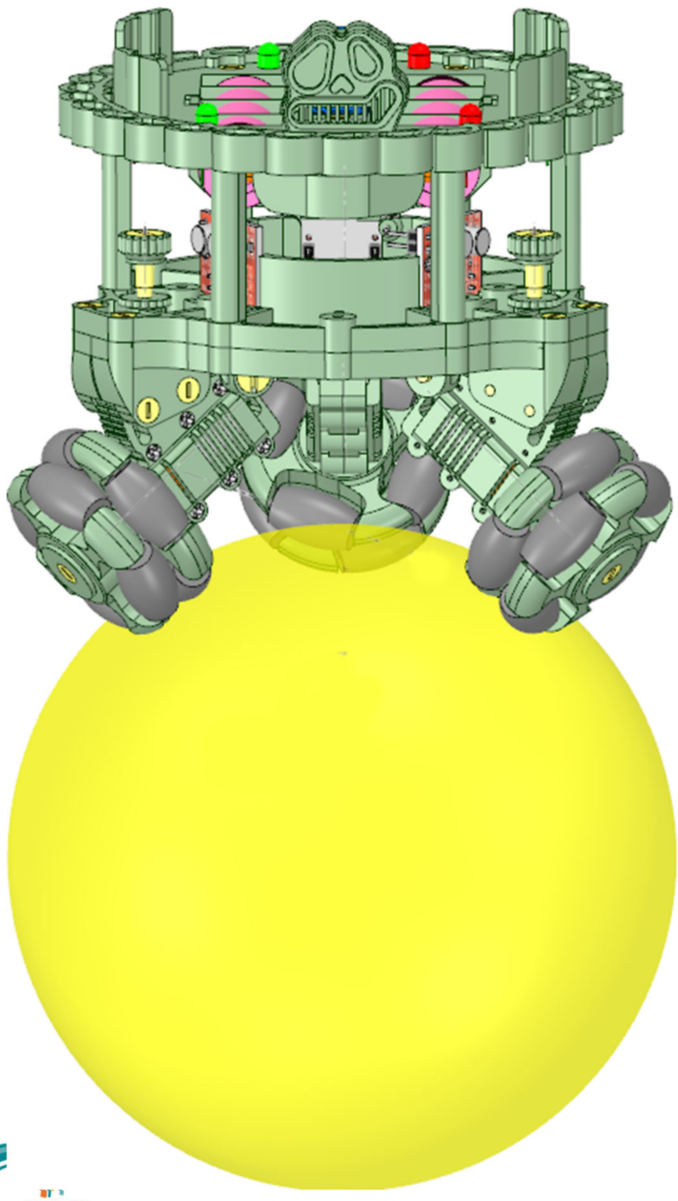
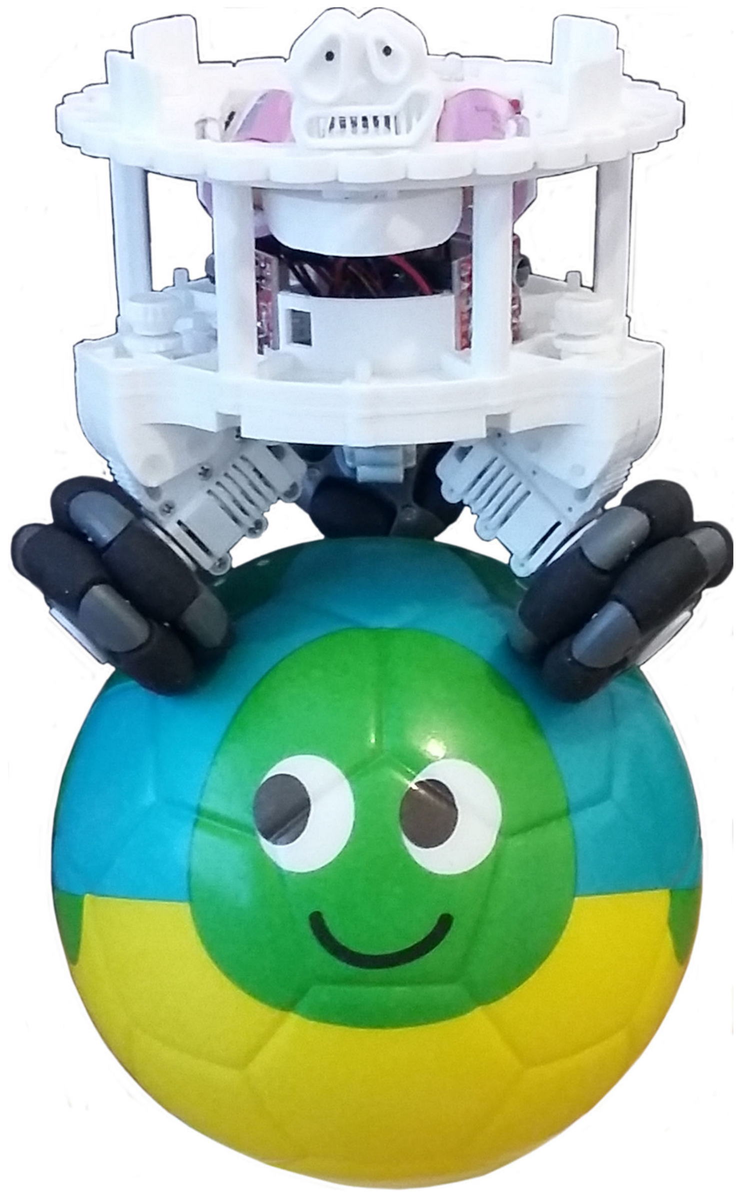
Ball Balancing Robot

Calibration

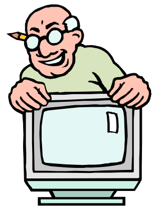




ARDUINO OPEN-SOURCE COMMUNITY

Issue: 1.1 Released: 08/12/2025 TechKnowTone

CAUTION



Lithium batteries can be extremely dangerous, if not handled and cared for properly. This design does not include any form of current limiting circuit, like a fuse. So, care must be taken to ensure that the wiring guidelines are followed accurately, that checks are made for short-circuits, and that battery polarities are marked, and they are inserted the correct way round. Failure to do so, could result in an explosive fire.

Charging Practices: Always remove batteries from your project to charge them. Use a charger, designed for the battery used, and from a trusted supplier. Choose a flat, non-flammable surface to charge on, away from flammable materials. Never leave unattended when charging. Don’t charge overnight. Monitor charging to ensure charge characteristics are as expected. Only pair batteries with similar characteristics. Do not overcharge, or leave charging for prolonged periods. This increases the risk of damage and fire.

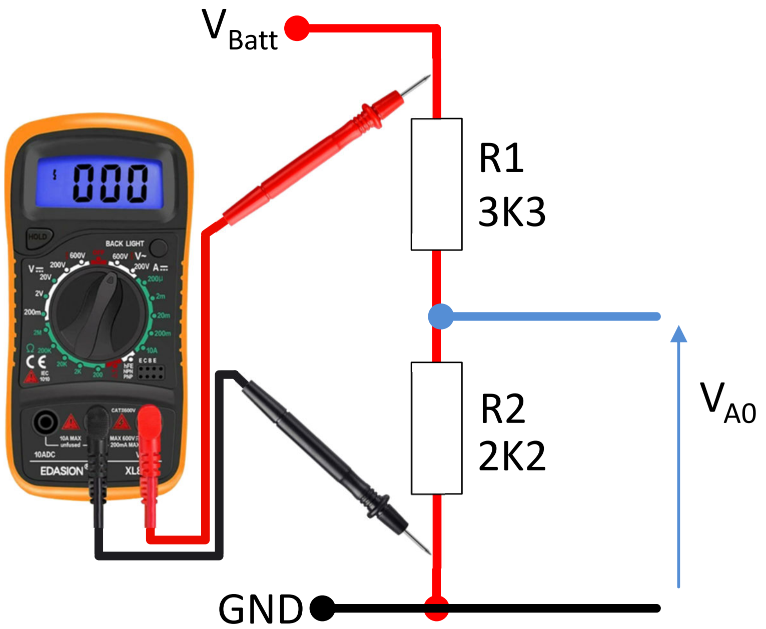
Battery care & maintenance: Stop using a battery if it is swollen, damaged, dented or leaking. Never charge a damaged battery. Never allow a Lithium battery to discharge below 3.2 volts, as cell damage will occur. Avoid extreme temperatures. Do not charge or store batteries in very hot or cold environments. Don’t cover batteries whilst charging, as this can trap heat, causing overheating.

In case of fire: Get out and stay out. If a fire starts, leave immediately, and call the fire brigade. For low voltage Lithium batteries, water is a safe extinguisher.

Built-in Monitoring: Most of my project designs include code, and circuitry, to monitor battery voltage, whilst in use. This code then seeks to alert the operator, when the battery has reached a critical low voltage, before shutting down power consuming circuitry; including the micro. Time should therefore be spent on calibrating this feature, as a precaution, for good battery management and maintenance.

Carefully dispose of batteries that damaged, or discharged below their critical voltage.

Battery Monitor (Protection)



$$V_{A0} = \frac{V_{Batt} \times R2}{R1 + R2}$$

$$V_{A0D} = \frac{V_{A0} \times 1023}{5}$$ voltage read by 10-bit ADC

$$V_{A0} = \frac{V_{Batt} \times 2K2}{5K5}$$

$$V_{A0D} = \frac{V_{Batt} \times 0.4 \times 1023}{5}$$

$V_{FSD} = 12.5v$ @ $V_{A0} = 5$

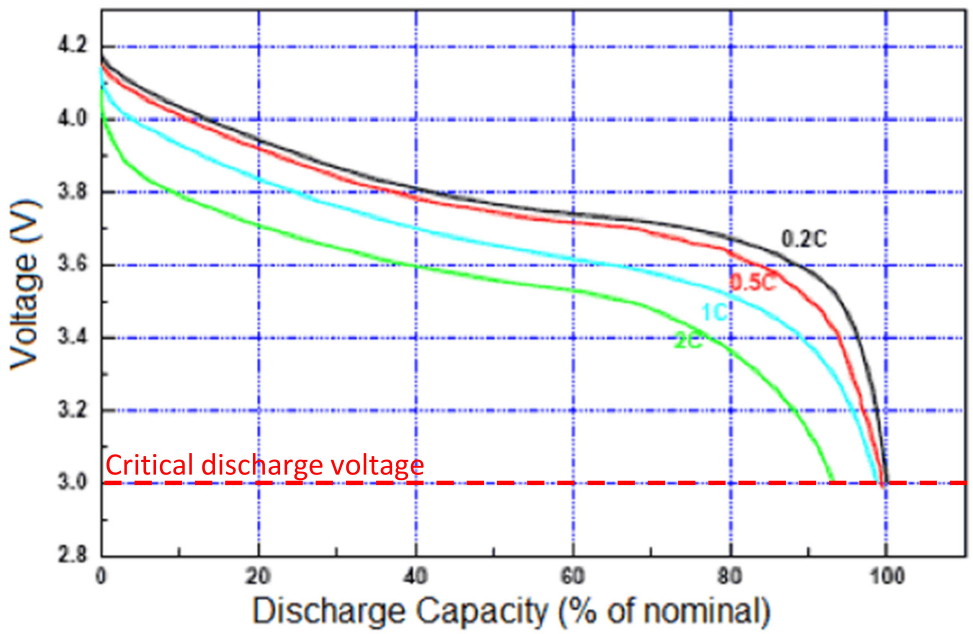
Two cells in series gives a nominal 7.4v constant discharge voltage. To prevent damage, stop using once the following conditions are reached:

3.60 + 3.00 = 6.60v (one battery fades early)
3.30 + 3.30 = 6.60v (both batteries fade together)

Hence $V_{A0D} = 540$ @ $V_{Batt} = 6.60v$

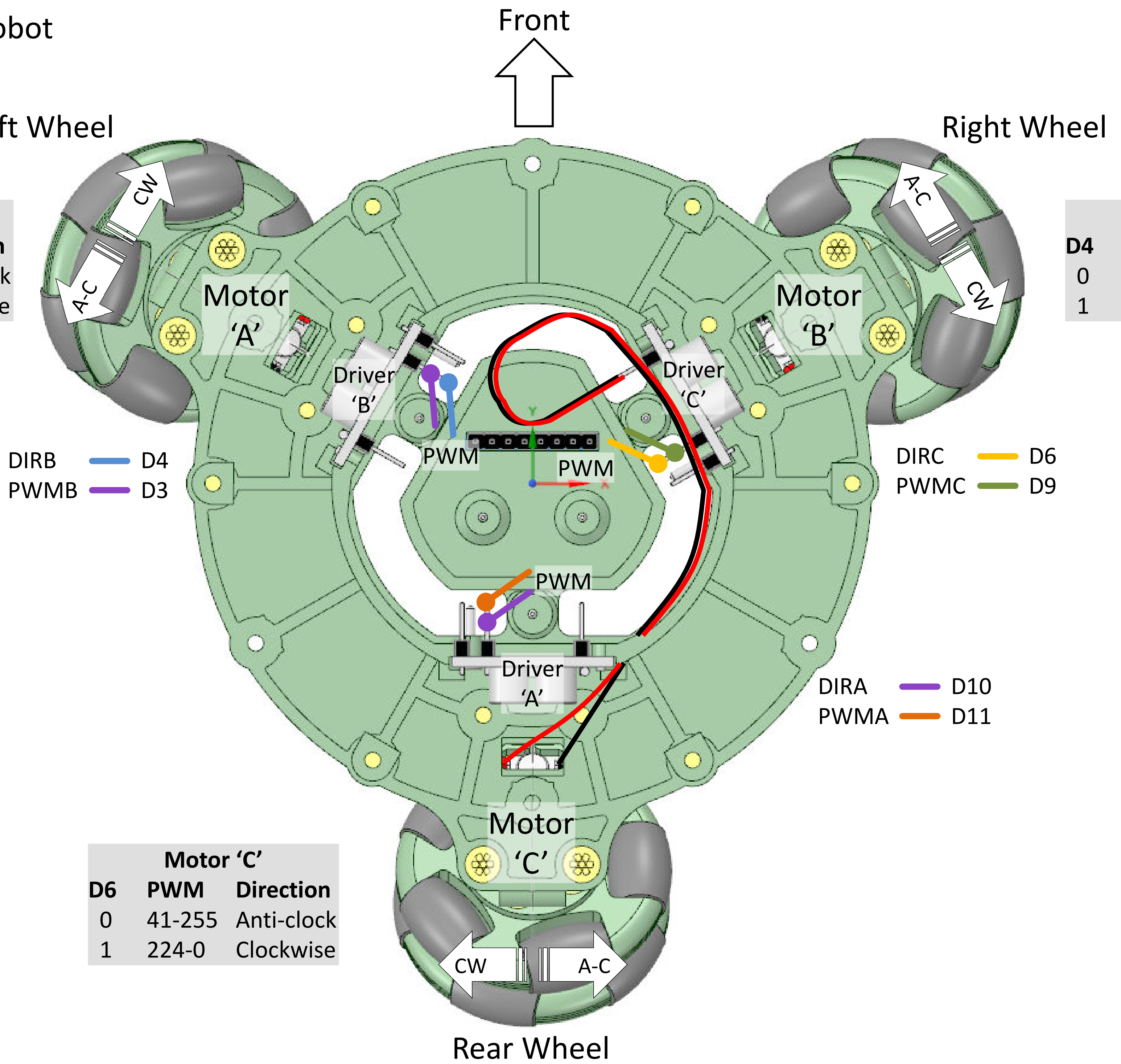
The code will shut down when the value drops to 540.

18650 Lithium Battery
Discharge Profile



Discharge: 3.0V cutoff at room temperature.

Ball Balancing Robot
Motor Cal.



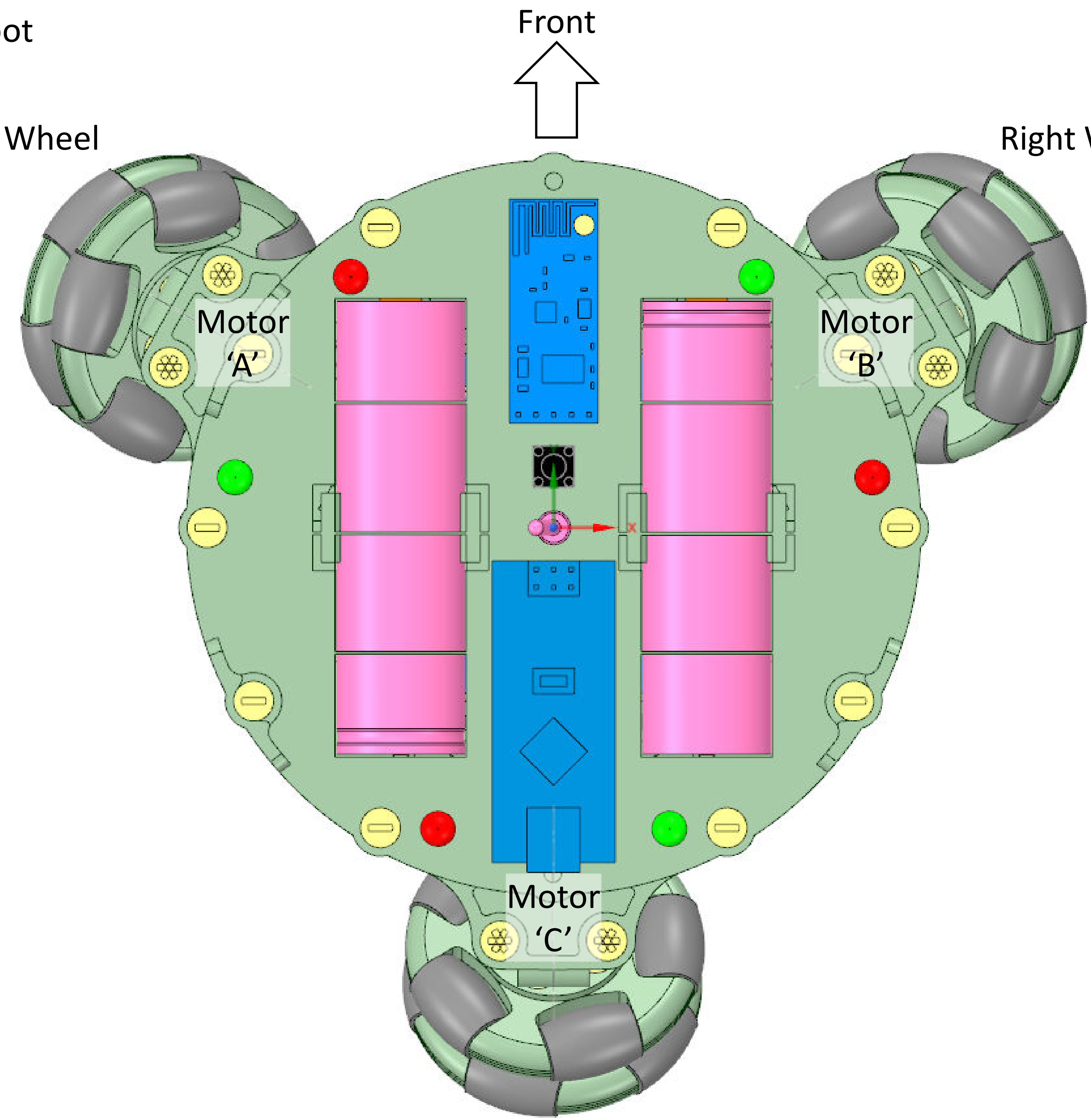
Motor 'A'		
D10	**PWM**	**Direction**
0	49-255	Anti-clock
1	223-0	Clockwise

Motor 'B'		
D4	**PWM**	**Direction**
0	36-255	Anti-clock
1	233-0	Clockwise

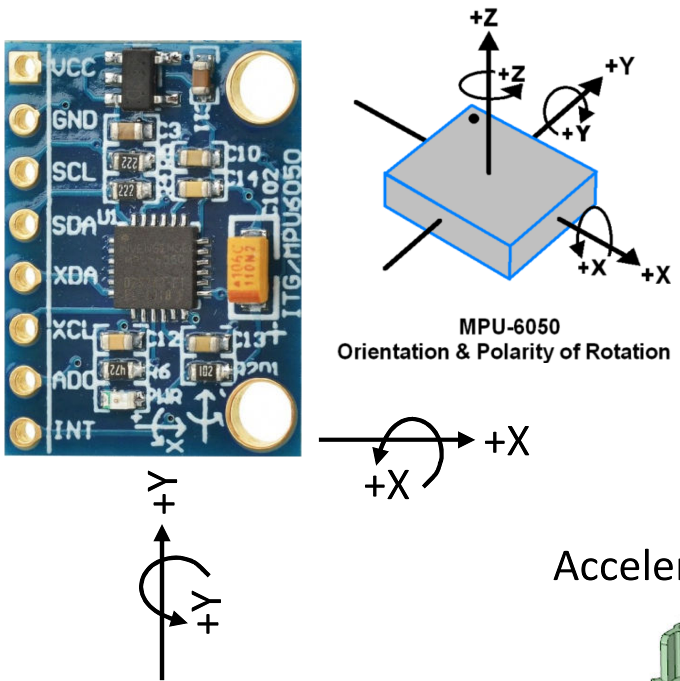
Motor 'C'		
D6	**PWM**	**Direction**
0	41-255	Anti-clock
1	224-0	Clockwise

Issue: 1.1 Released: 08/12/2025 TechKnowTone

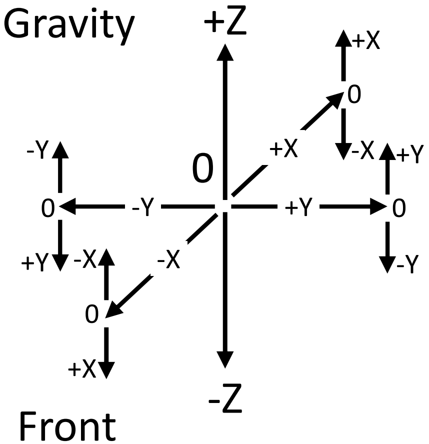
Ball Balancing Robot
Hips Cal.

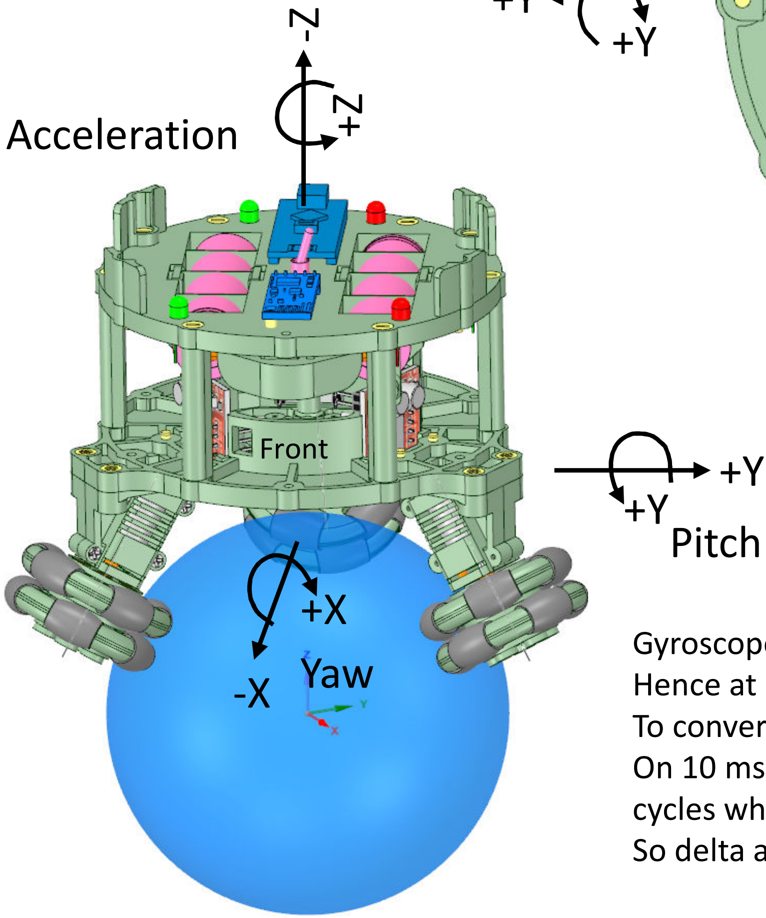


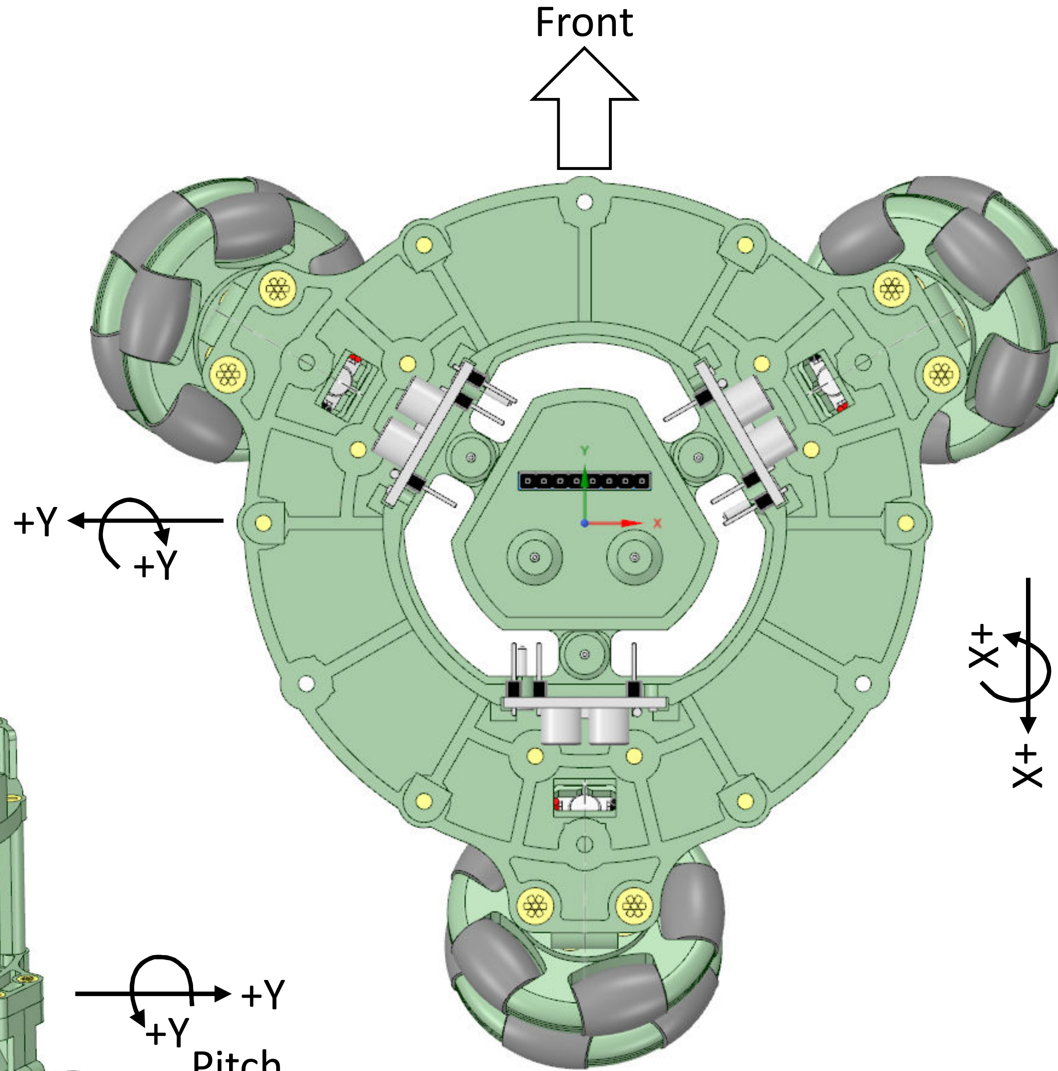
MPU-6050 Orientation



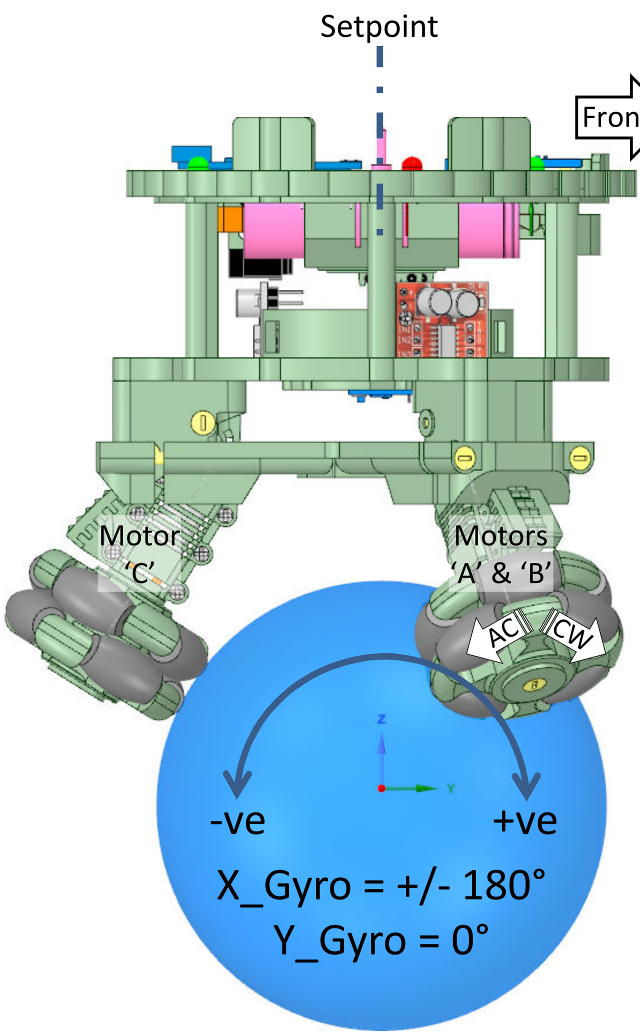
MPU-6050
Orientation & Polarity of Rotation

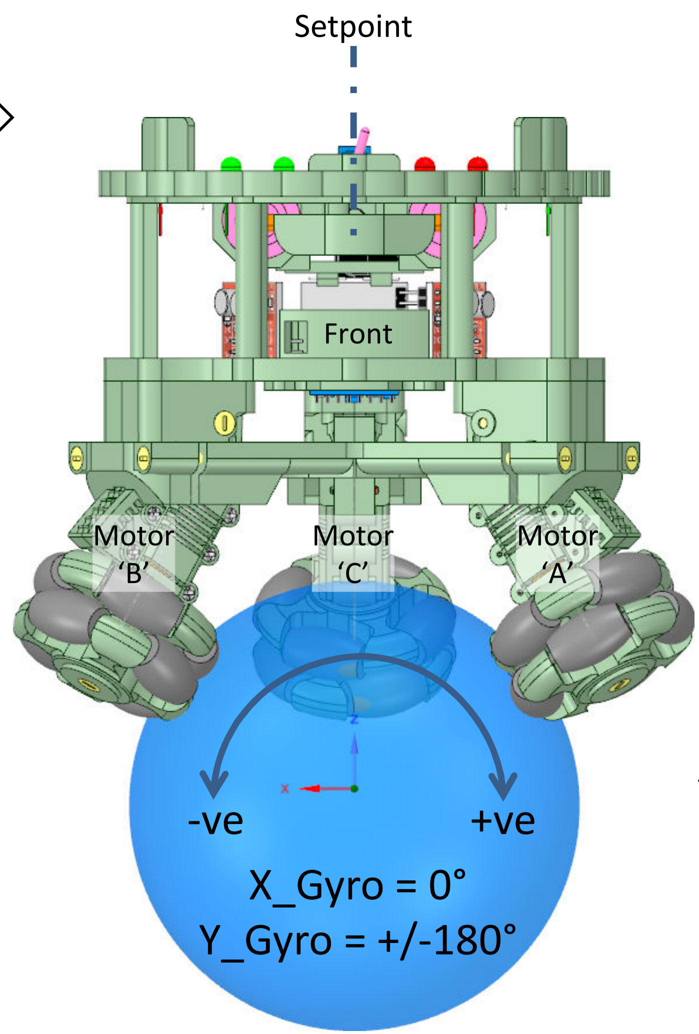


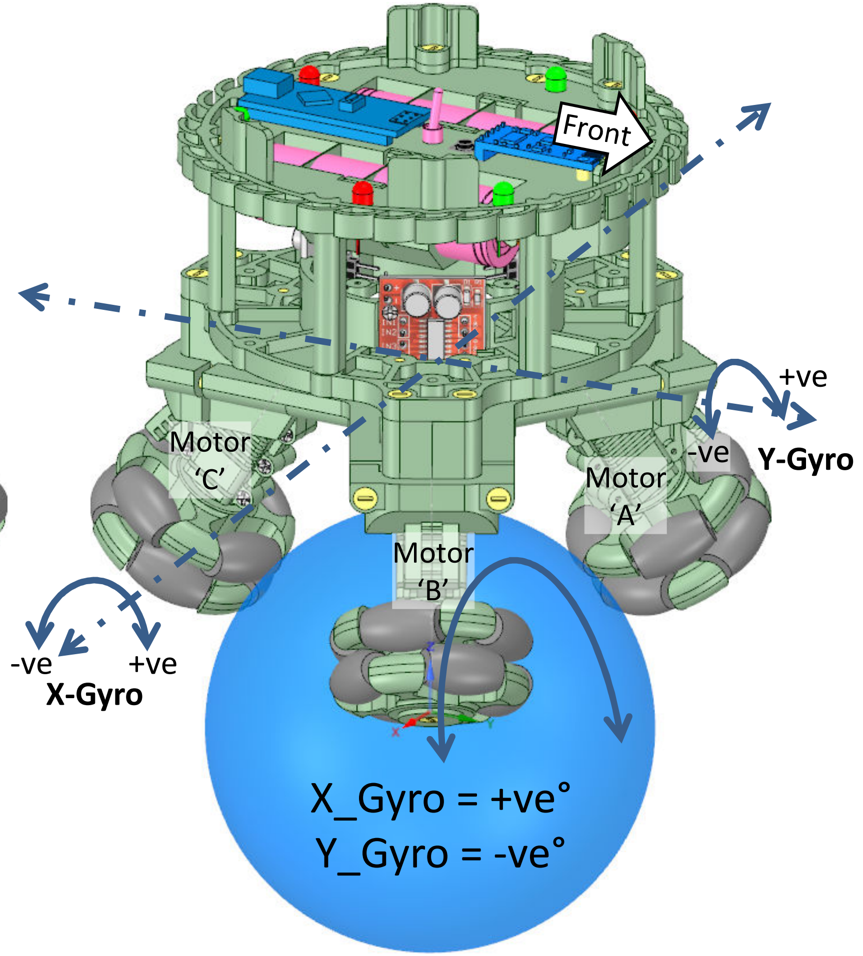


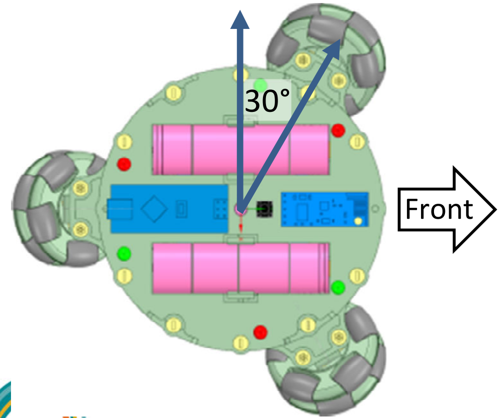


Gyroscopes are set at +/-250 °/sec FSD.
Hence at 32,767 FSD; rotation of 1 °/sec = 131.
To convert this to a gyro angle we use the time between readings.
On 10 ms cycle we would accumulate a count of 1310 over a 100 cycles when rotating at 1 °/sec.
So delta angle per 10ms cycle = gyro rate * 0.00007633









Gyro X & Y angles to Motor clockwise drive relationships:

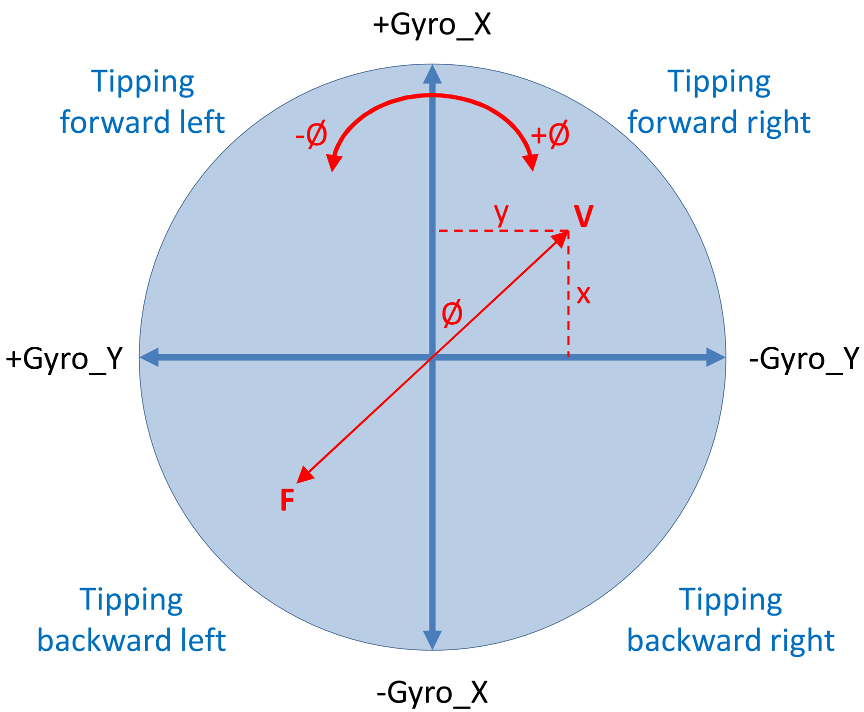
Motor A^{CW} = -(X_Gyro * sin(30°)) + (Y_Gyro * sin(60°)) = -X_Gyro*0.5 + Y_Gyro *0.86603

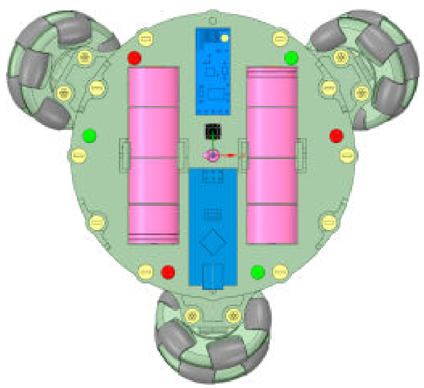
Motor B^{CW} = (X_Gyro * sin(30°)) + (Y_Gyro * sin(60°)) = X_Gyro*0.5 + Y_Gyro *0.86603

Motor C^{CW} = Y_Gyro

Note: here we are calling the Pitch gyro X_Gyro and Yaw gyro Y_Gyro to be consistent with the accelerometer values, which are used in the code for gyro drift correction.

Movement angles and vectors





If +X & -Y then: $\varnothing^{0 \text{ to } +90} = 57.2958 * \tan^{-1}(y/x)$

If +X & +Y then: $\varnothing^{0 \text{ to } -90} = 57.2958 * \tan^{-1}(y/x)$

If -X & -Y then: $\varnothing^{90 \text{ to } +180} = 180° - (57.2958 * \tan^{-1}(y/x))$

If -X & +Y then: $\varnothing^{90 \text{ to } -180} = -180° + (57.2958 * \tan^{-1}(y/x))$

Tilt V = sqrt(sq(x) + sq(y)) V is always +ve

Driving force vector F == PID(-V)

F needs to drive in opposite direction to V, so

If +X & -Y then: $\varnothing^{90 \text{ to } -180} = -180° + (57.2958 * \tan^{-1}(y/x))$

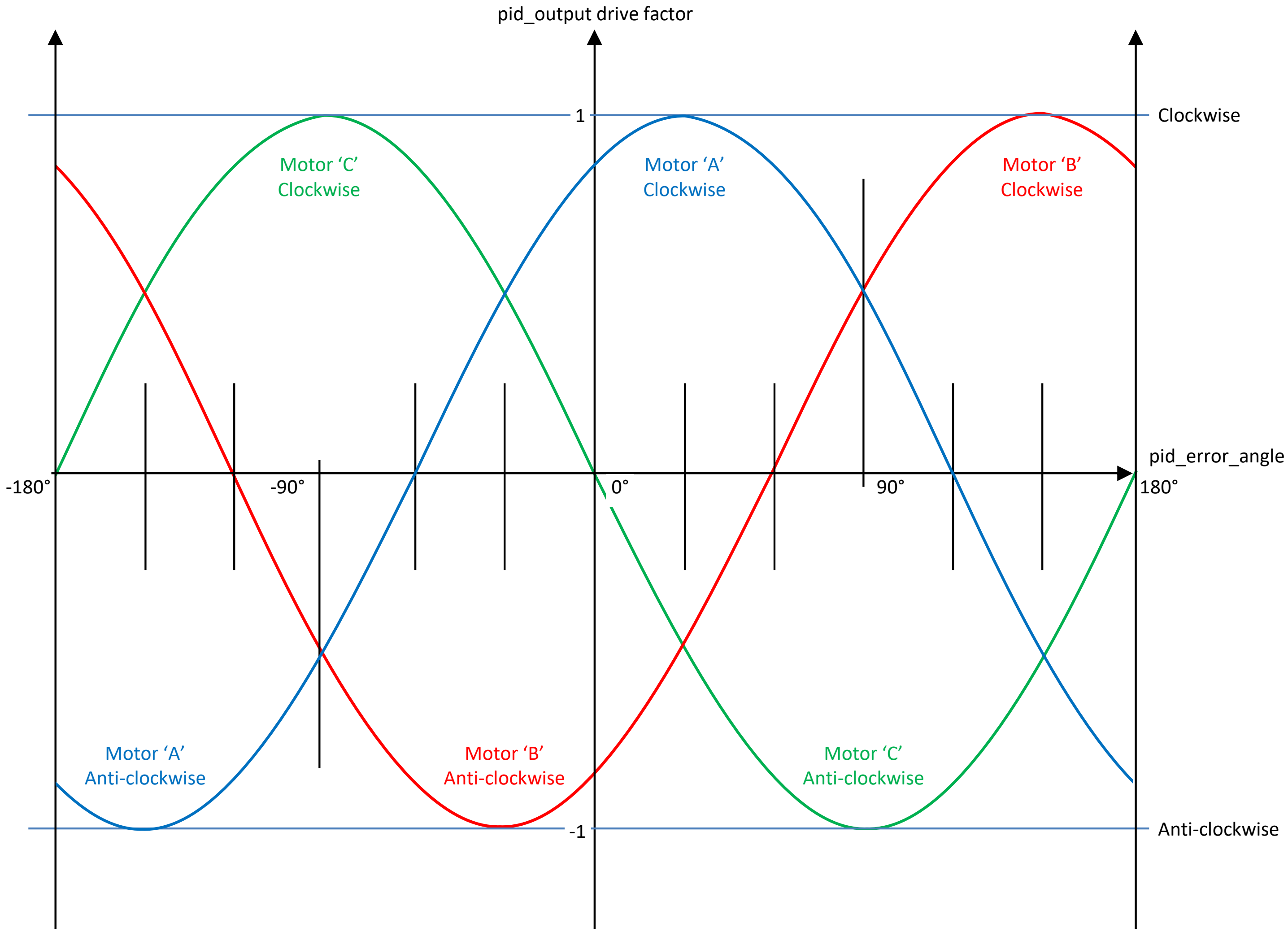
If +X & +Y then: $\varnothing^{90 \text{ to } +180} = 180° - (57.2958 * \tan^{-1}(y/x))$

If -X & -Y then: $\varnothing^{0 \text{ to } -90} = -(57.2958 * \tan^{-1}(y/x))$

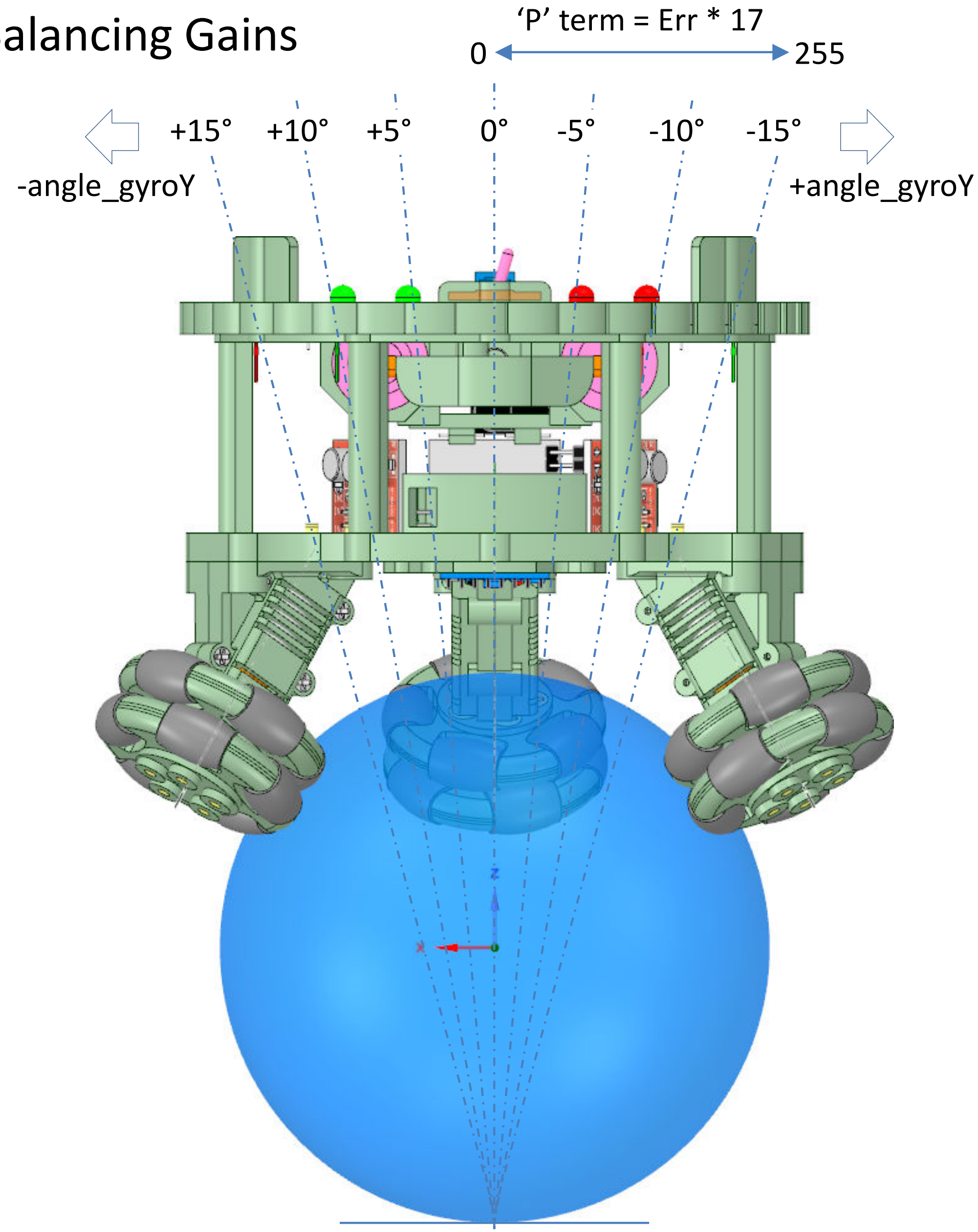
If -X & +Y then: $\varnothing^{0 \text{ to } +90} = -(57.2958 * \tan^{-1}(y/x))$

Where 1 radian = 57.2958 degrees

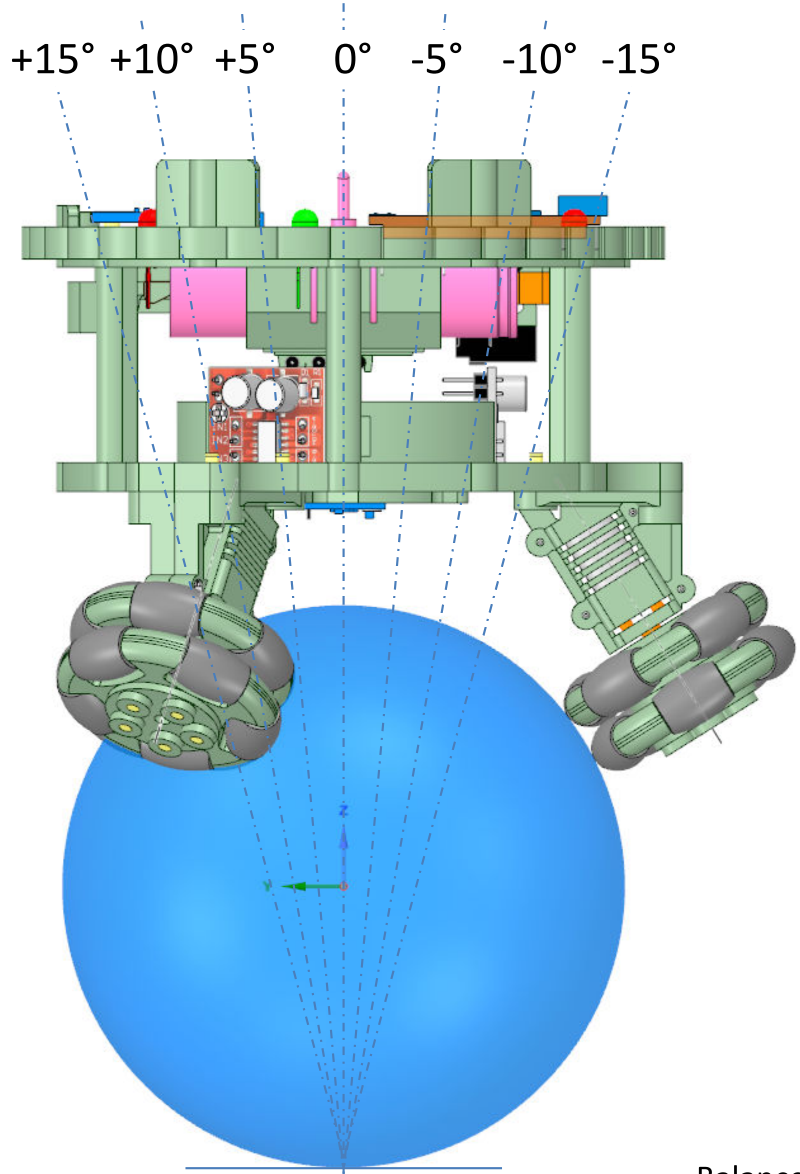
Motor drive factors v error angle



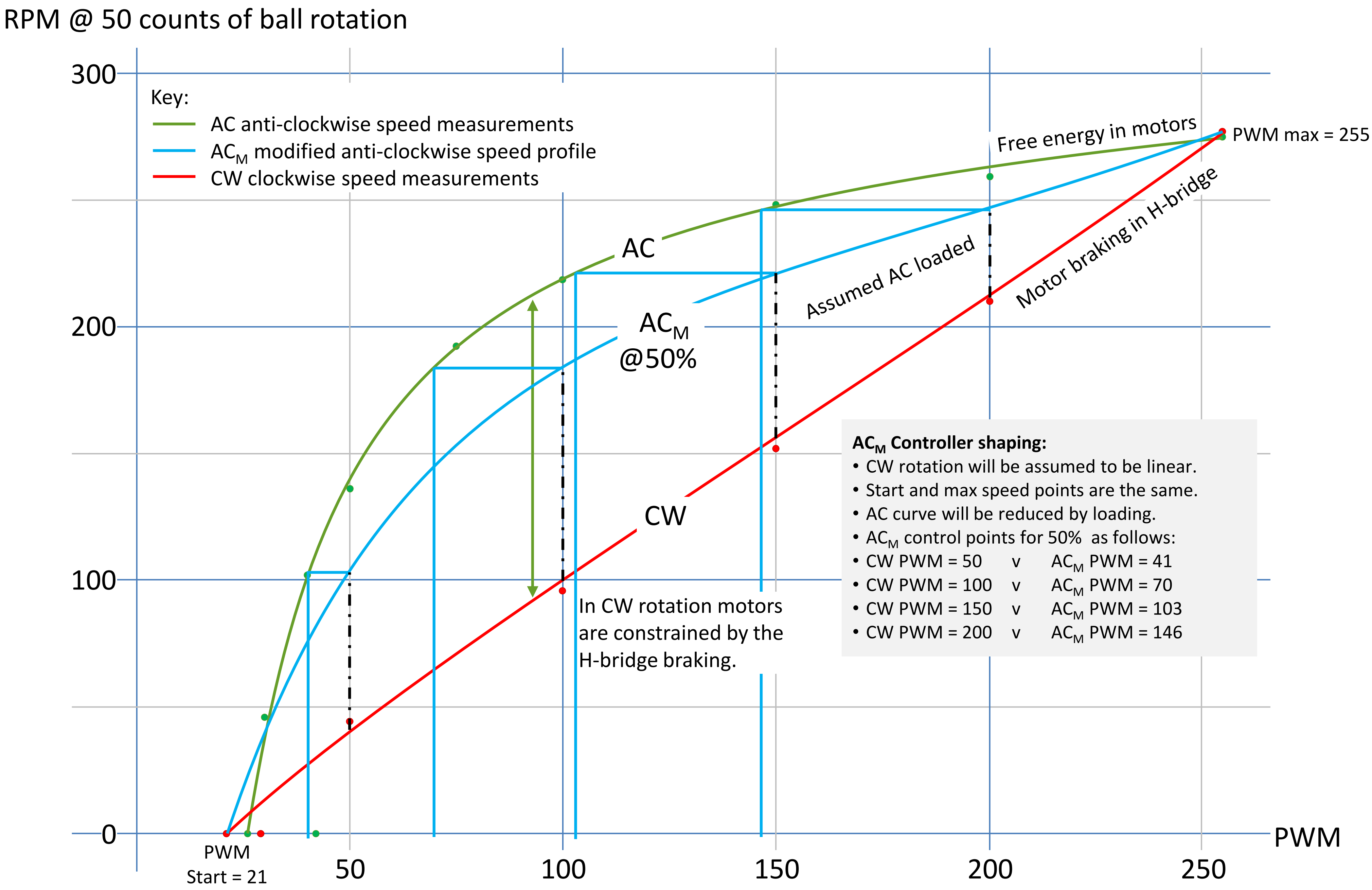
Balancing Gains



pid_outputX = pid_p_gain * pid_error_tempX

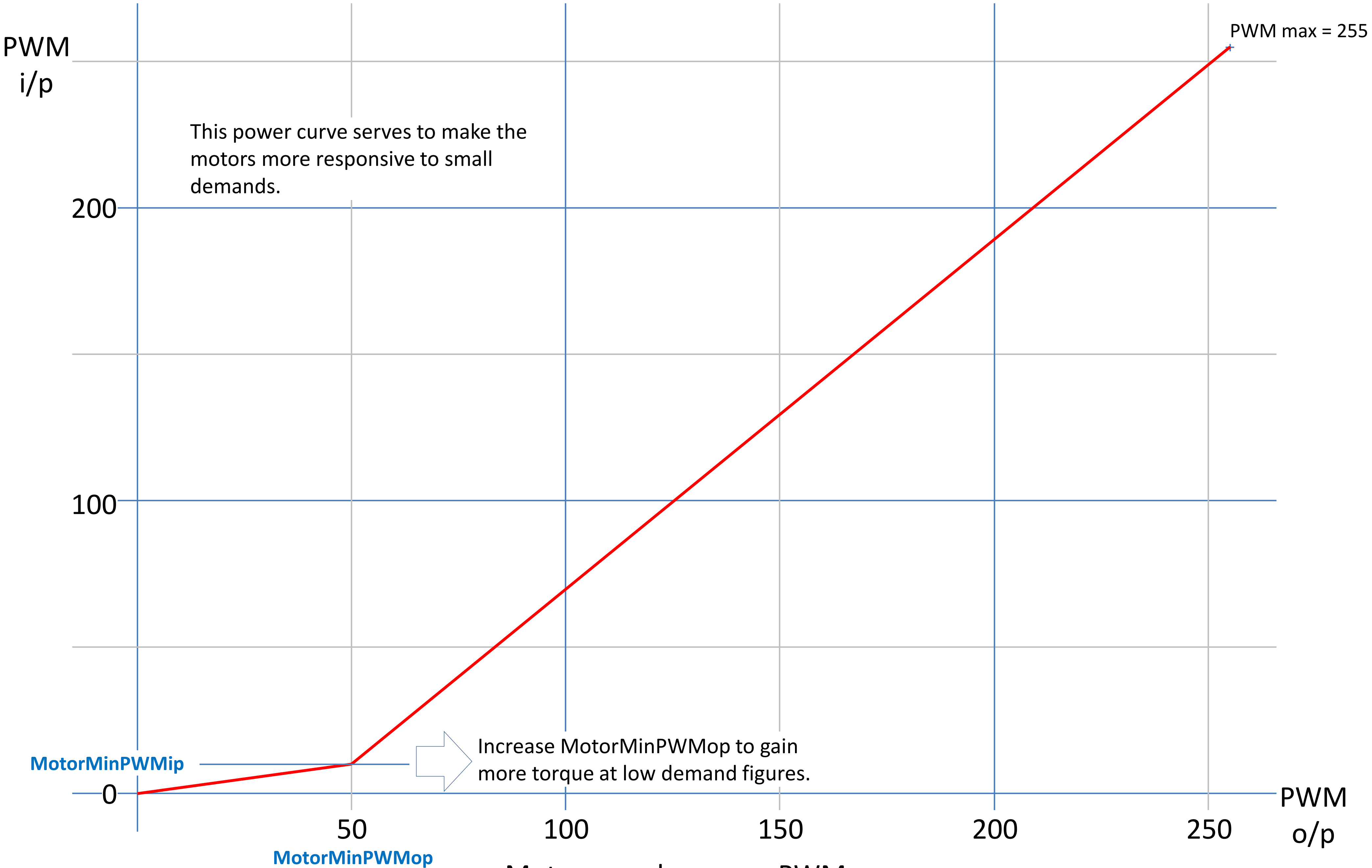


BalanceBot Gains:
pid_p_gain = 8.0
pid_i_gain = 0.5
pid_d_gain = 5.0



Motor speed curves v PWM

Motor PWM Demand v Power chart



Motor speed curves v PWM