 + mk_\mathrm{p}}$$



$$\frac{PV}{SP} = \frac{mk_\mathrm{p}}{\tau s + \left(mk_\mathrm{p} + 1\right)}$$

$$\frac{PV}{SP} = \frac{\dfrac{mk_\mathrm{p}}{mk_\mathrm{p} + 1}}{\dfrac{\tau}{mk_\mathrm{p} + 1} s + 1} = \frac{A_\mathrm{prop}}{\tau_\mathrm{prop} s + 1}$$

Closed loop
Proportional

$$G = \frac{m}{\tau s + 1}$$

Motor alone

$$A_\mathrm{prop} = \frac{mk_\mathrm{p}}{mk_\mathrm{p} + 1} \leq 1$$

$$\tau_\mathrm{prop} = \frac{\tau}{mk_\mathrm{p}+1} < \tau$$

When scaling in %
$e_\text{in motor}$ = 100%
$\text{RPM}_\text{out motor}$ = 100%

m = 1

$$A_{\mathrm{prop}} = \frac{mk_{\mathrm{p}}}{mk_{\mathrm{p}} + 1} \leq 1$$

$$\tau_{\mathrm{prop}} = \frac{\tau}{mk_{\mathrm{p}}+1} < \tau$$

What k_{p} is best?