Design 4: Voltage Margin and Bulk Capacitance

TI Precision Labs – Motor Drivers

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Overview

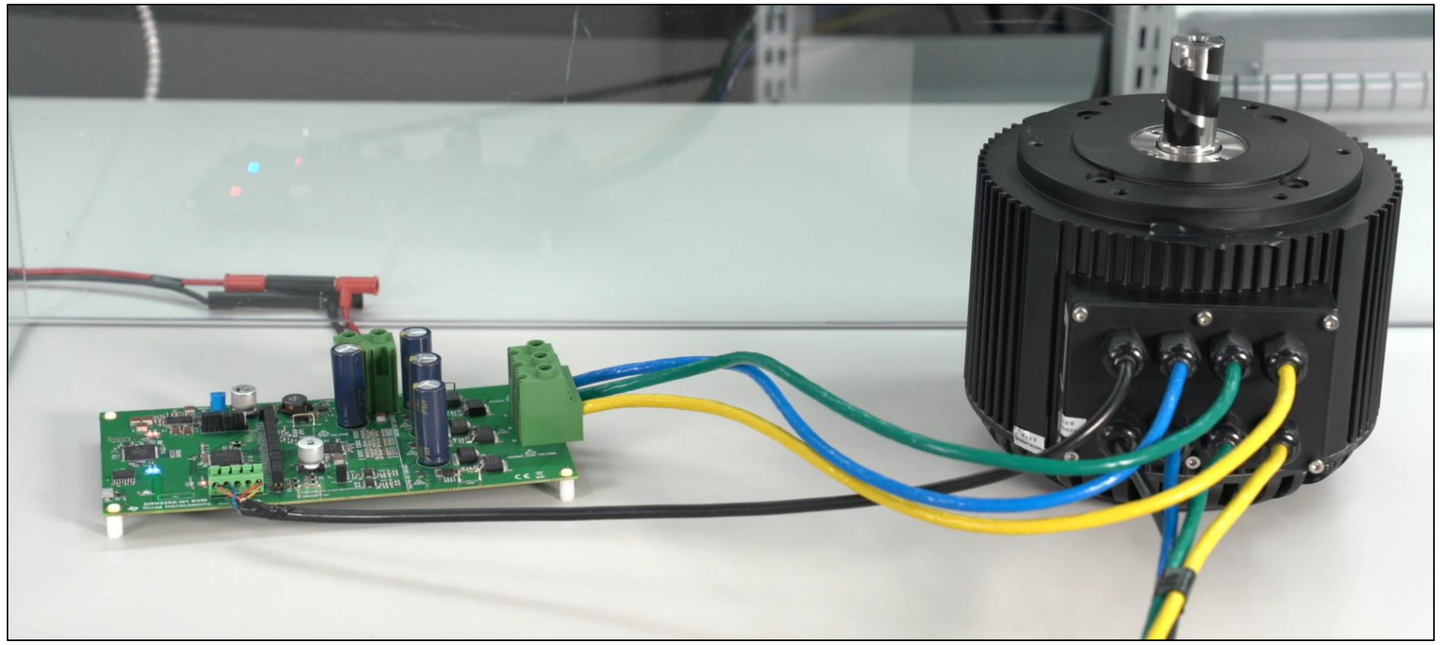
- What is voltage margin?
  - Power supply and motor stalling
  - Power supply and motor braking
  - Power delivery
- What is bulk capacitance?
  - Bulk capacitors, ripple and transients
  - How to choose your bulk capacitor
  - Bulk capacitance and voltage margin relationship

Voltage margin in DC motor systems

- A range above and below the normal operating voltage of a system in which a system can operate temporarily without sustaining permanent damage.
- It is specific to **each individual motor system** – not just the driver

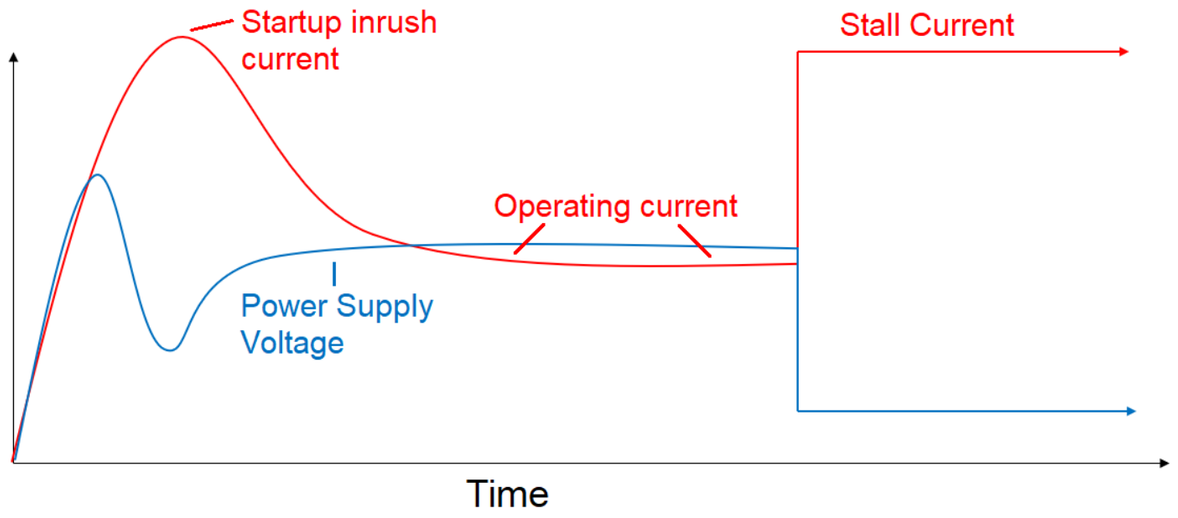
Most significant factors when choosing the voltage margin for your motor system:

- Braking method(s)
- Stall current
- Power delivery

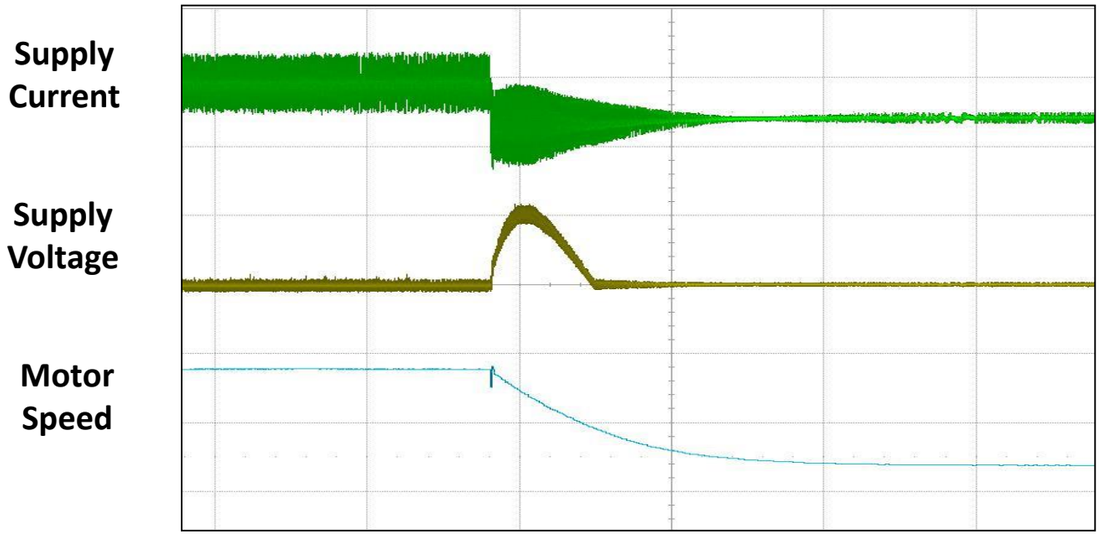


Power supply in motor systems

- When the motor in a system is applying torque but not spinning (stalling), it requires **more current** from the power supply, and the voltage in the power supply **dips below** normal operating voltage.



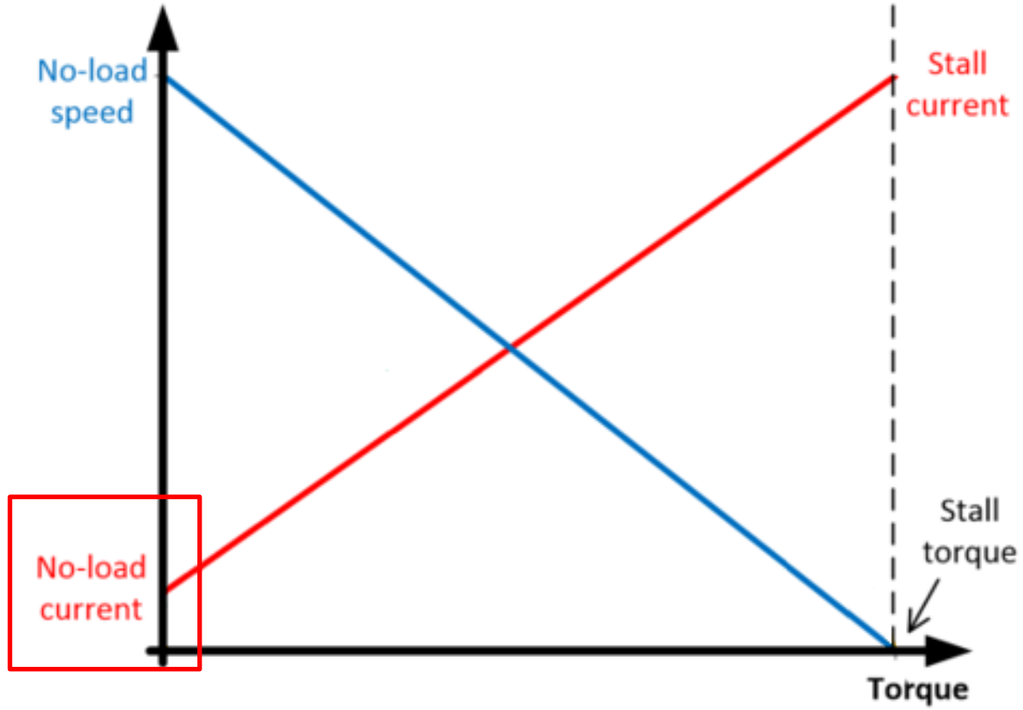
- When the motor in a system spins without being supplied (coasts), it generates current which returns to the supply and the power supply **spikes above** normal operating voltage.



Motor stalling

Example:

- You have a power tool, stick it into a large plank of wood, and attempt to spin the tool at full speed.
- The tool is **not spinning**, but it is applying **maximum torque**. This is stalling.



- Maximum amount of current is outputted, power supply voltage decreases to its minimum
- This minimum voltage depends on the specs of your motor system

Voltage margin and motor braking

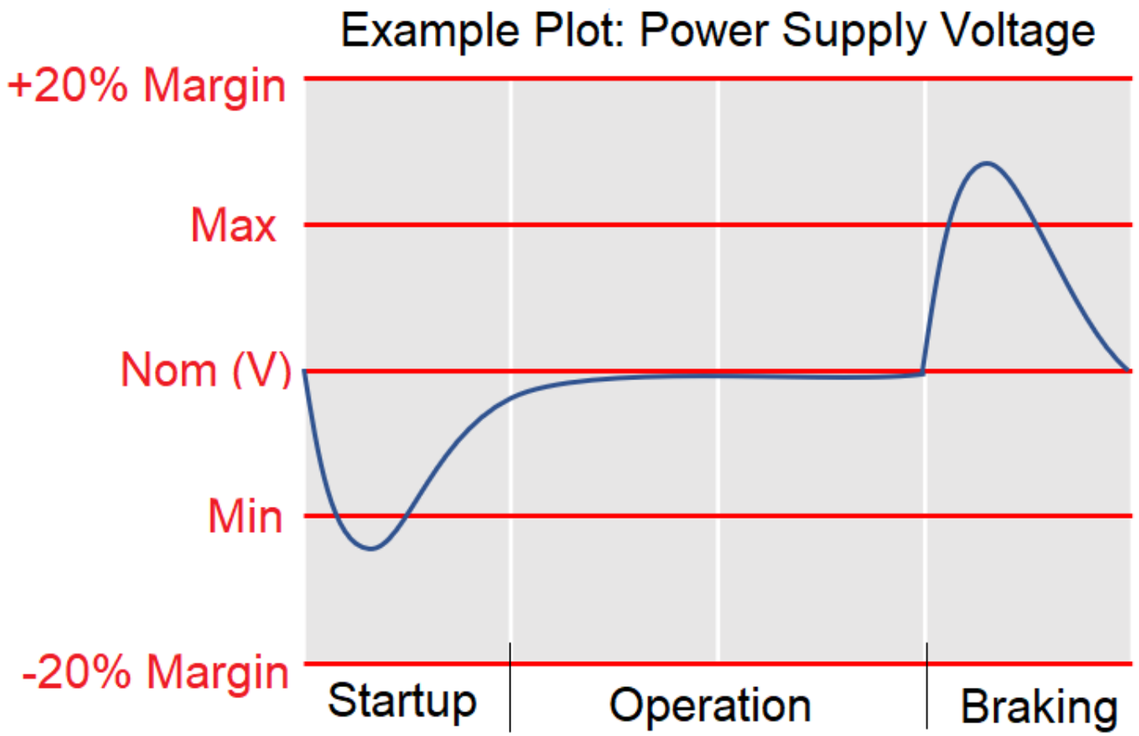
Think of the motor as a wind turbine, generating current.

- **Coasting** – FETs are off, current recirculates through the body diodes. Generates a large amount of voltage in the power supply
- **Resistive braking** – current dissipates as heat across a resistor
- **FET braking** – has the current go through the FETs by shorting the motor.

Braking techniques are often mixed together to mitigate stress on the voltage margin.

Choosing voltage margin

Example: 50W motor with a coasting braking system



Example rule of thumb to follow when considering voltage margin of a system:

Power Supply	Recommended Voltage Margin
<100W	∓20%
100W – 1kW	∓50%
>1 kW	∓100%

Characteristics of bulk capacitance

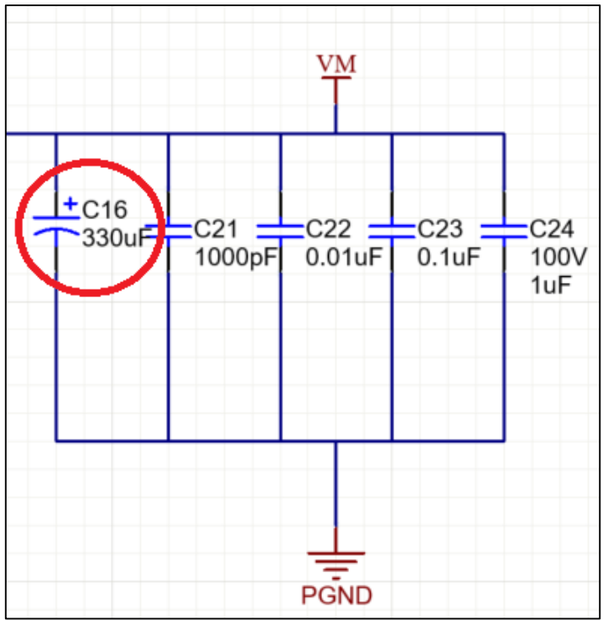
- Used in parallel with power supply – Vm or VBat

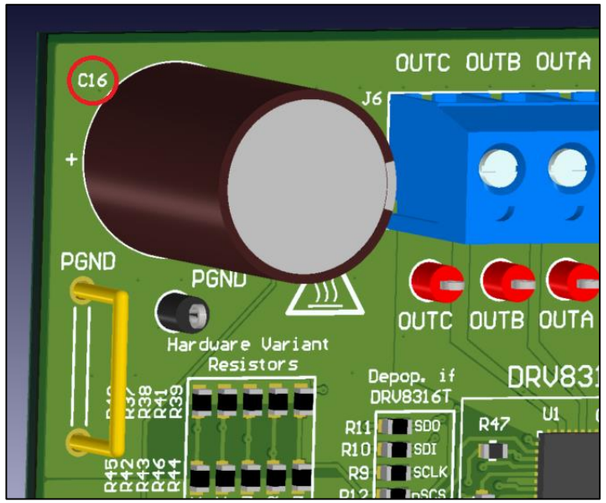
Pros of increased bulk capacitance:

- Provides a “safety net” of current.
- Flattens ripple current and transients on supply due to inrush current

Cons of increased bulk capacitance

- increases cost and footprint size



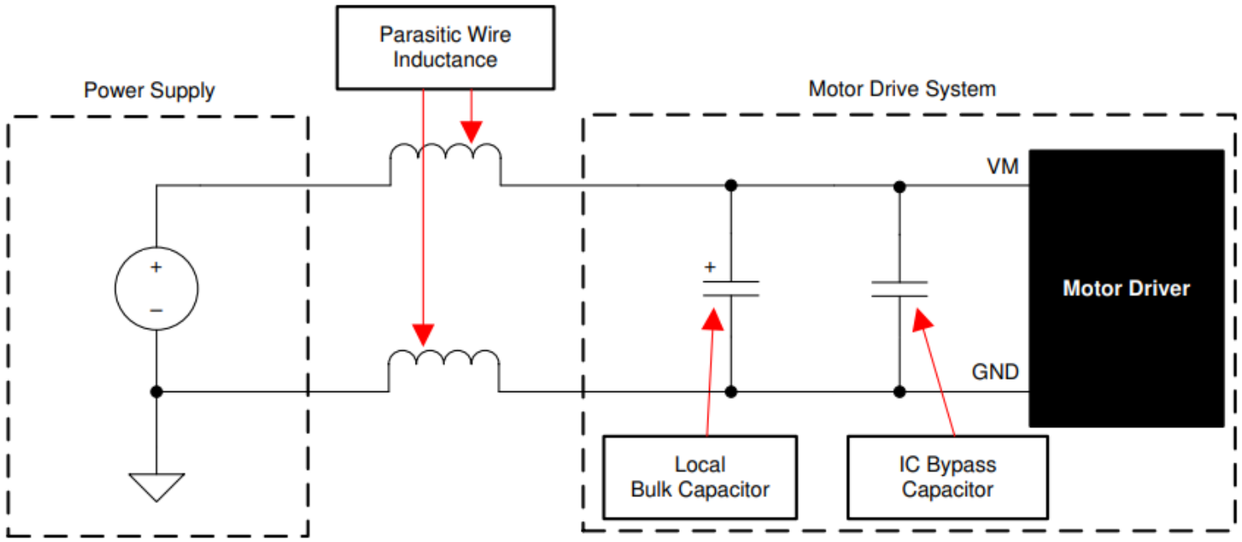


How to choose bulk capacitors

- Equivalent Series Resistance: high ESR = high power loss
- Location
- Voltage rating of bulk caps
- Power supply discharge rate
- Ripple and transients – How much is acceptable?
- Trace length & parasitic inductance
- Stall current
- Rough estimation of required C_{bulk}:

$$\frac{1}{2} C_{bulk} \Delta V^2 > \frac{1}{2} L I^2$$

(assumes all system energy comes from motor)

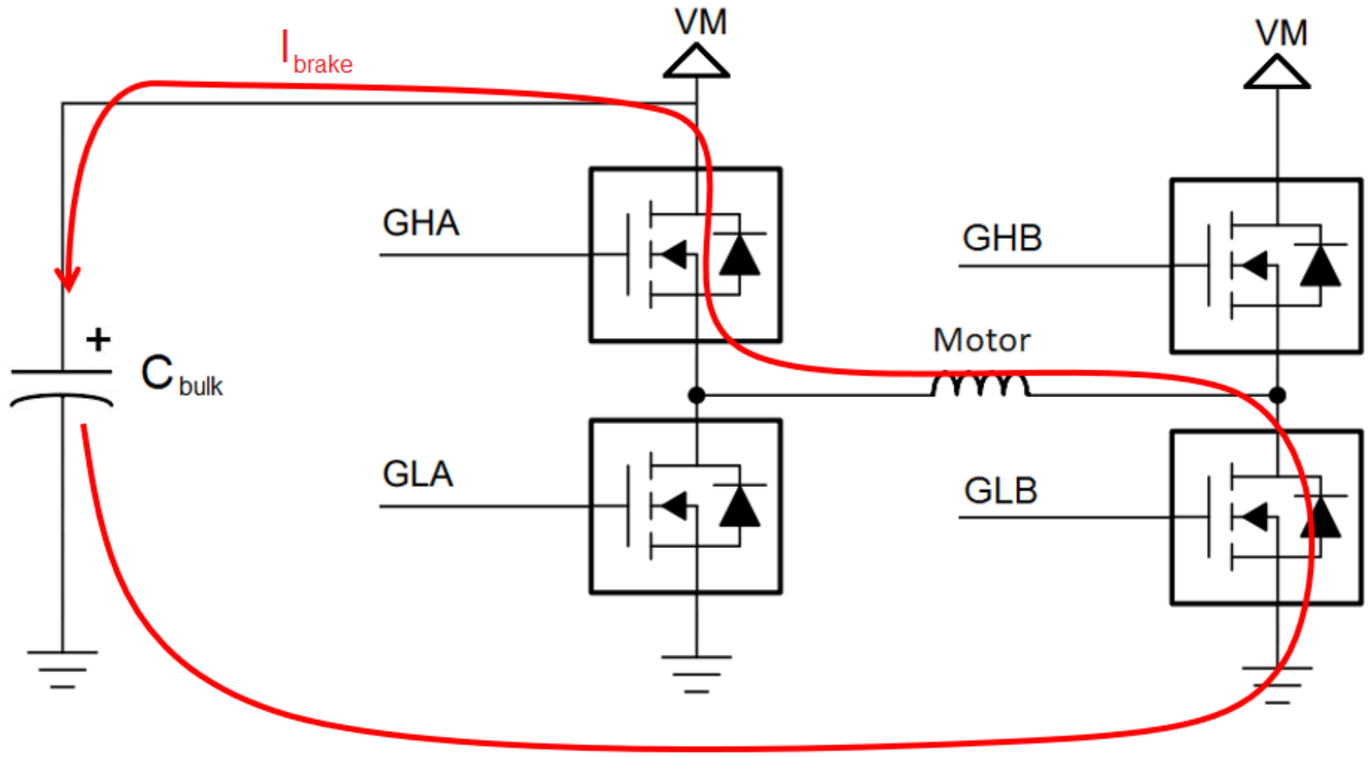


Comments on capacitor properties

Property 1	Property 2	Tradeoff
Capacitance	Price	Larger capacitors cost more.
Capacitance	Footprint Space	Larger capacitors take up more space.
Material	Frequency	Aluminum/tantalum capacitors have high inductance, not good for high frequency. Ceramic capacitors are better for high frequency/heavy switching (e.g. charge pump).
Material	Capacitance	Aluminum/tantalum capacitors have much higher capacitance than ceramic capacitors.
Bias Voltage	Effectiveness	Ceramic capacitors suffer from **voltage derating.** These caps lose effectiveness when they approach their voltage rating.

Voltage margin and bulk capacitance relationship

- During regenerative braking, capacitors can absorb some of the current flowing towards the power supply, mitigating voltage change
- Larger bulk capacitors used = lower voltage margin required



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