Digital Servo Amplifier Basics

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mcma
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Digital Servo Amplifier Basics

Servo Basics
1. What is a Servo?
2. Input Command
3. Amplifier Operation

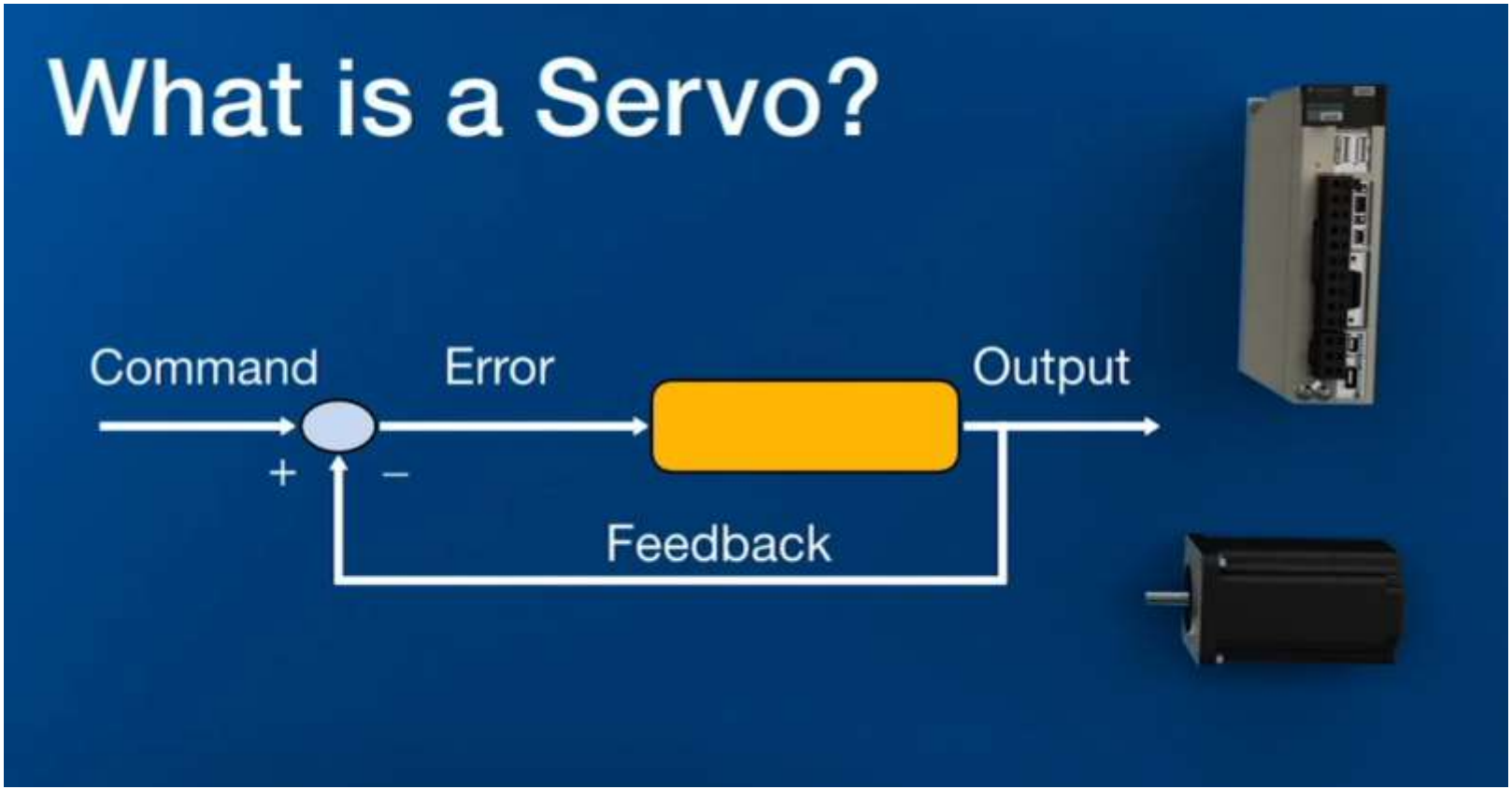
Digital Control Loops
1. Function
2. Examples
3. Types
4. Bandwidth
5. Tuning Process
6. Tuning Filters

Amplifier Power
1. Input Types
2. Regeneration
3. DC Bus Sharing

Installation Infrastructure
1. Input Power
2. Noise Filter
3. EMI
4. Heat Loads

Servo Basics – What is a Servo?

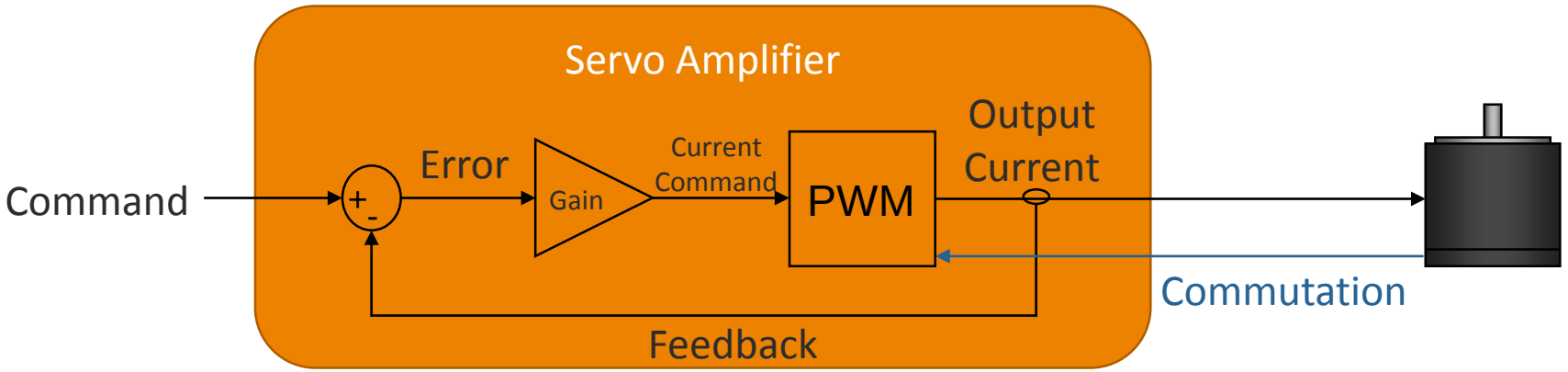
- Servo: a device that produces motion in response to a command, regulating the output based on feedback



Source: Yaskawa America Inc. YouTube video “Servo Basic Concepts” eLV.ServoMotion.01.BasicConcepts

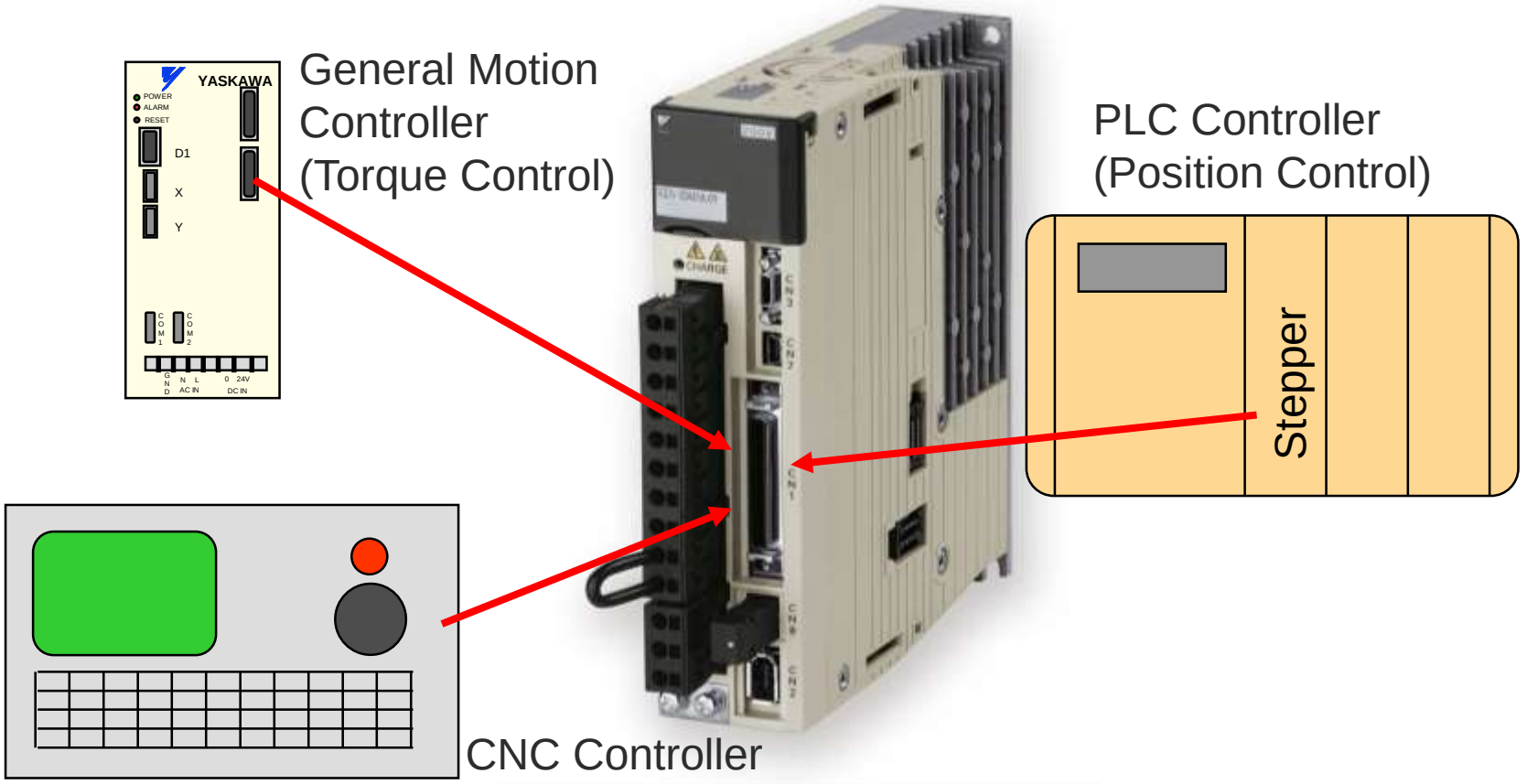
Servo Basics – What is a Servo?

- The “servo” is both the servomotor and servo amplifier
- Servo Amplifier: A device which controls the torque, speed and/or the position of a motor
  - by comparing command and feedback signals
  - and making corrections to the command to eliminate the error
- Servo = Amplifier = Amp = Drive



Servo Basics – Input Command

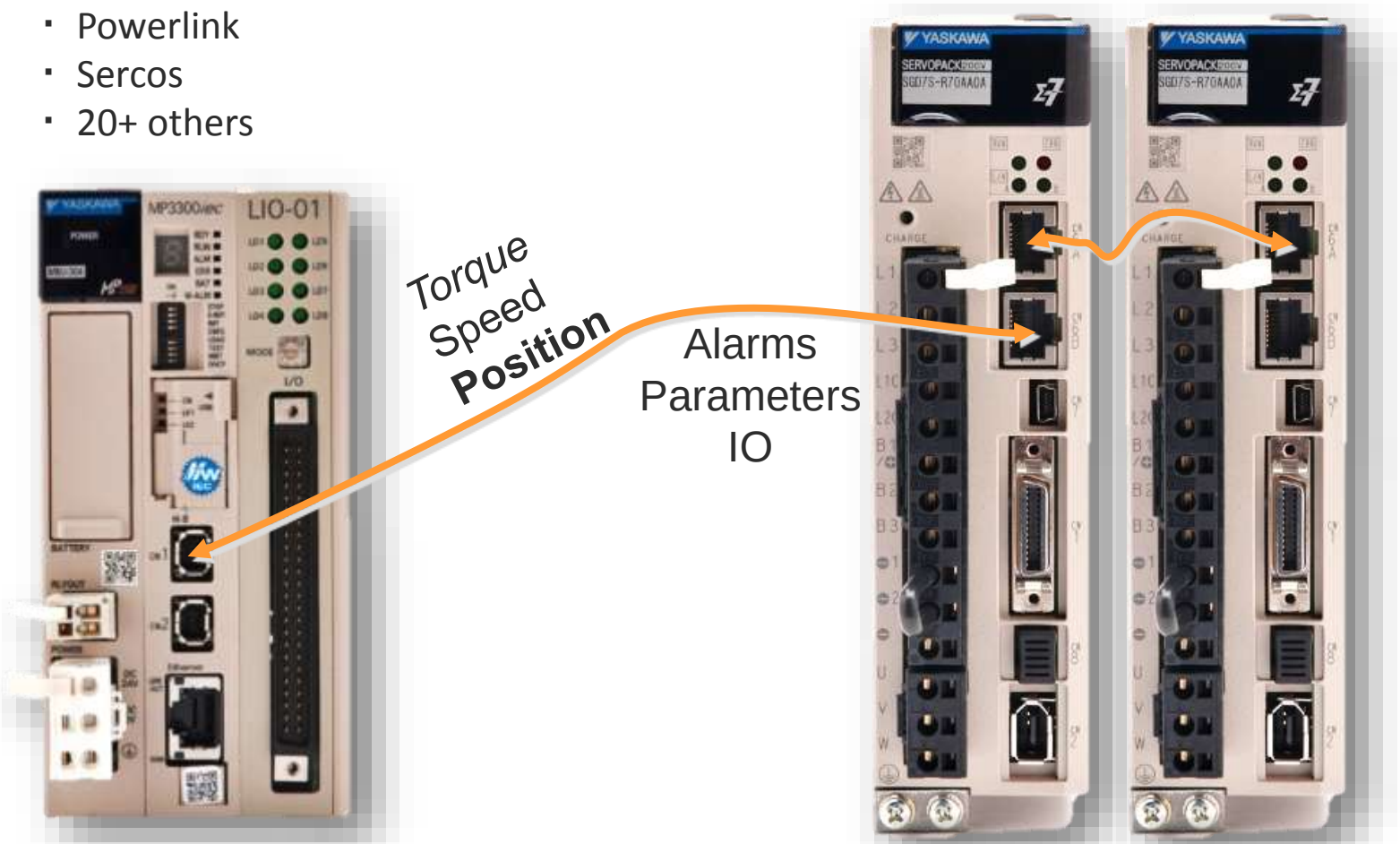
- Servos interface with a variety of host controllers, including motion controllers, CNC's, indexers, and PLC's
- Host controller signal – low voltage (±10v typical) analog or pulses



Servo Basics – Input Command

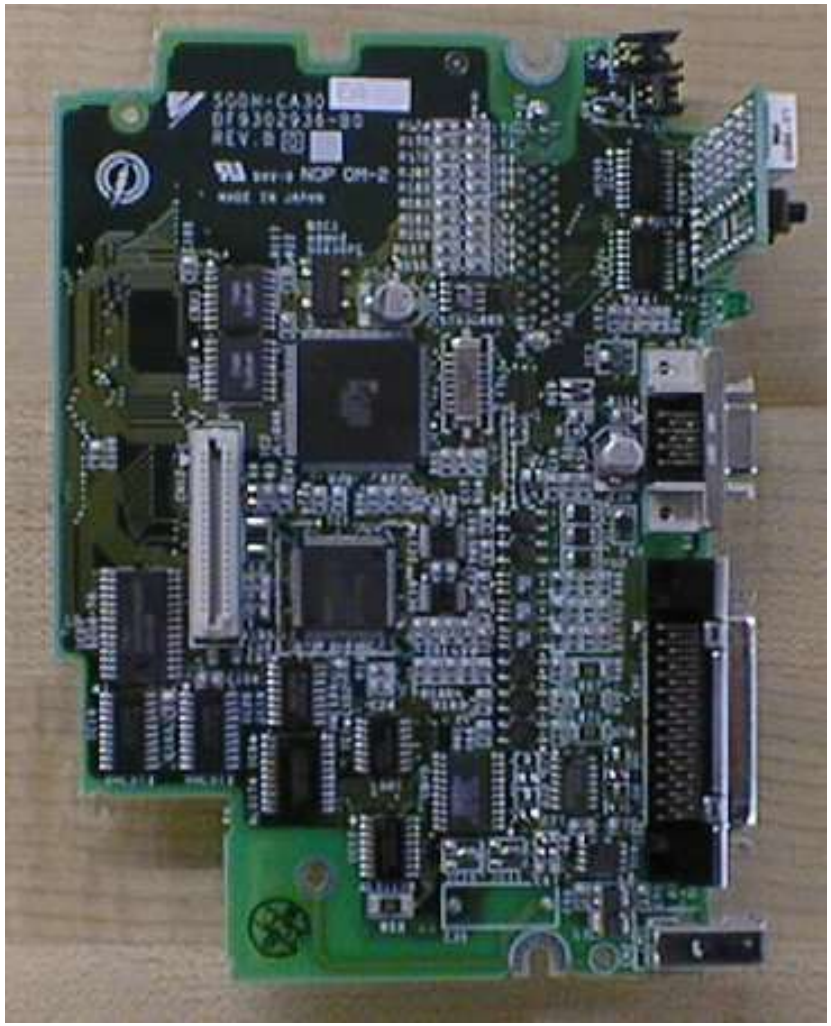
- Fieldbus Networks Common to Servos
  - Mechatrolink
  - EtherCAT
  - Profinet
  - Powerlink
  - Sercos
  - 20+ others

- Fieldbus Advantages
  - Simplified wiring
  - Data transfer between amplifier and controller



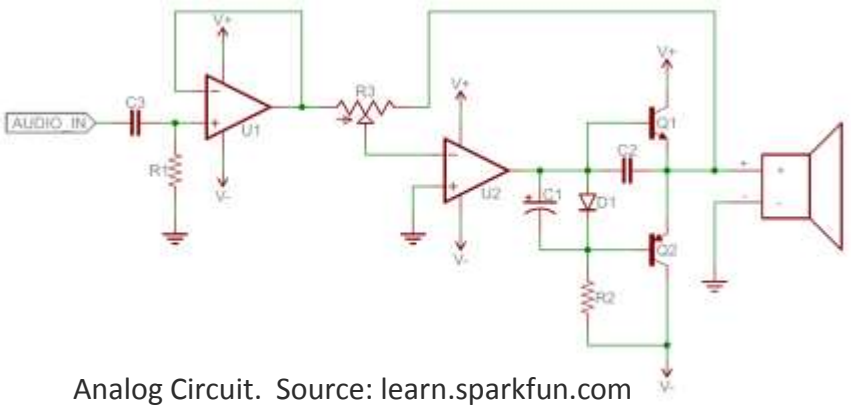
Servo Basics – Amplifier Operation

- Control Circuit
  - Performs the “thinking” functions of the amplifier
  - Interface to motion controller
    - Inputs: Digital, analog, encoder
    - Outputs: Digital, analog, pulse
  - Closes control loops
    - Key Performance Indicator: velocity loop frequency response, range from 250Hz to 3200Hz
  - Control circuit may be very complex with many features, or may be a very simple “Dumb Amp”

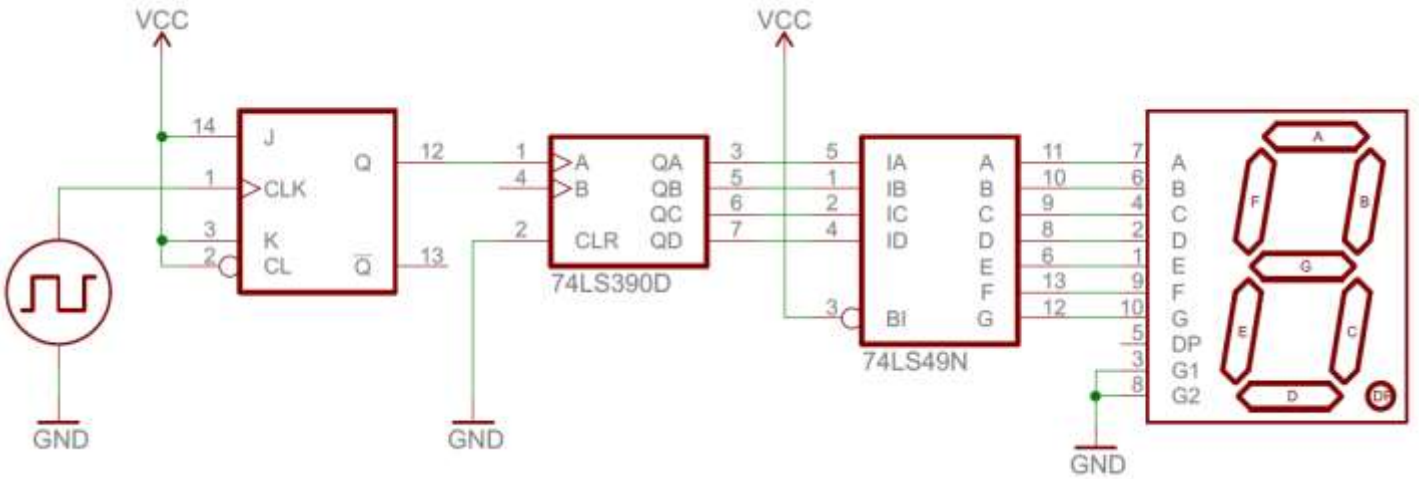


Servo Basics – Amplifier Operation

- Digital Control Circuit
  - The control circuit of a “digital” servo amplifier is digital instead of analog
  - Values for speed, torque, etc. are stored as digital values rather than voltage levels
  - Same result – command current to the motor



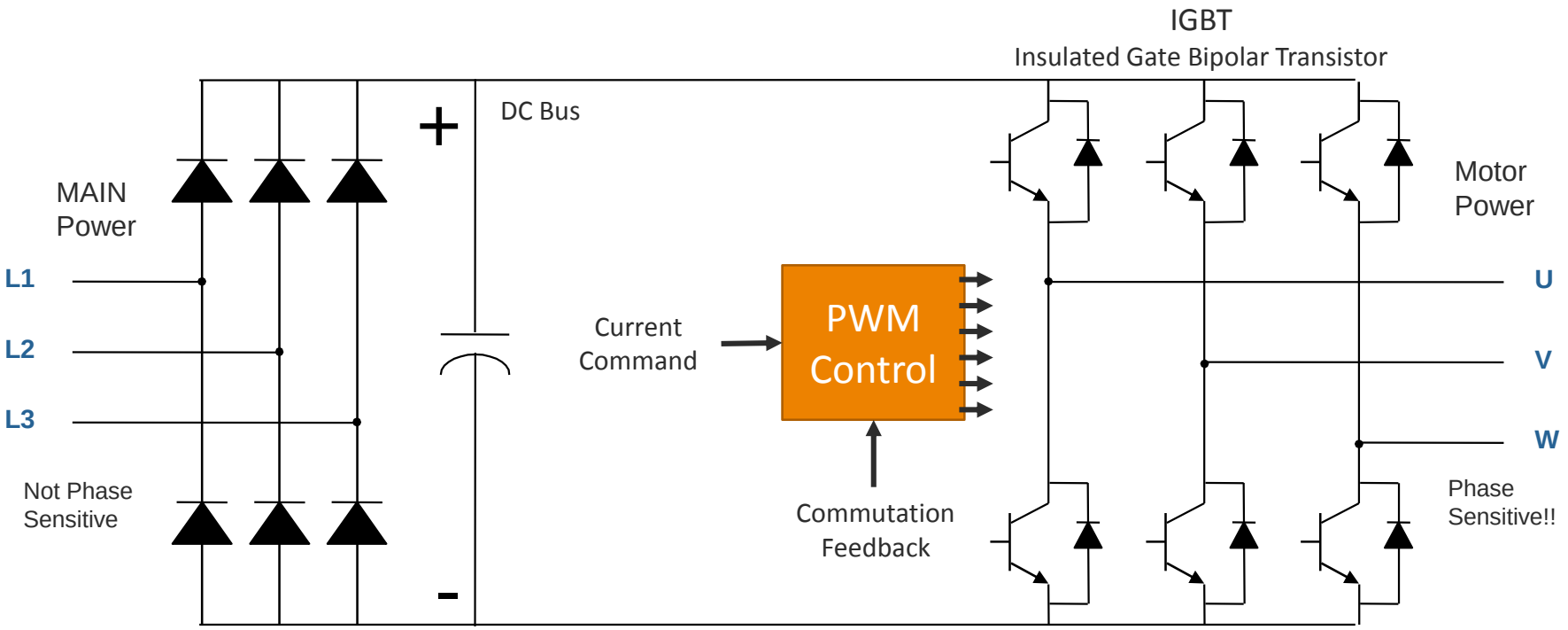
Analog Circuit. Source: learn.sparkfun.com



Digital Circuit. Source: learn.sparkfun.com

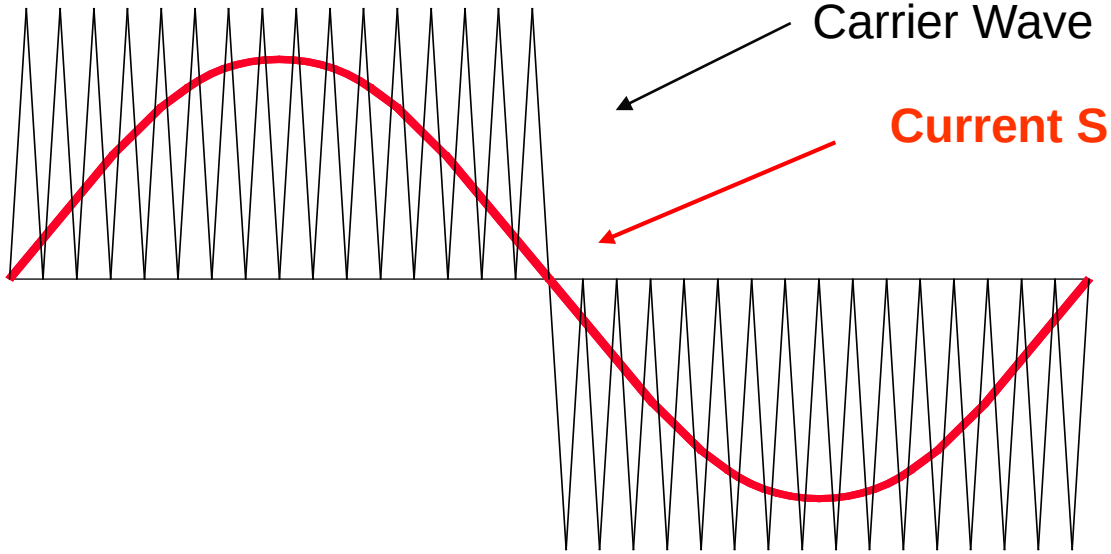
Servo Basics – Amplifier Operation

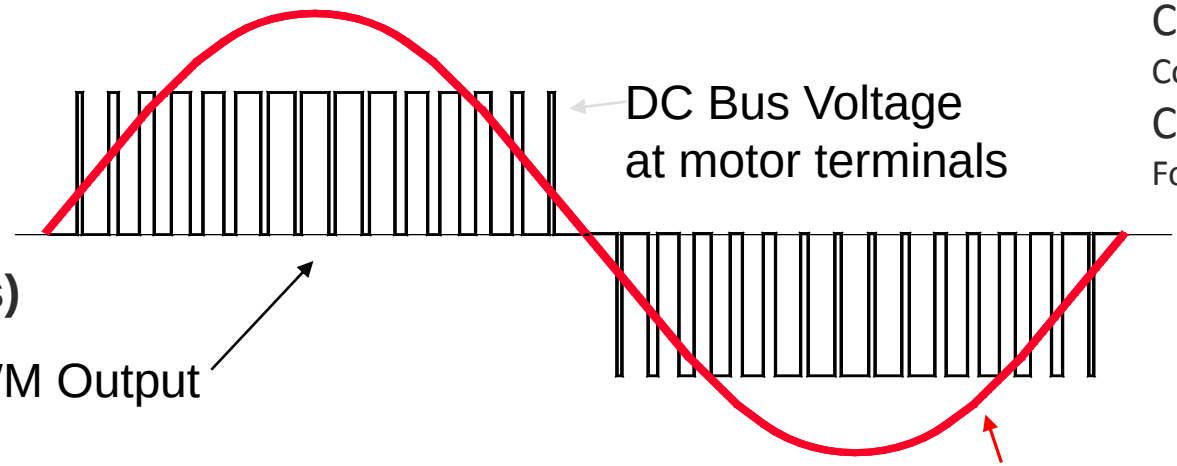
- Typical Power Circuit (Simplified Diagram)



Servo Basics – Amplifier Operation

- Pulse Width Modulation (PWM)

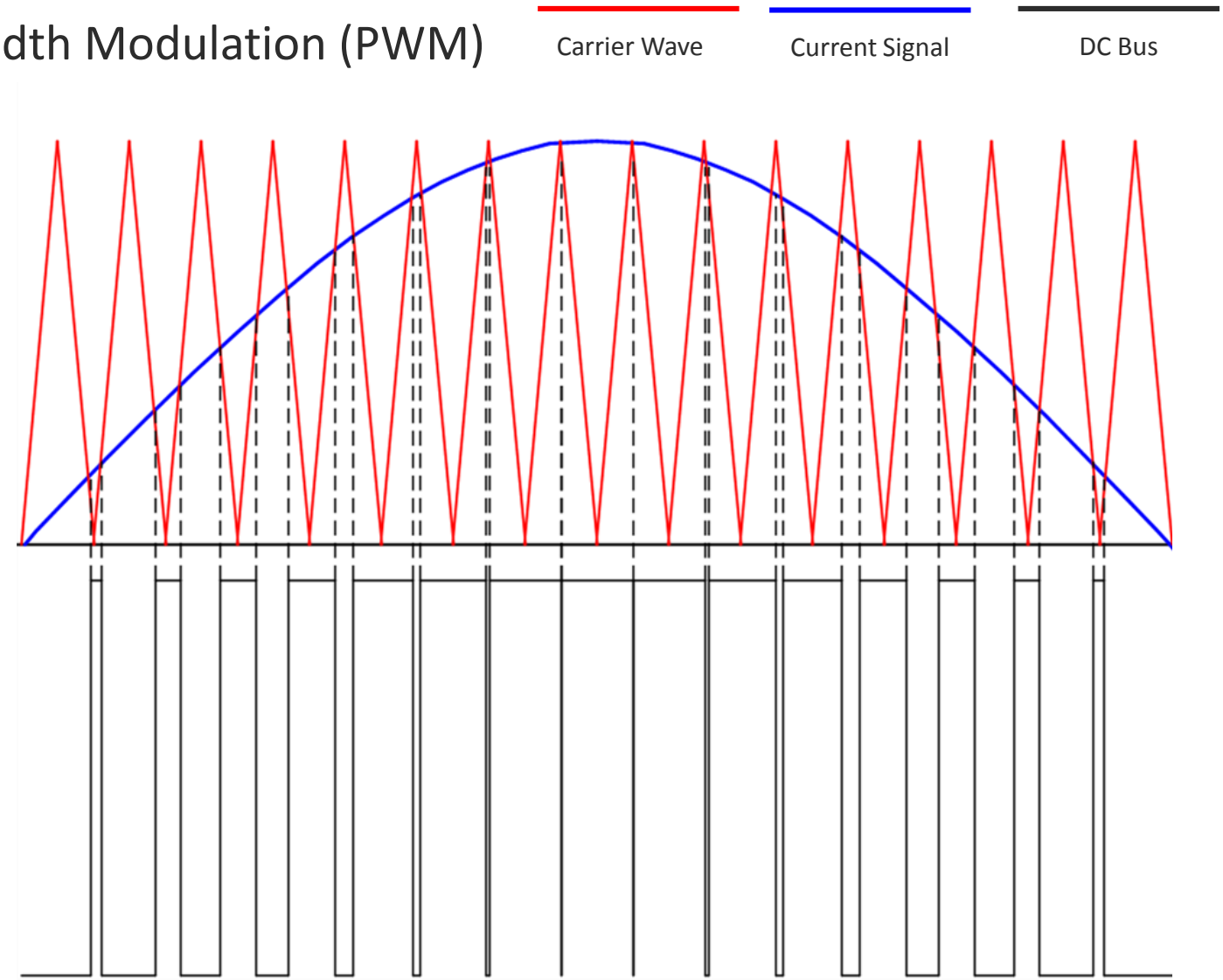




Current Amplitude
Commands Motor Torque
Current Frequency
Follows Motor Speed

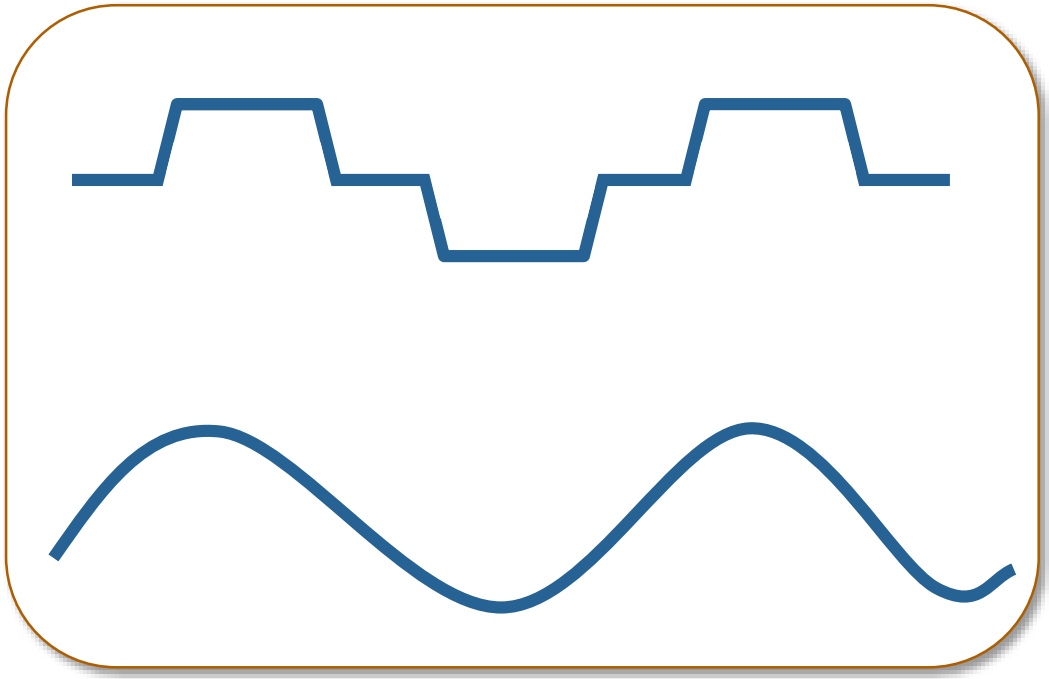
Servo Basics – Amplifier Operation

- Pulse Width Modulation (PWM)



Servo Basics – Amplifier Operation

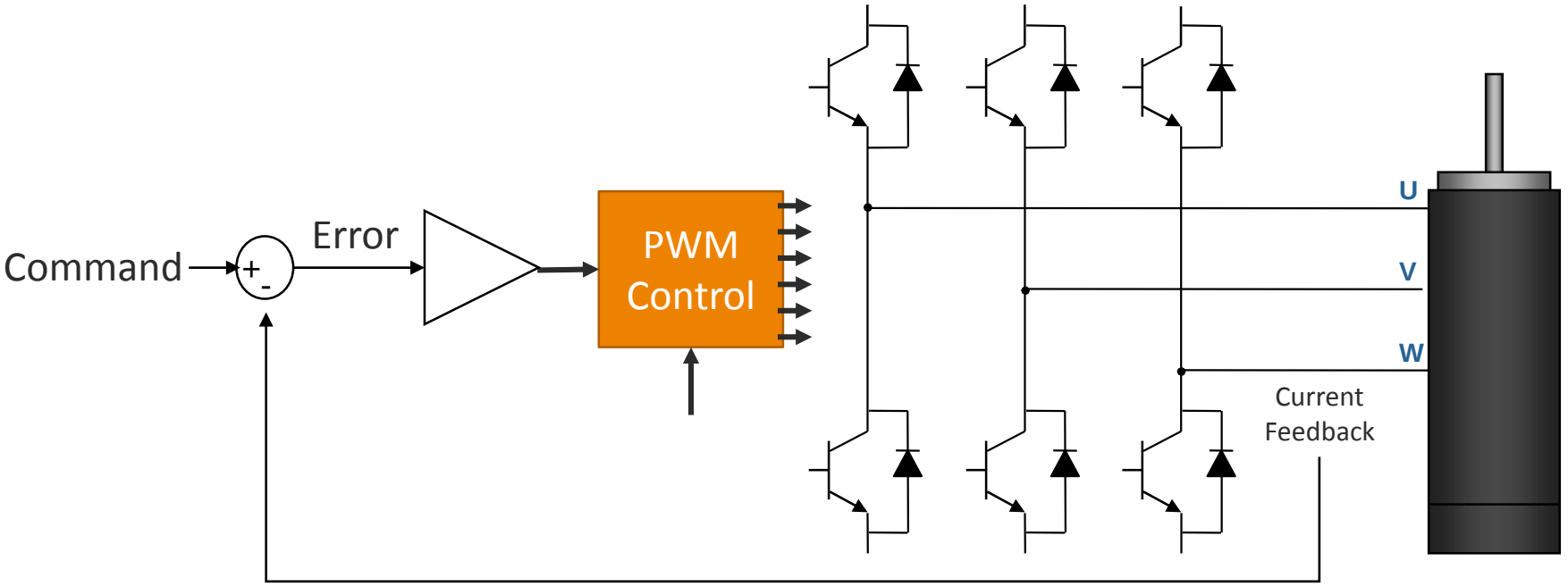
- Commutation Types
  - Trapezoidal
    - Trap Drive
    - Trapezoidal commutation based on Hall Effect sensor feedback
    - Cost Effective
  - Sinusoidal
    - AC Drive
    - Sinusoidal commutation based on encoder feedback
    - Significant reduction in torque ripple ➔ smooth motion at low speed



Commutation signal from “Trap Drive” (above) and Sinusoidal

Servo Basics – Servo ON

- PWM is active
- Servo “Enable” or “Power”
- Control circuit is active
- Current amplitude may be very low



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5. Tuning Process
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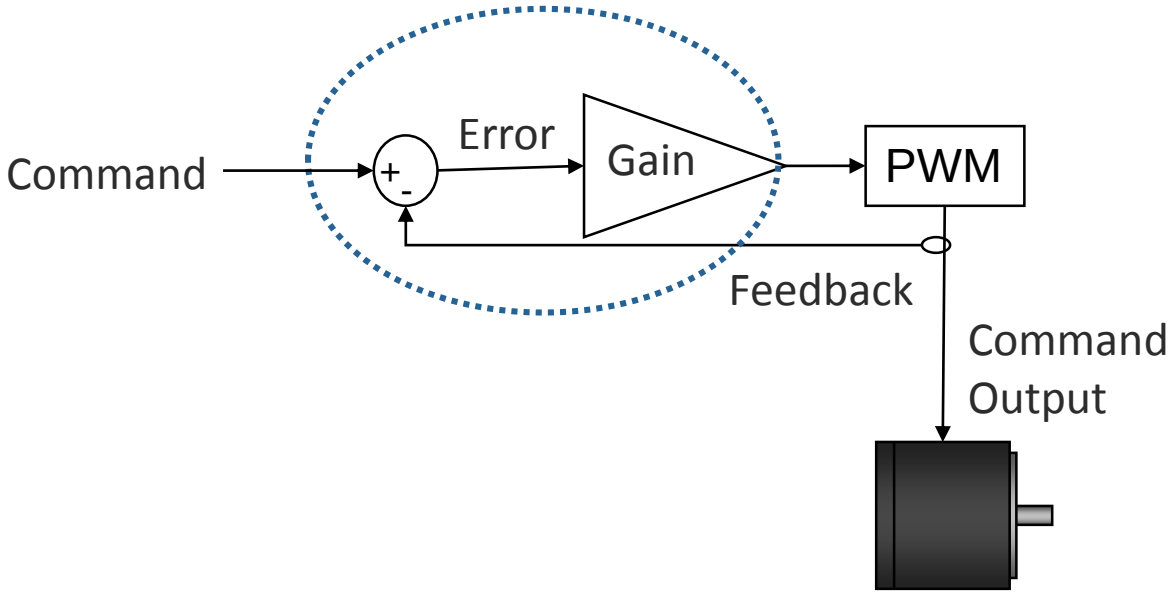
Digital Control Loops - Function

- Function and architecture of digital control loop
  - **Command** is compared to **Feedback**
  - The difference is **Error**
  - **Gain** amplifies **Error**
  - **Output Command** is the amplified **Error**



- Q: Why close the loop?
  - A: Minimize and eliminate ERROR

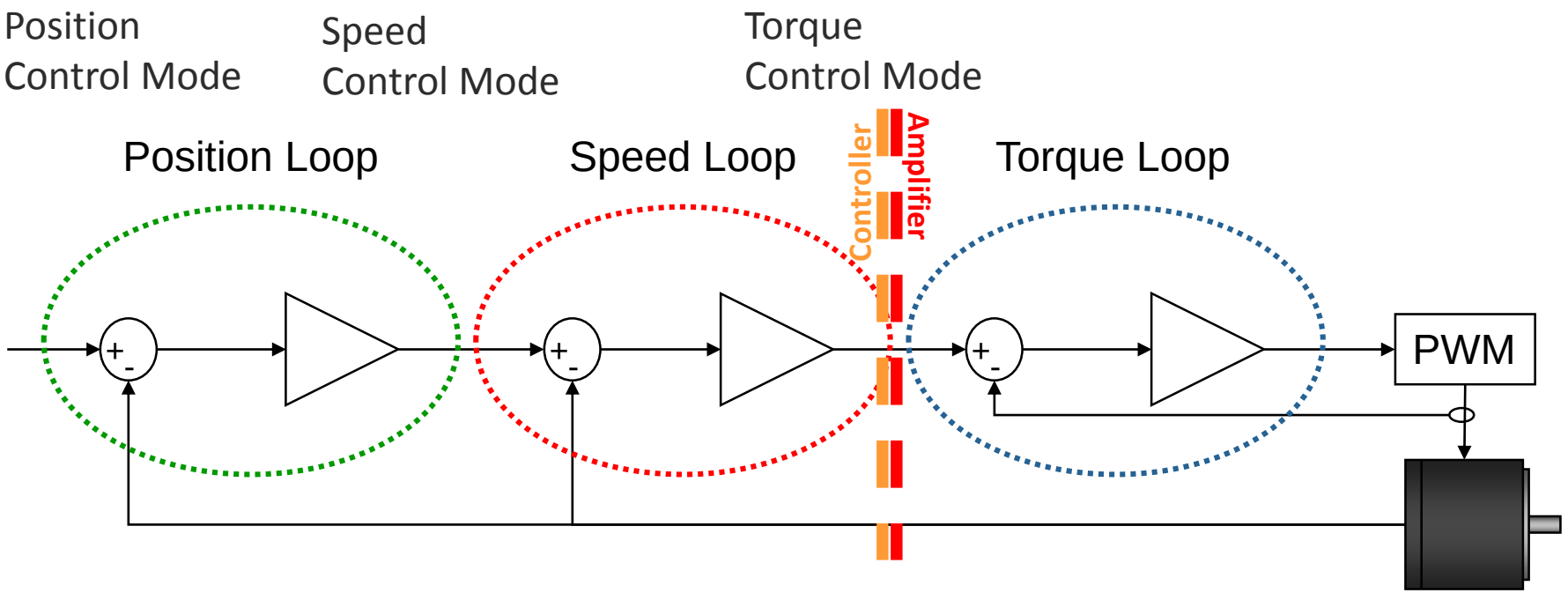
Digital Control Loops - Examples

- Examples of closed loop systems
  - Cruise Control

  - Furnace with “smart” thermostat

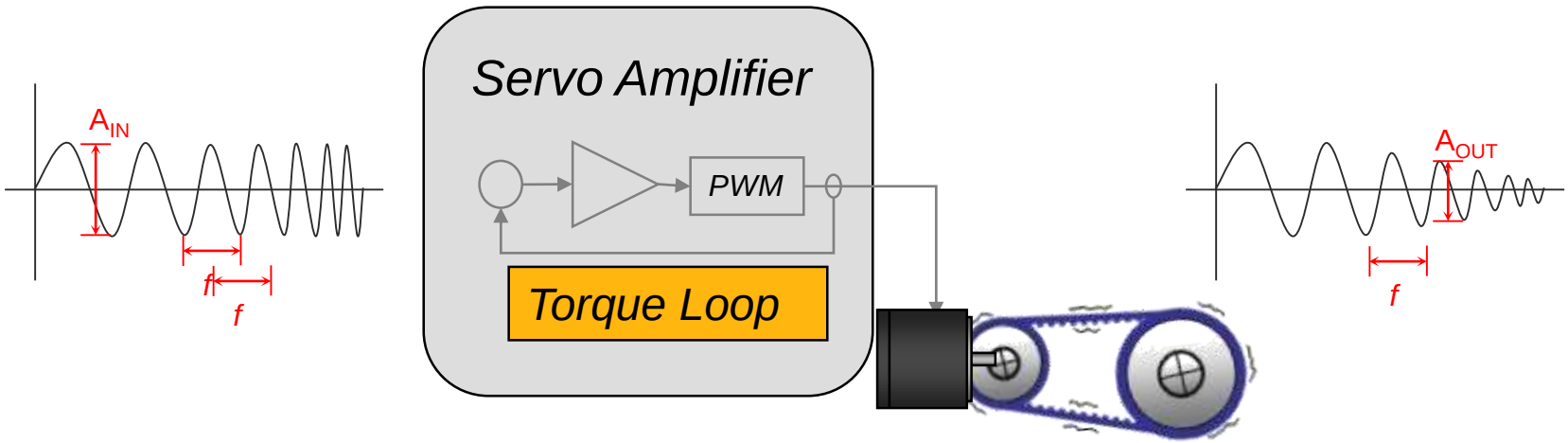
Digital Control Loops - Types

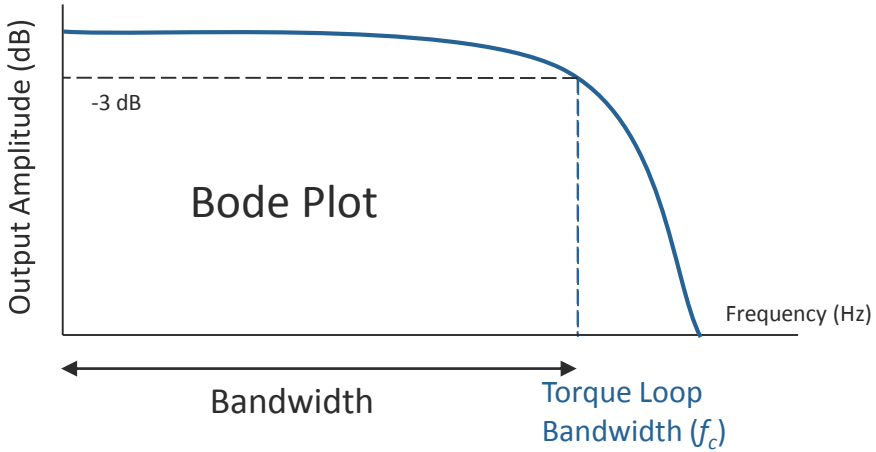
- Types of control loops: Torque/Velocity/Position
  - Output of one loop is the input of the next
  - Torque loop only - “dumb” amp
  - Some amplifiers add speed loop and position loop modes
  - Match to signal from motion controller



Digital Control Loops – Bandwidth

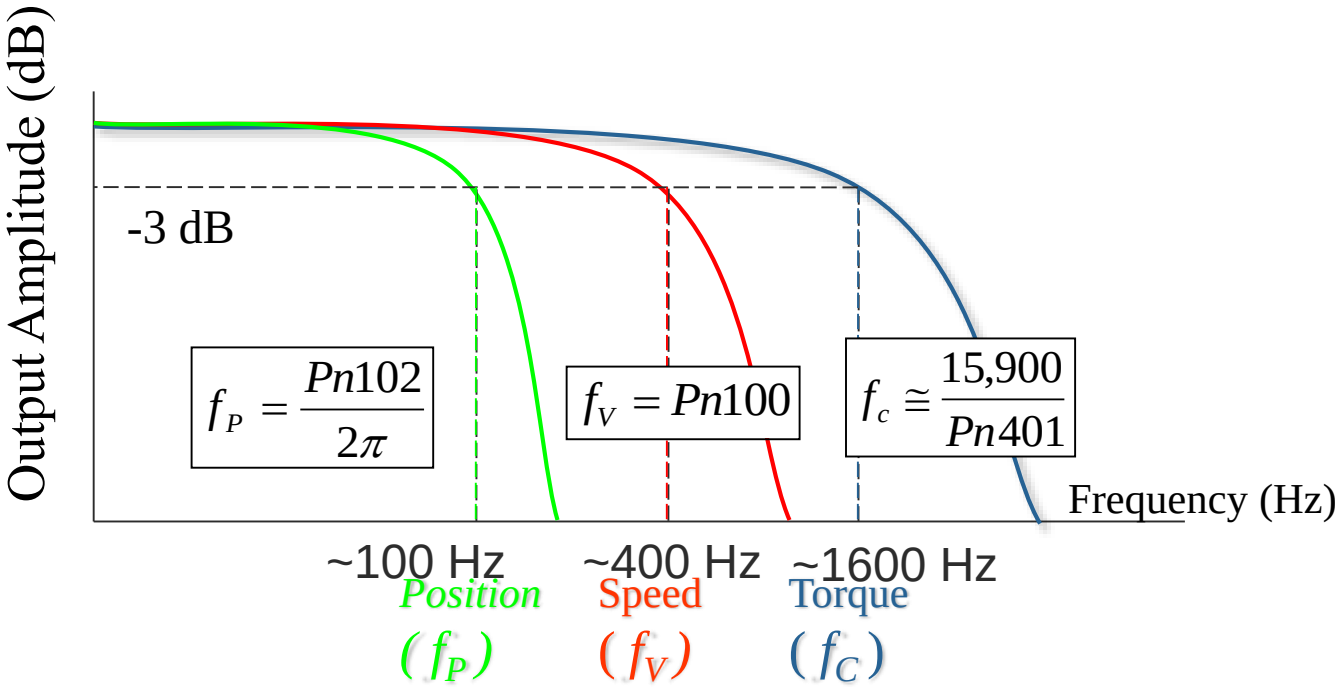
- Bandwidth is the useable range of frequencies for a control loop - when the output amplitude reduces to -3dB (70.7%) of the input.





Digital Control Loops - Bandwidth

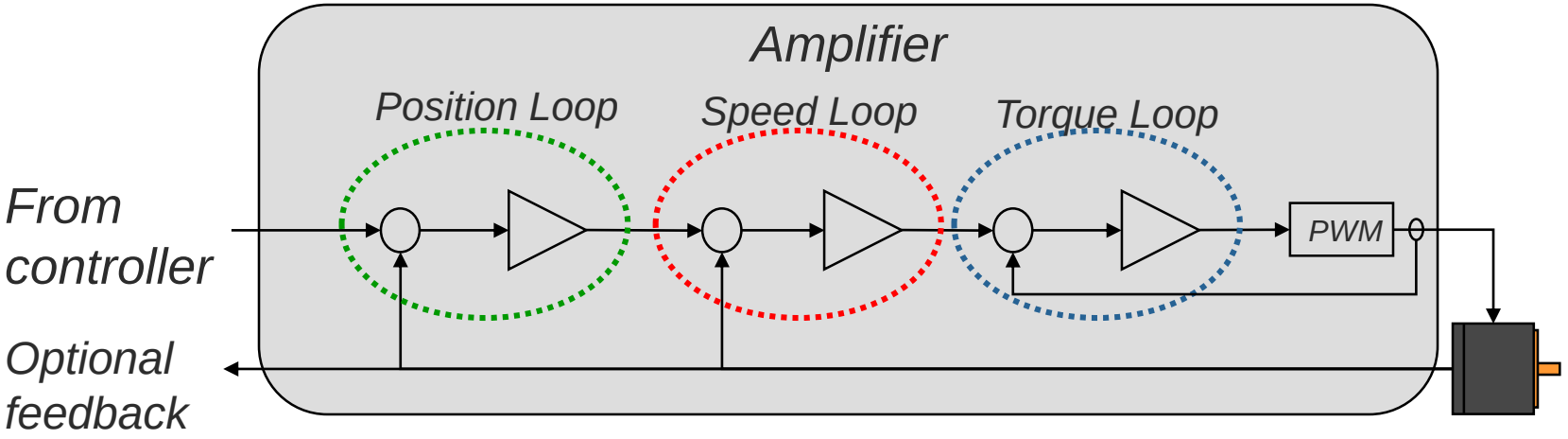
- Control Loop Bandwidth
  - Bandwidth determined by tuning parameters
  - Maintain stable bandwidth ~ 4x separation between loops
- Causes of tuning instability
  - Control loop bandwidth separation – adjust parameters
  - Mechanical compliance – apply filters



Digital Control Loops – Tuning Process

- Tuning = adjust error response
- Three Control Loops
  - Torque
  - Speed
  - Position

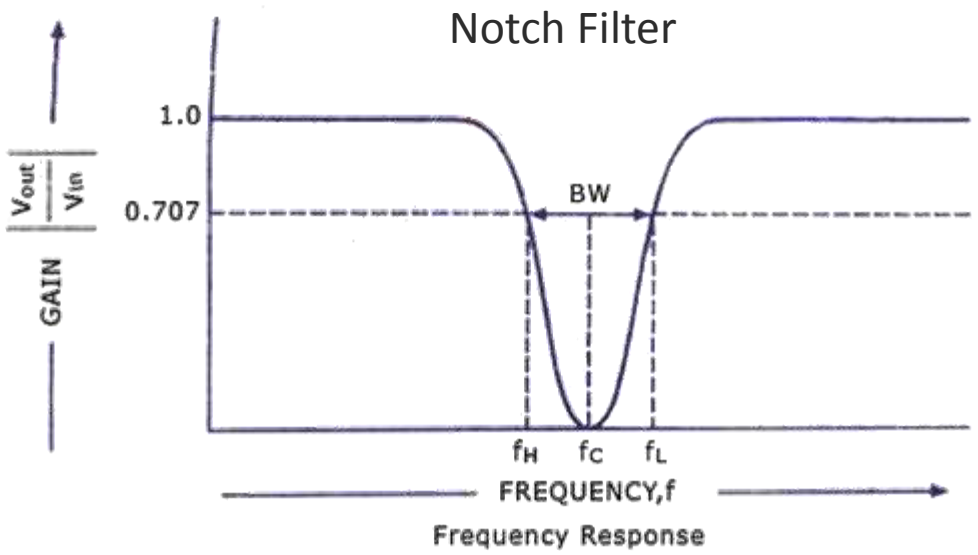
- General Tuning Process
  - Minimize mechanical compliance
  - Torque loop tuning to the motor and torque loop filters
  - Speed loop gains
  - Position loop gains
  - Auto-Tuning

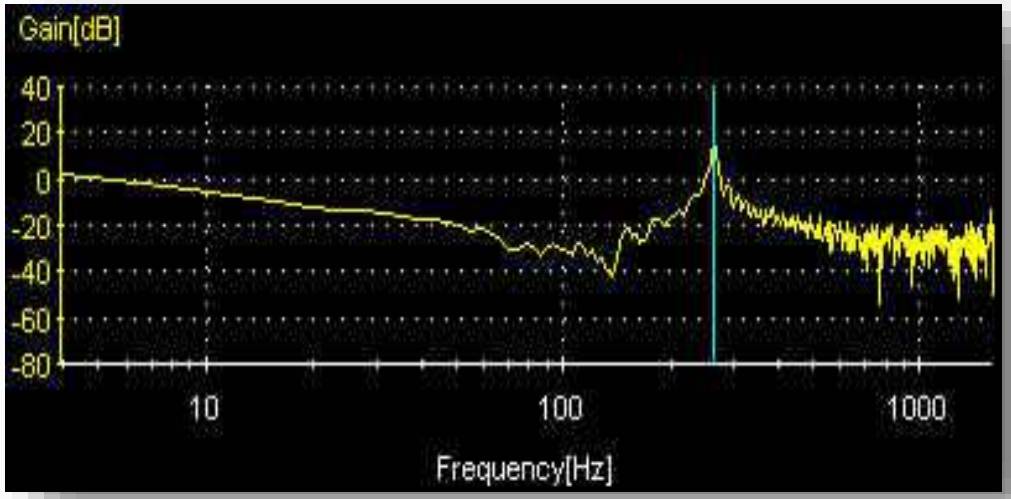


Remember – when control loops exist outside the amplifier (in the controller) they must also be tuned.

Digital Control Loops – Tuning Filters

- Low Pass Filter
- Notch Filter
- Advanced filters for lower frequencies
- Measurement can reveal problem frequencies caused by mechanical compliance





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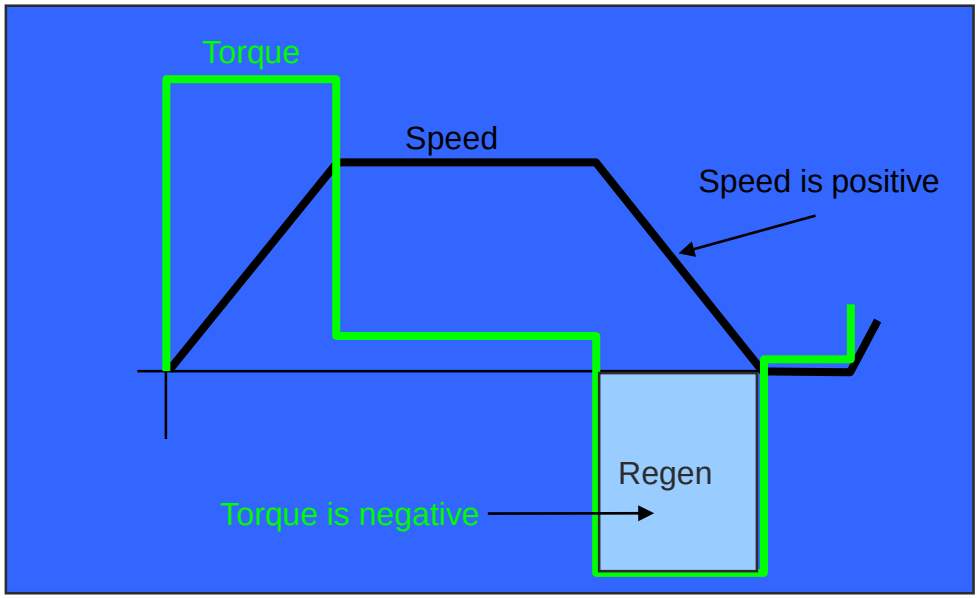
Amplifier Power – Input Types

- Amplifier Power Input Types
  - DC – Power Supply
  - AC – 100V, 200V, 400V internal power supply
- Considerations
  - Available Power
  - Servo Capacity – higher capacity available in higher voltages
  - Current rating drives the cost of an amplifier

Rotary Servo Motor Model		Rated Power	Rated Torque	Peak Torque	Rated Speed	Max Speed	Rotary Inertia	SGDV-□□□□	SGD7S-□□□□	SGDV-□□□□	SGD7S-□□□□	SGD7W-□□□□	SGDV-□□□□
			Nm	Nm	rpm	rpm	x10⁻⁴kg·cm²	24/48VDC	100VAC	200VAC	200VAC	200VAC	400VAC
 **SGMMV** Low Inertia Ultra-Small Capacity	SGMMV-B3E	3.3W	0.0105	0.0263	3000	6000	0.000441	1R7E	N/A	N/A	N/A	N/A	N/A
	SGMMV-B5E	5.5W	0.0175	0.0438	3000	6000	0.000796	1R7E					
	SGMMV-B9E	11W	0.0350	0.0875	3000	6000	0.002210	1R7E					
	SGMMV-A1A	10W	0.0318	0.0955	3000	6000	0.000272	2R9E	R90F		R90A	1R6A, 2R8A	
	SGMMV-A2A	20W	0.0637	0.1910	3000	6000	0.000466	2R9E	R90F		R90A	1R6A,2R8A	
	SGMMV-A3A	30W	0.0955	0.2860	3000	6000	0.000668	2R9E	2R1F		1R6A	1R6A, 2R8A	
 **SGM7A** Low Inertia Small Capacity	SGM7A-A5A	50W	0.159	.557	3000	6000	0.0217	N/A	R70F	N/A	R70A	1R6A, 2R8A	N/A
	SGM7A-01A	100W	0.318	1.11	3000	6000	0.0337		R90F		R90A	1R6A, 2R8A	
	SGM7A-C2A	150W	0.477	1.67	3000	6000	0.0458		2R1F		1R6A	1R6A, 2R8A	
	SGM7A-02□	200W	0.637	2.23	3000	6000	0.139		2R1F		1R6A	1R6A, 2R8A	1R9D
	SGM7A-04□	400W	1.27	4.46	3000	6000	0.216		2R8F		2R8A	1R6A, 2R8A, 7R6A	1R9D
	SGM7A-06A	550W	1.75	6.69	3000	6000	0.315		N/A		5R5A	5R5A, 7R6A	N/A
	SGM7A-08□	600W	1.91	8.36	3000	6000	0.775				5R5A	5R5A, 7R6A	3R5D
	SGM7A-10□	1.0kW	3.18	11.1	3000	6000	0.971				120A	N/A	3R5D

Amplifier Power - Regeneration

- "Regeneration" means that the motor is generating energy rather than using energy
- This happens during deceleration because the load forces the motor to move in the direction opposite to that in which torque is being applied

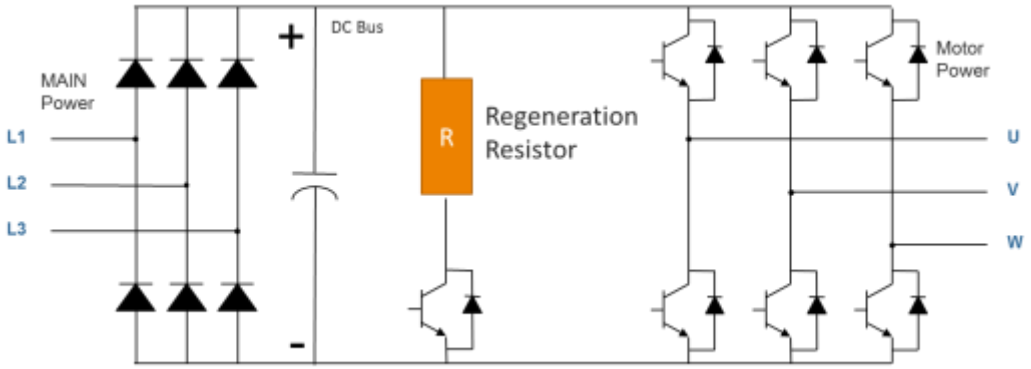


Factors that Increase Regen

- High Speed
- High Inertia
- High Deceleration Rate
- Vertical Applications
- Low Friction

Amplifier Power – DC Bus Sharing

- Handling Regeneration Energy
  1. Burn off through a regeneration resistor
  2. DC bus sharing
     - Energy released by one servo is used by the other



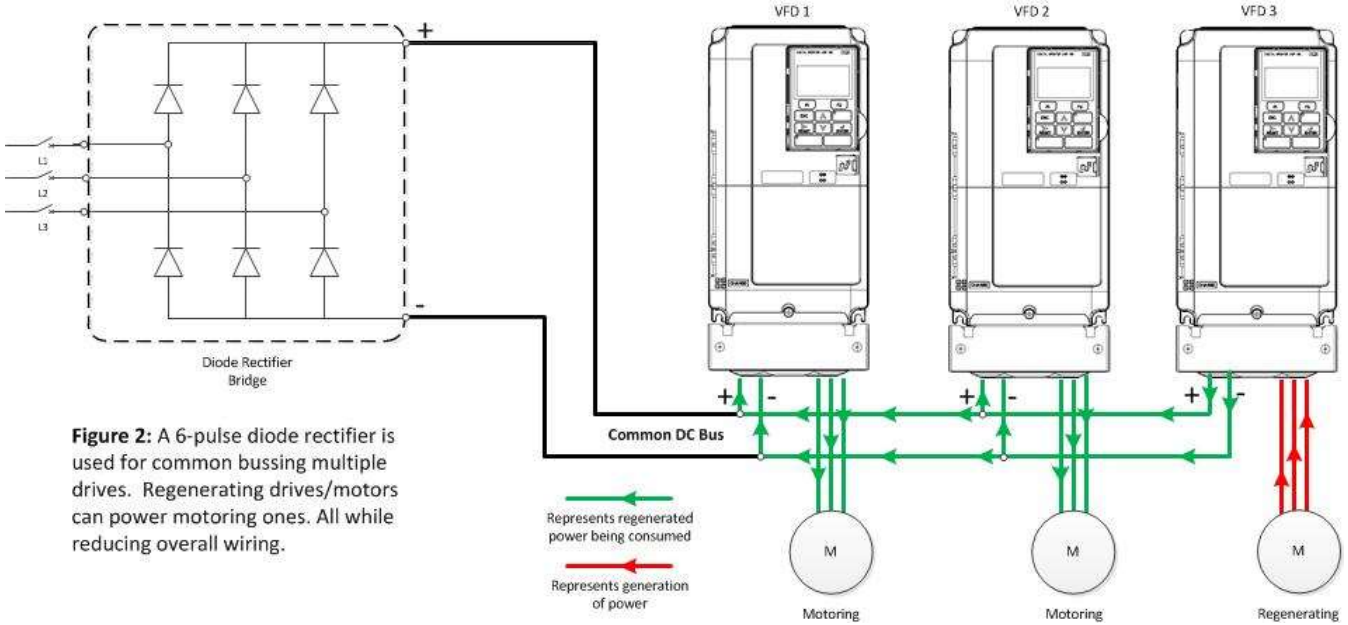


Figure 2: A 6-pulse diode rectifier is used for common bussing multiple drives. Regenerating drives/motors can power motoring ones. All while reducing overall wiring.

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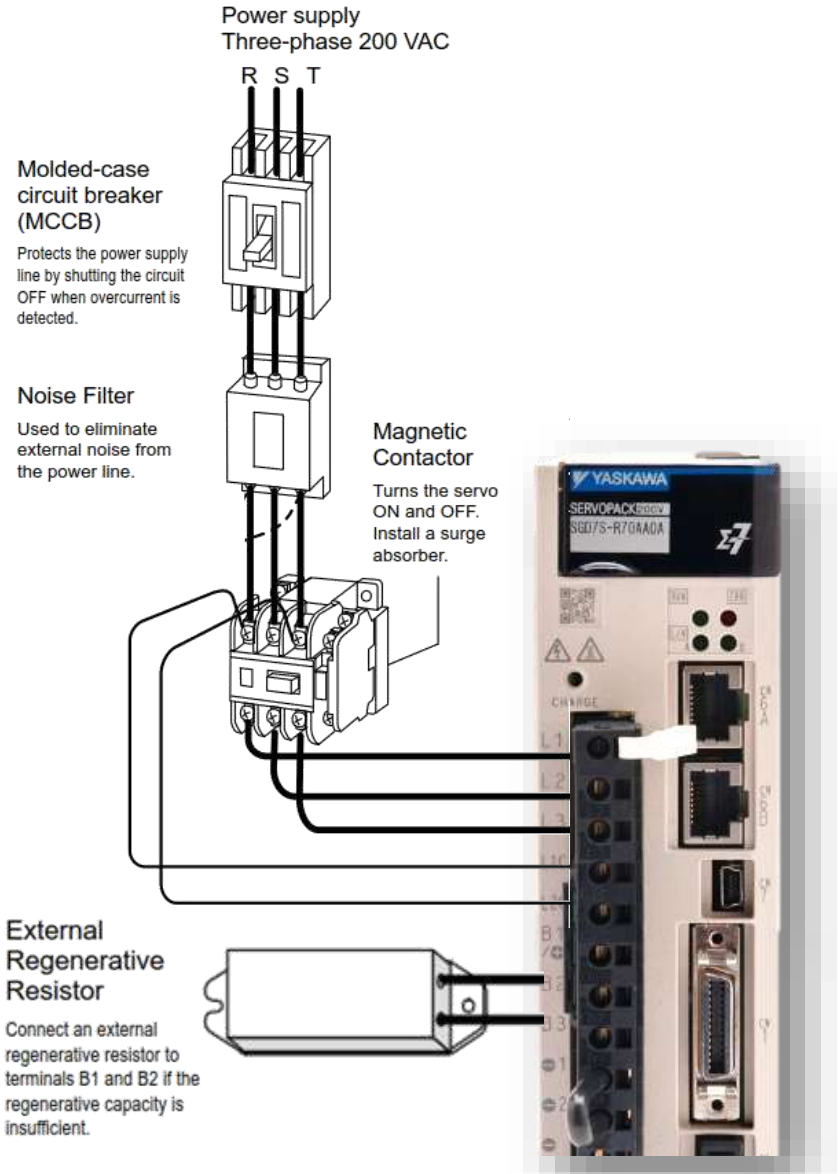
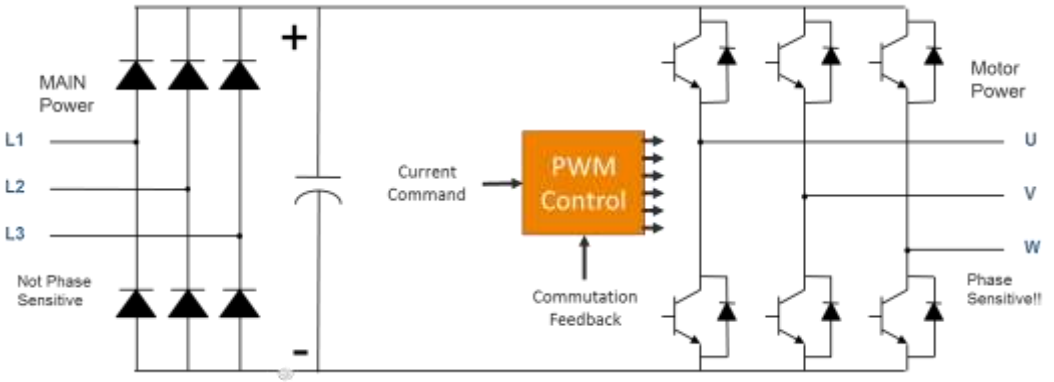
Installation Infrastructure – Power Wiring

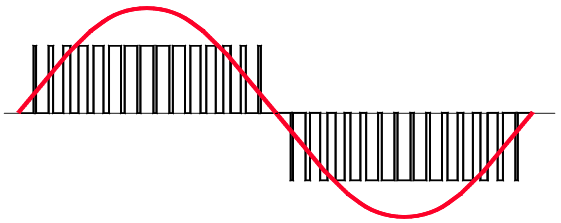
- Input Power
  - Noise Filter
  - Contactor
  - Main Power
  - Control Power
- Peripheral Devices
  - Regeneration Resistor



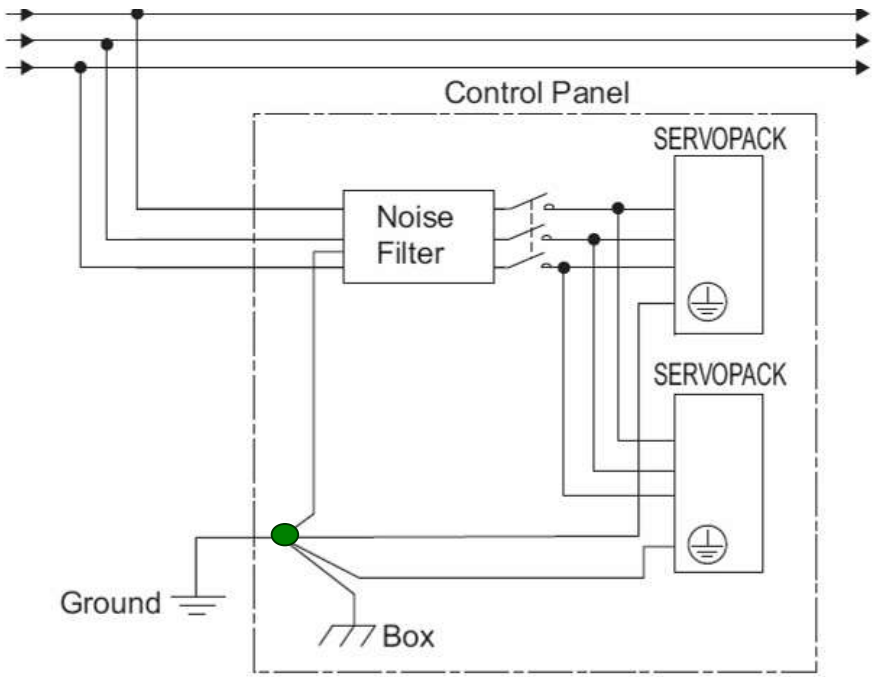
Installation Infrastructure – Noise Filter

- Noise Filter
  - Protect other devices on the AC power line from the electrical noise created by the amplifier PWM

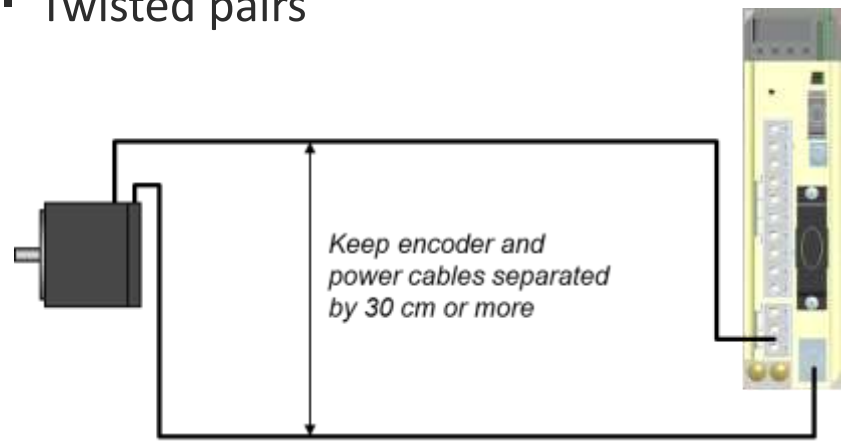




Installation Infrastructure – EMI

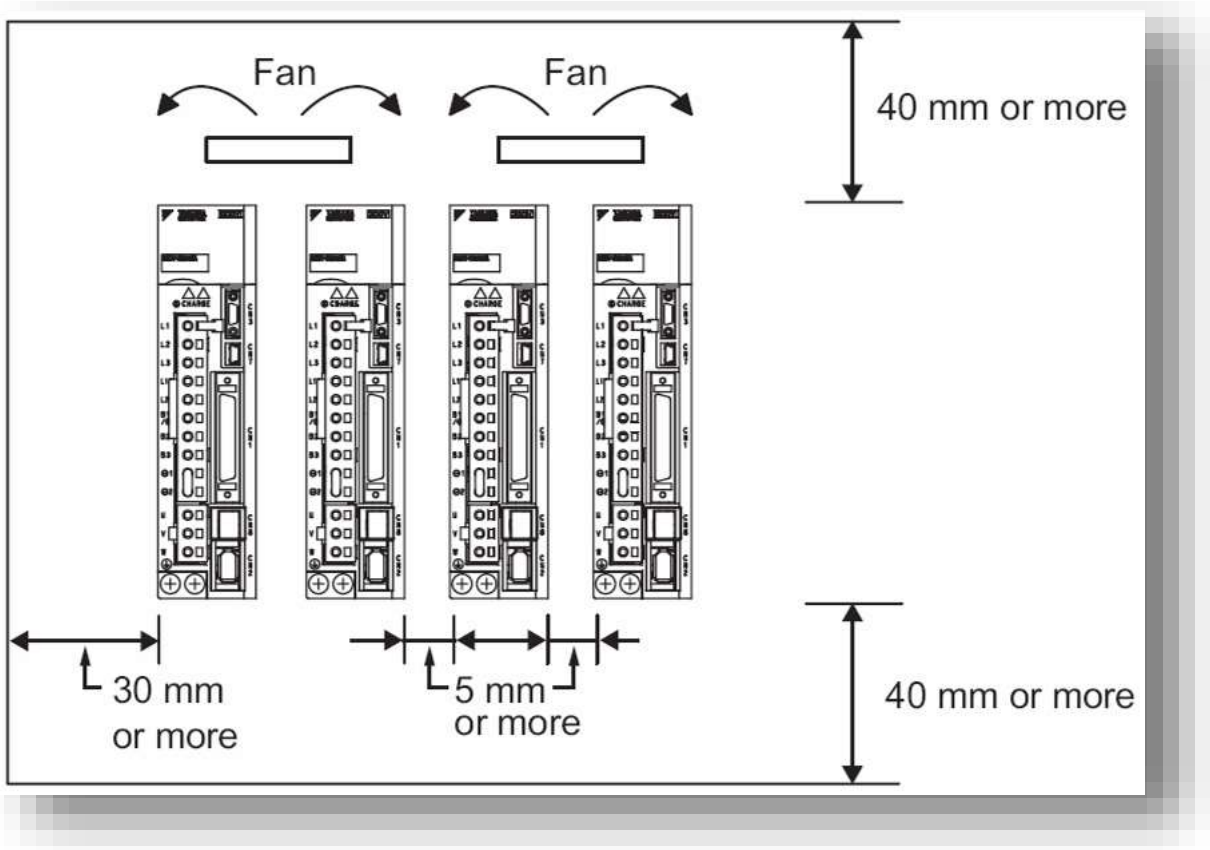


- Electromagnetic Interference (EMI)
  - Radiated
  - Conducted
- Good wiring practices
  - Single point “star” grounding
  - Isolate earth ground from DC power supply output
  - Physical separation of power cables and signal cables
  - Shielded cable
  - Twisted pairs



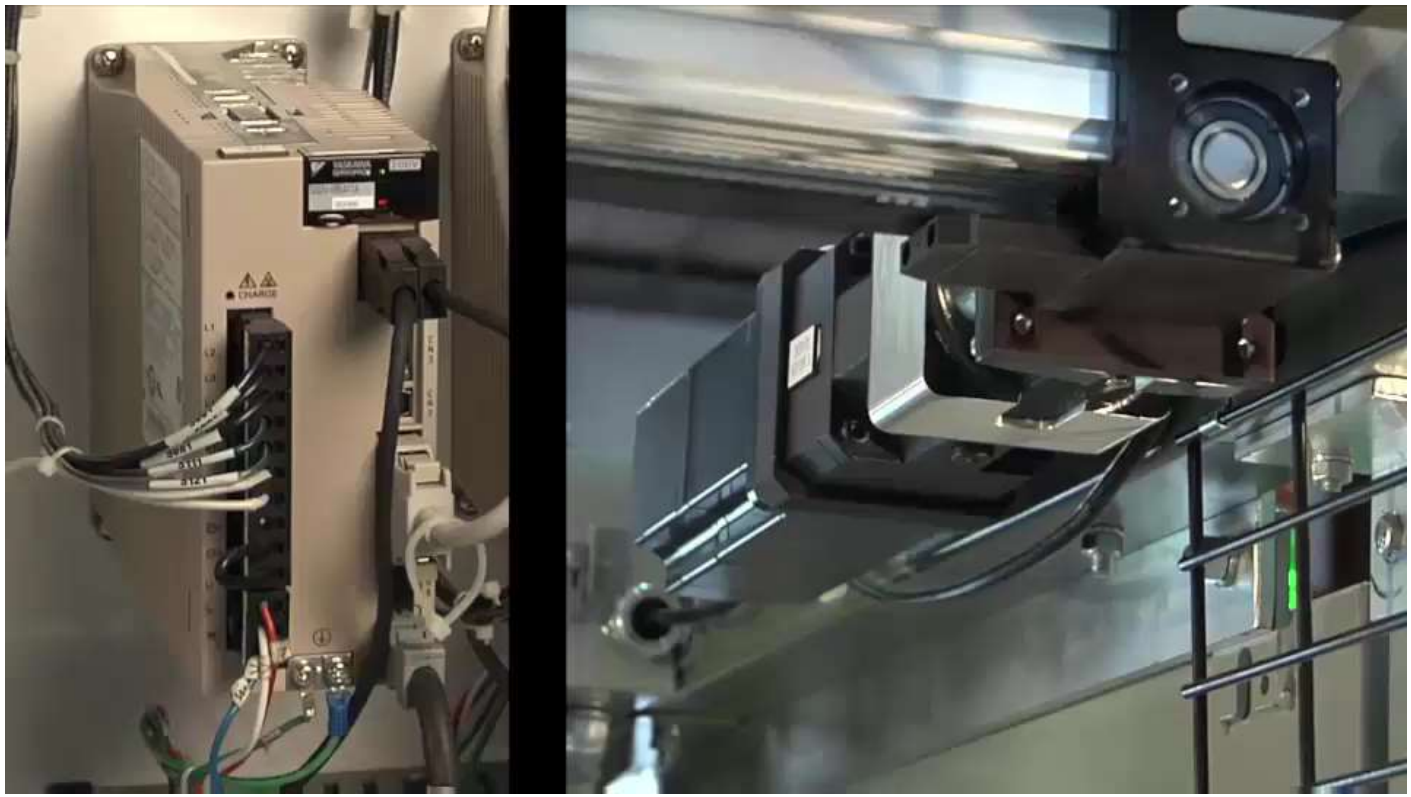
Installation Infrastructure – Heat Loads

- Heat Loads / Cooling
  - Mounting separation specification
  - Flat, vertical mounting surface for heat conduction and convection
  - Amplifier generates heat from power loss



Thank You!

- Fundamentals of digital servo amplifiers still apply
- Advancements in Technology ➔
  - Better performance
  - More Options
  - New Applications



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