

Robotics & BLDC

Advanced Solutions Group (ASG) Bob Card

Power Solutions Group (PSG) CJ Waters

August 6, 2021

Public Information

Agenda

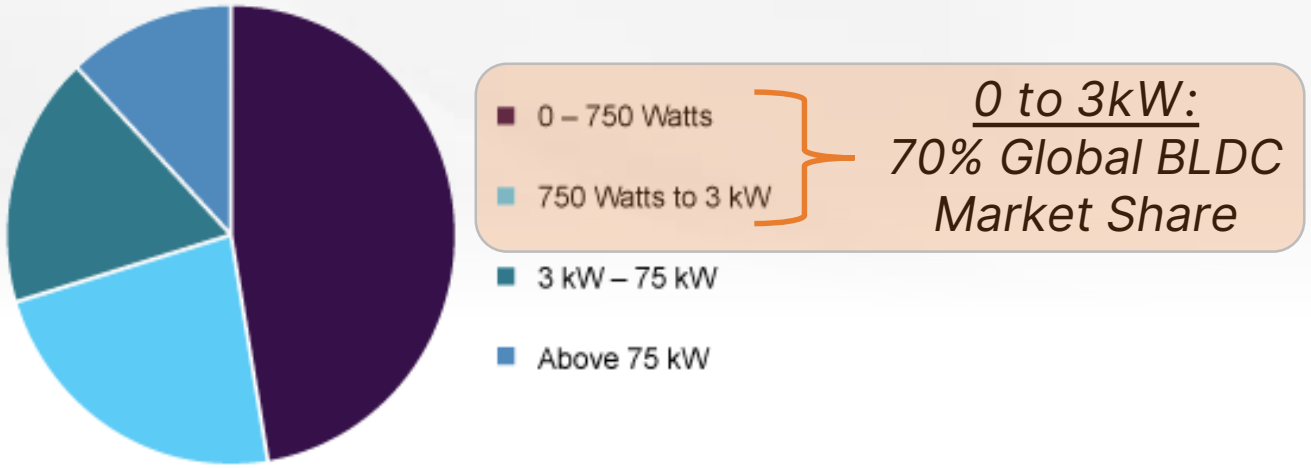
- *BLDC & Robotics Market*
- *BLDC Intro*
  - *6-step Trapezoidal Commutation Sequence*
- *"1st Order Approximation" BLDC Gate Drive to Switch (MOSFET/IGBT/IPMs) Matching Tables:*
  - *up to 6kW*
  - *12V, 24V, 48V, 60V, 120V, 200V, 300V, 400V & 650V*
- *On Line BLDC Design Tool for IPMs*
- *onsemi Product Portfolios*
  - *Gate Drivers*
  - *FET's*
  - *IGBT's*
- *Americas Robotics Customer List by Region*

Public Information

BLDC Market & Applications

Global BLDC Market: $17.1B (2020)

Global BLDC Market Share, by Power Output (%):



0 to 3kW:
70% Global BLDC Market Share

Source: www.grandviewresearch.com

0 – 3kW BLDC Applications:

- *Fans,*
- *Pumps,*
- *Compressors,*
- *CNC Machine Tools,*
- *Domestic Appliances:*
  - *refrigerator, freezer, air conditioner, dish washer, washing machine, humidifiers, food processor, blenders, vacuum cleaner*
- *HVAC*
- *Garden & Power Tools*
- *Automotive*
- *eBikes*
- *Medical*
  - *Ventilators*
  - *Oxygen Concentrators*
  - *Hospital bed Control*
  - *Wheel Chairs*
- *Dentistry Tools*
- *Factory 4.0*
- *Drones*
- *Garage & Gate Systems*
- *Robotics*

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Global Robotic Segments & CAGR

Cobot – Collaborative Robot (Human Interaction)
AMR - Autonomous Mobile Robot
AGV - Automated Guided Vehicle
UAV – Unmanned Aerial Vehicle (Drone)

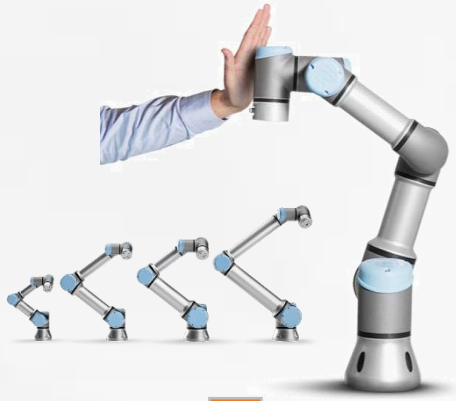
Industrial Robots



Global CAGR:
14.11%
(2019 – 2024)
RESEARCH AND MARKETS

Smart Robots

Collaborative



Global CAGR:
41.8%
(2020 – 2025)
Market Data Forecast

Mobile Robots

Warehouse



Global CAGR:
11%
(2019 – 2025)
GRAND VIEW RESEARCH

Delivery



Global CAGR:
49%
(2018 – 2026)
Mordor Intelligence

Drones



Global CAGR:
49%
(2020 – 2030)
RESEARCH AND MARKETS

Smarter (AI)

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All Robots Have Motors

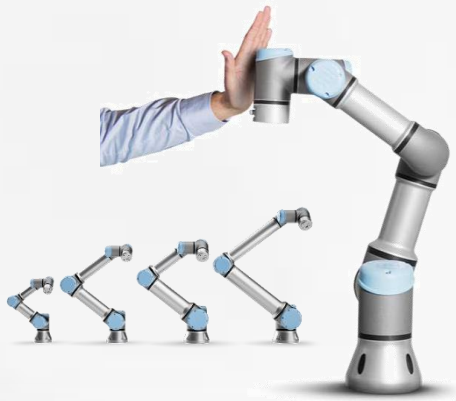
Cobot – Collaborative Robot (Human Interaction)
AMR - Autonomous Mobile Robot
AGV - Automated Guided Vehicle
UAV – Unmanned Aerial Vehicle (Drone)

Industrial Robots



Smart Robots

Collaborative



Mobile Robots

Warehouse



Delivery



Drones





Attributes

- *Efficient (Longer Battery Life)*
- *Compact (High Power Density)*
- *Robustness & Extended Life*
- *High Torque @ Low Speeds*
- *Dynamic Response*
- *Smooth Operation*
- *Low Thermals*
- *Low Noise*

Public Information

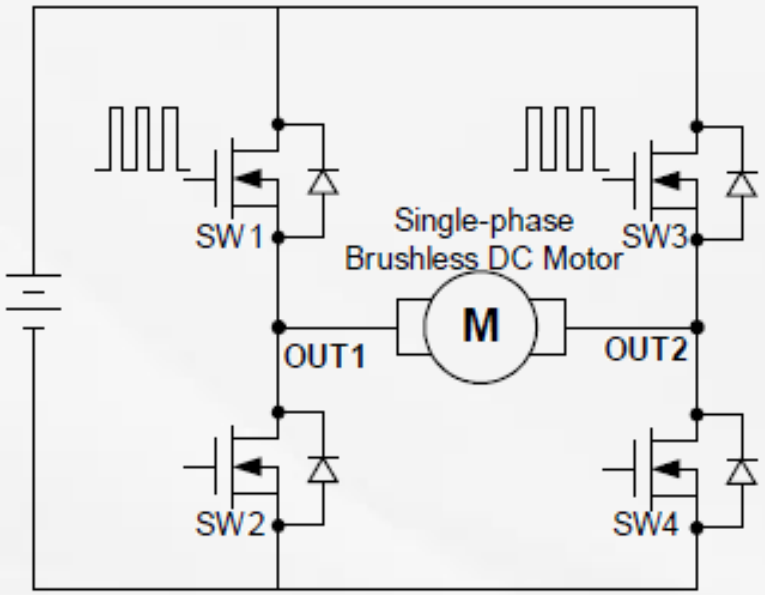
Motor Type Comparison

Feature:	BLDC Motor:	Brushed Motor:	BLDC Advantages:
Commutation	Electronic commutation based on rotor position information	Mechanical Brushes and commutator	Transistors replace mechanical brushes
Efficiency	High	Moderate	Transistors based drives operate very efficiently
Maintenance	Little/none	Periodic	No brushes/commutator maintenance
Thermal Performance	Better	Poor	Only the armature windings generate heat, which is the stator and is connected to the outside case of the BLDC. The case dissipates heat better than the rotor located inside of the brushed DC motor.
Power Density: Output Power / Frame Size (Ratio)	High	Moderate/Low	Modern permanent magnet and no rotor losses.
Speed /Torque Characteristics	Flat	Flat	No brush friction to reduce useful torque.
Dynamic Response	Fast	Slow	Lower rotor inertia because of permanent magnets.
Speed Range	High	Low	No mechanical limitation imposed by brushes or commutator.
Electric Noise	Low	High	No arcs from brushes to generate noise, causing EMI issues.
Lifetime	Long	Moderate	No brushes and commutator

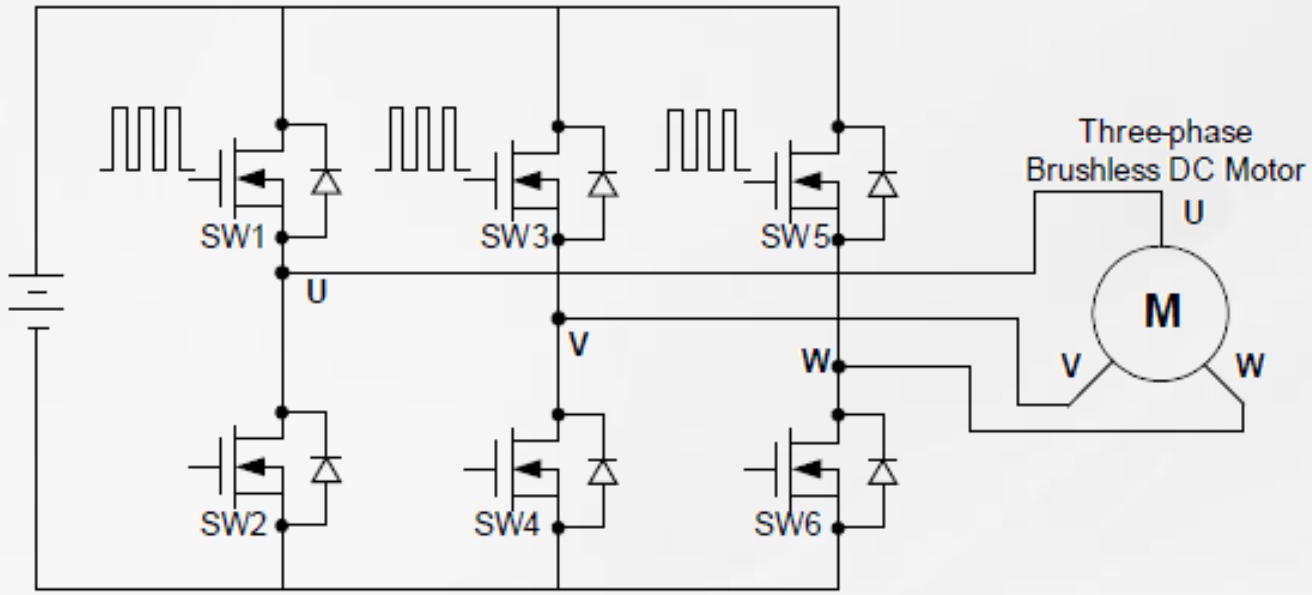
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BLDC Motor Drive Generic Block Diagram



(a) H-bridge

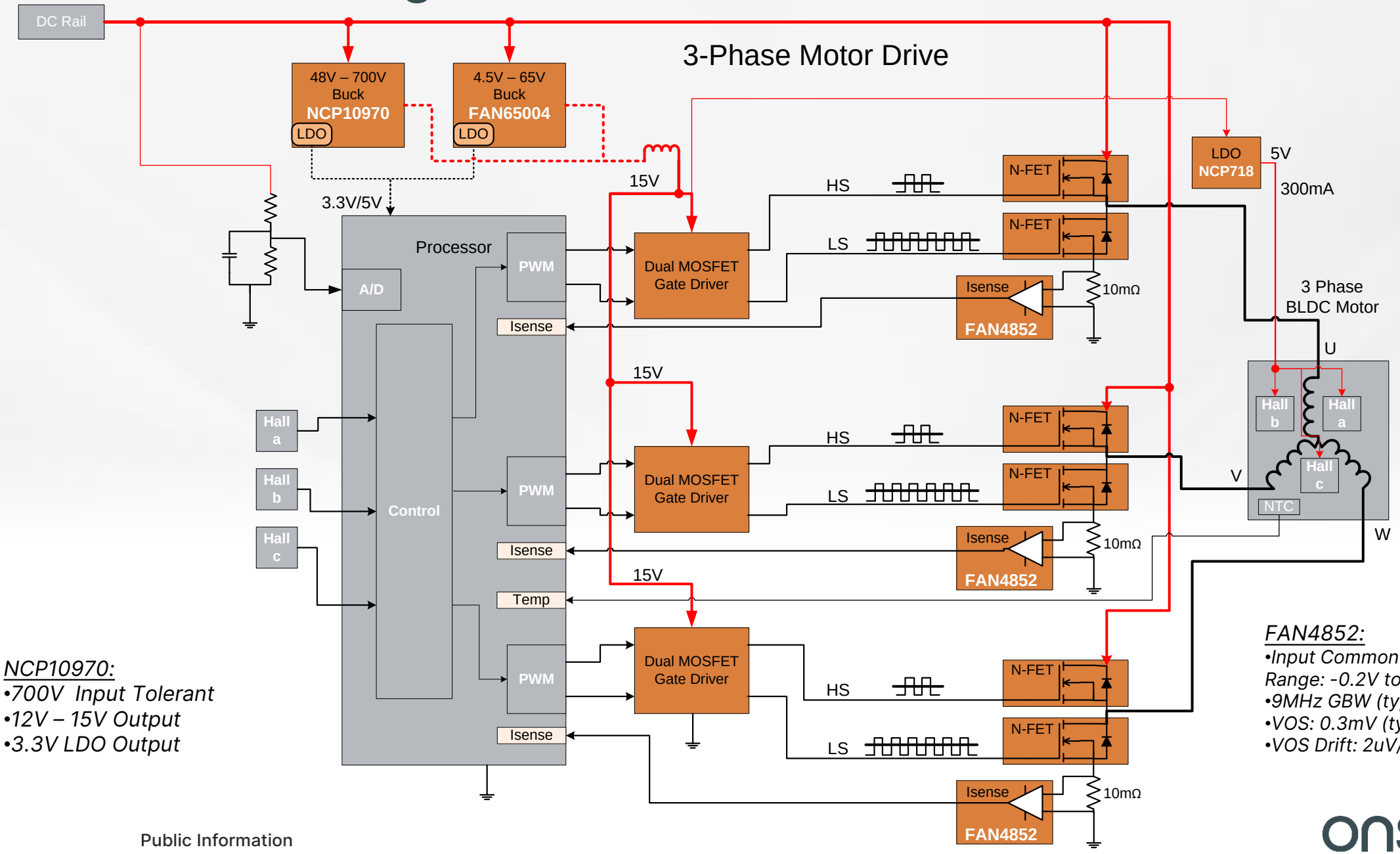


(b) Three-phase bridge

	1-phase:	*3-phase:*
Quiet:	*Moderate*	*Excellent*
Efficiency:	*Good*	*Excellent*

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3-Phase Block Diagram (12V to 700V DC Rail) N-FET's



NCP10970:
- *700V Input Tolerant*
- *12V – 15V Output*
- *3.3V LDO Output*

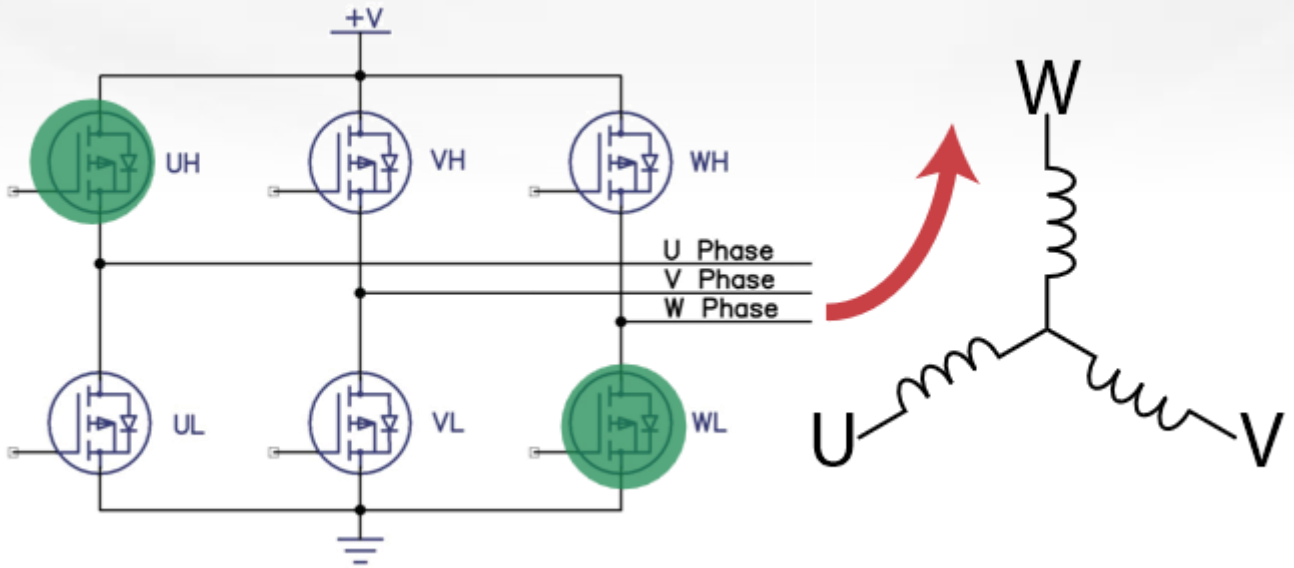
FAN4852:
- *Input Common Mode Range: -0.2V to 3.8V*
- *9MHz GBW (typ)*
- *VOS: 0.3mV (typ).*
- *VOS Drift: 2uV/⁰C (max).*

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Trapezoidal – What is It?

Trapezoidal Commutation (a.k.a. 6-Step Control) is a basic control scheme for 3-phase BLDC motors where:

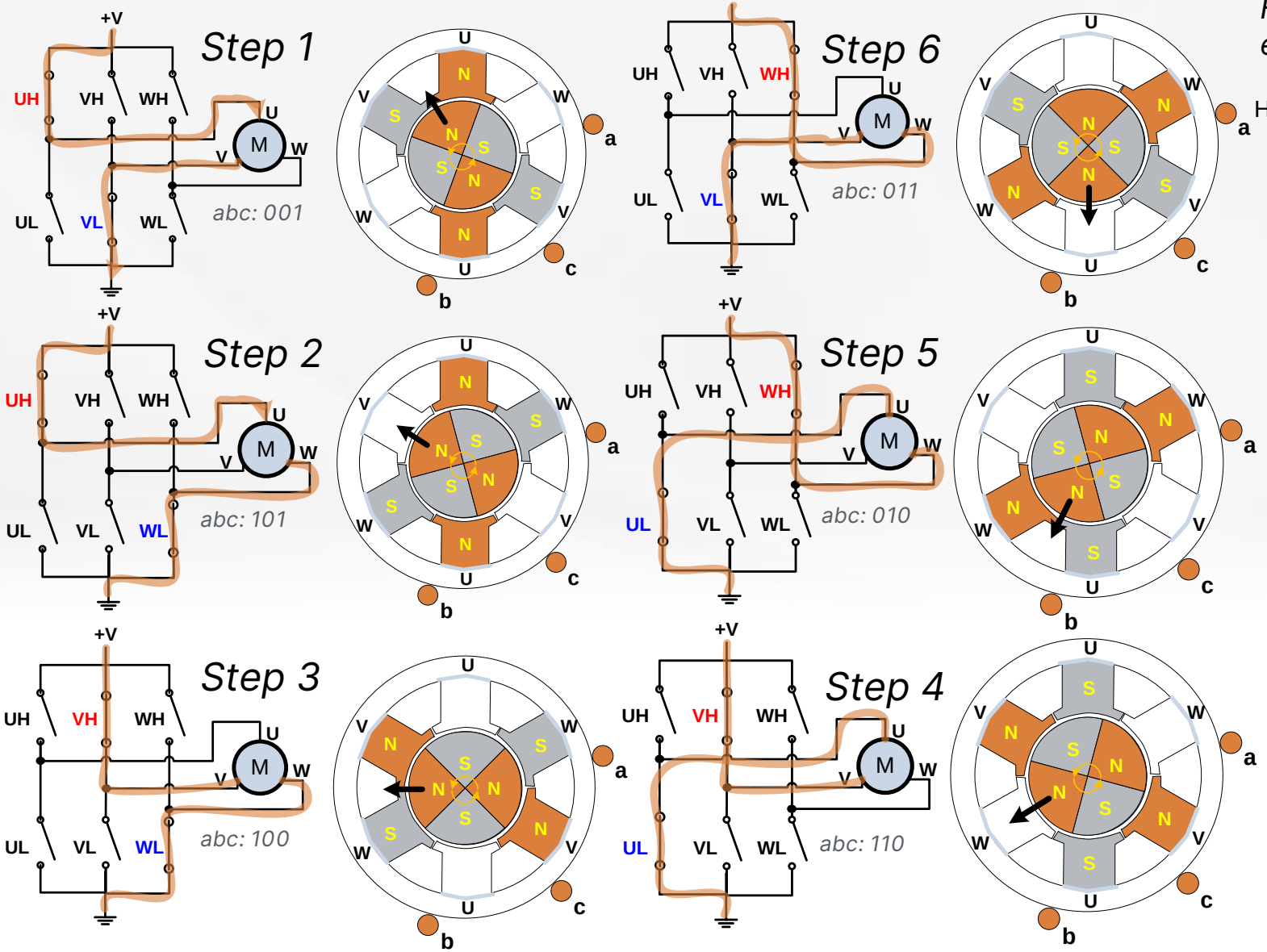
- *Current flows through only two phases at any moment in time, with the third phase floating.*
- *Only two power switches(MOSFET or IGBTs) are permitted to be enabled simultaneously.*
- *There are six discrete states of power application to the motor.*

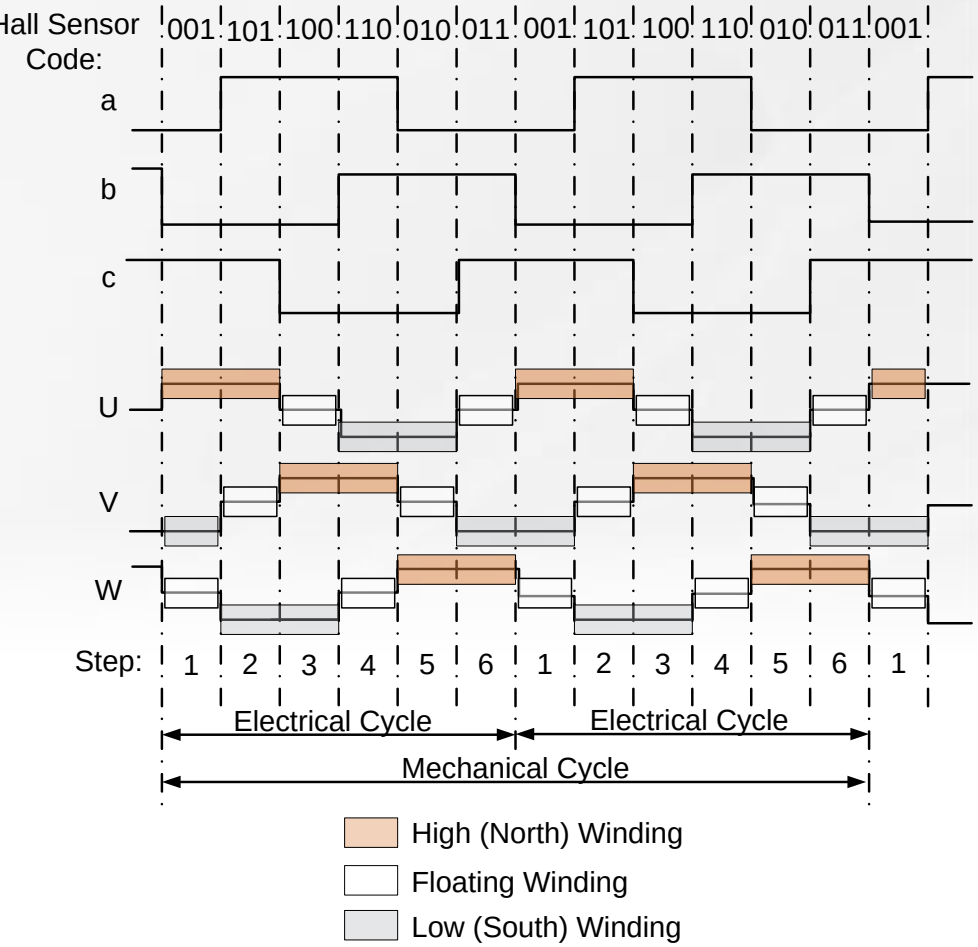


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Trapezoidal – Six Power Semi States

Hall (a, b, c) feedback decoded to a lookup table for FET Control and Commutation Sequencing (Trapezoid) every 60⁰ electrical, 30⁰ mechanical rotation.





Hall Sensors:

- *120⁰ Phase Shift*
- *Rotor North = Logic "1"*

33% Duty Cycle for each FET (not inc PWM)

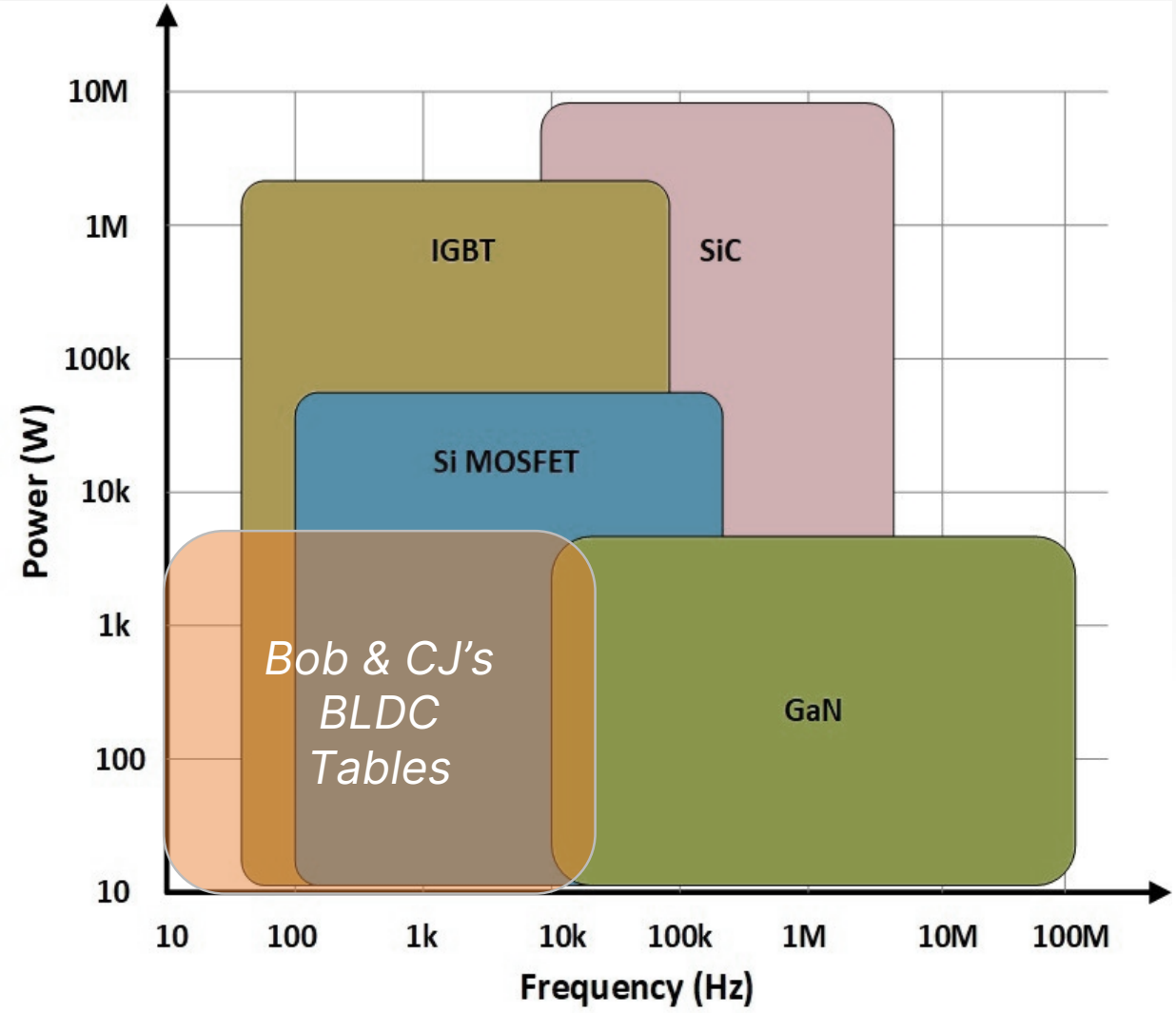
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BLDC Commutation Methods

	Trapezoidal (Trap)	Sinusoidal (Sine)	Field-Oriented Control (FOC)
Efficiency	High	Medium	High
Peak Torque	High	Medium	High
Acoustic Noise	High	Low	Medium
Torque Ripple	High (Sine+17%)	Low	Medium
MCU Capability	Low	Medium	High
Precision	Low	Low	High
Complexity/Skill	Low	Medium	High
ON Semi Solutions	Yes	Yes	Yes

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Power Switch Applications - Explained



- **Silicon MOSFET**
  - ✓ Low to mid-power applications
  - ✓ Reached theoretical performance limit
- **IGBT - Insulated Gate Bipolar Transistor**
  - ✓ Scaled for High voltage, high power
  - ✓ Least expensive per watt at high power
  - ✓ Slower but perfect for motor control
- **SiC - Silicon Carbide (breakthrough)**
  - ✓ High voltage, high current, high temperature
  - ✓ Faster switching requires gate drivers that can tolerate high dV/dt
- **GaN - Gallium Nitride (breakthrough)**
  - ✓ Low(er) voltage, high current
  - ✓ Fastest switching (higher dV/dt)
  - ✓ Narrow gate drive voltage range

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MOSFET & Gate Drive Selection Guidance

3-Phase BLDC (1st order Approximation)

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BLDC Design 1st Order Approximation… Starting Point

Customer Decision (Fractal) Tree

BLDC Electronics Selection:

Its Complicated…

1st Order Approximation New Starting Point

Customer A Final Decision

Portfolios of FETs/IGBT's/Gate Driver Old Starting Point

Customer B Final Decision

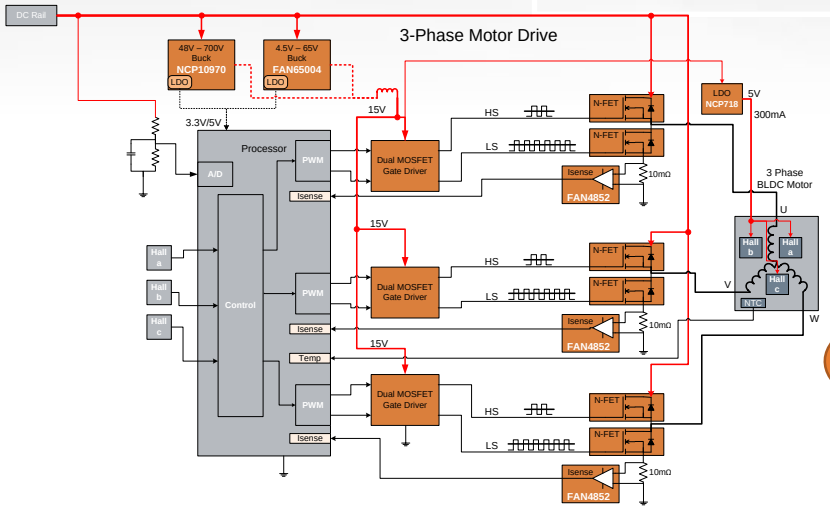
Many more complex decisions to be made

Customer C Final Decision

Example:

24V, 1 ¼ HP Motor:

What is the correct Gate Driver and Switch?



Considerations:

V_{DSS}, R_{DSON}, Q_G, $R_{\theta JA}$, $R_{\theta JC}$, T_J, I_{PHASE}, I_D
V_{CES}, $V_{CE(SAT)}$, I_C, E_{TS}, Packaging
i_G, V_{UVLO}, Cost, Thermals

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MOSFET $R_{DS(ON)}$ Effects, Relationships and Approximations

Drain Current I_D: ↑

Thermals & (Packaging) $R_{\theta JA}$ & T_J: ↓

Efficiency: ↑

Cost: ↑

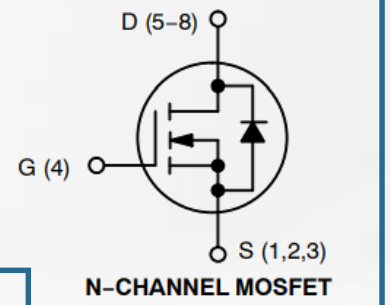
Conduction Losses P_D: ↓

Gate Charge Q_G: ↑

Customer's Decision:
1) *Application*
2) *Priorities*

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$V_{(BR)DSS}$	$R_{DS(ON)}$ MAX	I_D MAX
60 V	19.6 mΩ @ 10 V	28 A



Drain Current I_D: ↓

Thermals & Packaging $R_{\theta JA}$ & T_J: ↑

Efficiency: ↓

Cost: ↓

Conduction Losses P_D: ↑

Gate Charge Q_G: ↓

? ? ? ?

Lower $R_{DS(ON)}$ ⟵ ⟶ *Higher $R_{DS(ON)}$*

1st Order Approximation: w/o Customer Input →

$R_{DS(ON)}$ Selection:
Based on Cost vs Lowest RDSON while maintaining ~ 25°C J_T Headroom below J_T (max) For "normal operation" @ 85°C Ambient

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Junction Temperature, Packaging, Heat Sinks & Thermals

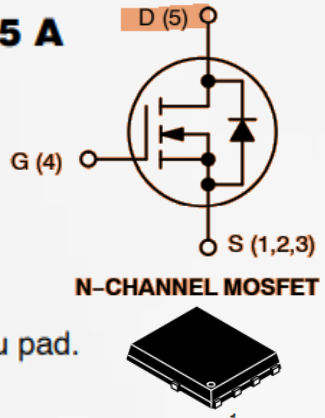
Example: Surface Mount Package w/o Heat Sink

NTMFS5C612NL **60 V, 1.5 mΩ, 235 A**

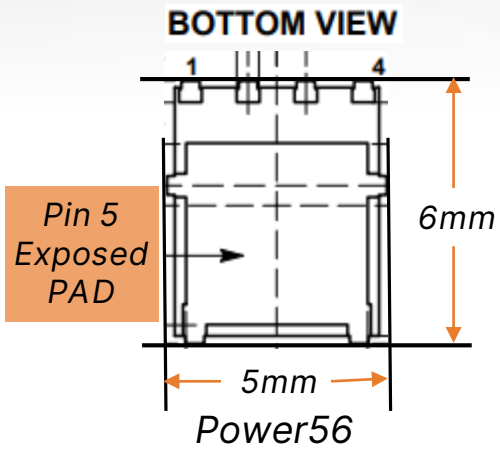
THERMAL RESISTANCE MAXIMUM RATINGS

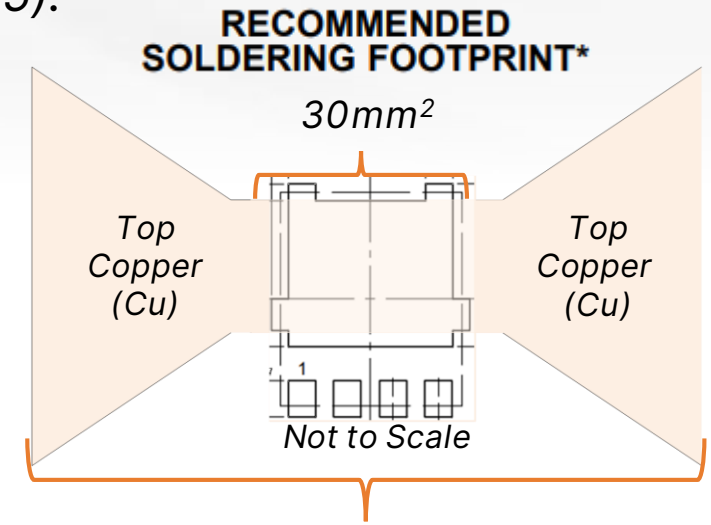
Parameter	Symbol	Value	Unit
Junction–to–Ambient – Steady State (Note 2)	$R_{\theta JA}$	39	°C/W
Operating Junction and Storage Temperature	T_J, T_{stg}	−55 to +175	°C

2. Surface–mounted on FR4 board using a 650 mm^2, 2 oz. Cu pad.



If 1W Power Dissipation @ 85⁰C Ambient Temp, then T_J = 124⁰C, or (39 + 85).





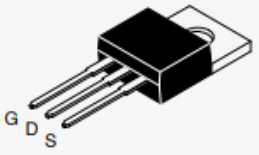
$T_J = P_{DISS} \times R_{\theta JA} + Ambient$

Example: Through Hole Package w/ Heat Sink

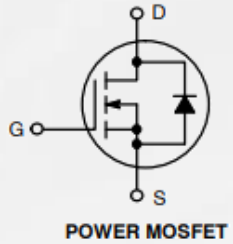
FCP190N65S3R0 **650 V, 17 A, 190 mΩ**

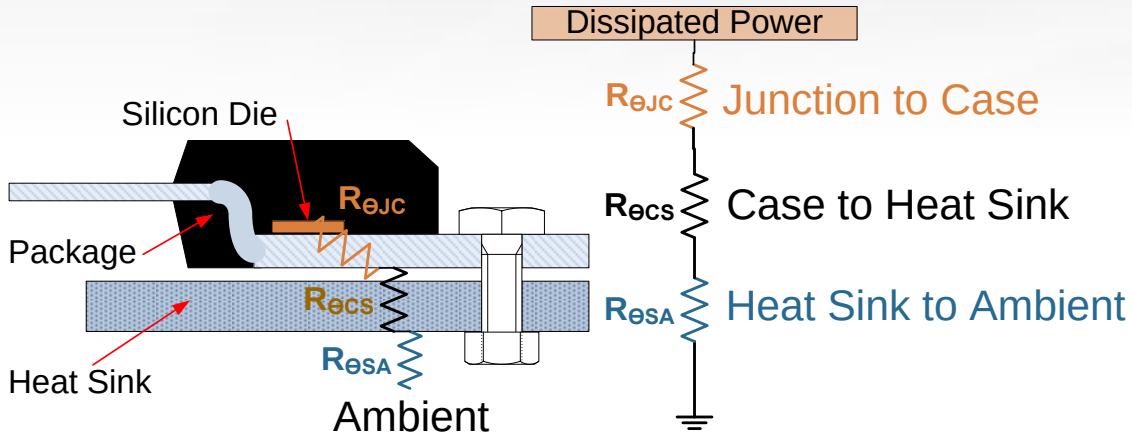
THERMAL CHARACTERISTICS

Symbol	Parameter	Value	Unit
$R_{\theta JC}$	Thermal Resistance, Junction to Case, Max.	0.87	°C/W
T_J, T_{STG}	Operating and Storage Temperature Range	−55 to +150	°C



If 1W Power Dissipation @ 85⁰C Ambient, then T_J = 85.87⁰C, or (0.87 + 85), assumes $R_{\theta CS}$ = 0, $R_{\theta SA}$ =0.





$T_J = P_{DISS} \times (R_{\theta JC} + R_{\theta CS} + R_{\theta SA}) + Ambient$

Public Information

MOSFET V_{DDS}, I_{PHASE}, Packaging and Max TJ @ 85^{0}C Ambient

Given:
1/4HP, 186W, Motor w/ 24V Rail

Selection Criterion (1st order approximation) Example:

N Channel MOSFET:

1) Voltage Rating V_{DSS}: ~ 2x Motor Voltage (24V), or ~60V

2) FET Current Rating (I_D): ~3x I_{PHASE} @ 25C (Motor Stall/Start up Condition).

Where:

$$I_{PHASE} = (2 \times P_{OUT} \times \sqrt{2}) / 3 \times V_{BUS} \times MI \times PF$$

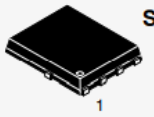
I_{PHASE} = Motor Phase Current, Amps
P_{OUT} = Electrical Power Output of Inverter to Motor, or 186.25W
PF = Motor Power Factor, 0.0 – 1.0, 1.0 is ideal
V_{BUS} = Motor Bus Voltage, VDC, or 24V
MI = Modulation Index, 0.0 – 1.0, typical is 0.9

I_{PHASE} (A):	3 x I_{PHASE} (A):	V_{BUS} (V):	Motor Power (W):	PF:	MI:
9.55	28.65	24	186	0.85	0.9

3) Packaging: Customer choice based on many factors like allowable space, through hole vs. smt rules, heatsink design capabilities, etc.
We selected the optimal package for size, cost and a common pcb footprint (convenient drop in replacement).

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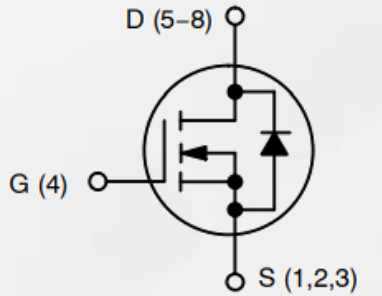
$V_{(BR)DSS}$	$R_{DS(ON)}$ MAX	I_D MAX
60 V	19.6 mΩ @ 10 V	28 A



SO−8 FLAT LEAD
CASE 488AA
STYLE 1



DFN5 5x6, 1.27P
(SO−8FL)
CASE 488AA
ISSUE N



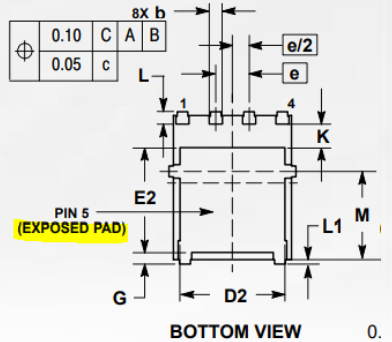
N−CHANNEL MOSFET

THERMAL RESISTANCE RATINGS

Parameter	Symbol	Value	Unit
Junction−to−Case − Steady State (Note 2)	$R_{\theta JC}$	4.8	°C/W
Junction−to−Ambient − Steady State (Note 2)	$R_{\theta JA}$	43.2	

MAXIMUM RATINGS (T_J = 25°C unless otherwise stated)

Parameter	Symbol	Value	Unit
Operating Junction and Storage Temperature Range	T_J, T_{STG}	−55 to +175	°C



4) Max T_J during normal operation, @ 85^{0}C Ambient:

P_{DISS} = I_{PHASE}^2 (A) x R_{DSON} (Ω) x 33% Duty Cycle (not including PWM)
P_{DISS} = 9.55^2 x 0.0196 x 0.33
P_{DISS} = 589mW
T_J @ 85^{0}C Ambient= P_{DISS} x $R_{\theta JA}$ + 85
T_J = 0.589 x 43.2 + 85
T_J = 110.5^{0}C
Head Room: 64.5^{0}C (175^{0}C − 110.5^{0}C)

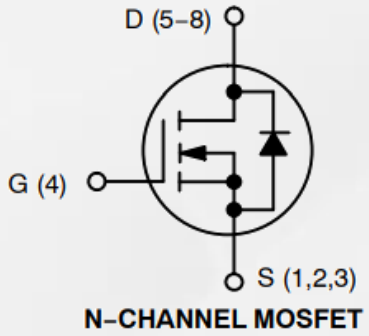
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MOSFET Total Gate Charge $Q_{G(TOT)}$

Given:
1/4HP, 186W, Motor w/ 24V Rail

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$V_{(BR)DSS}$	$R_{DS(ON)}$ MAX	I_D MAX
60 V	19.6 mΩ @ 10 V	28 A



Selection Criterion (continued):

N Channel MOSFET:

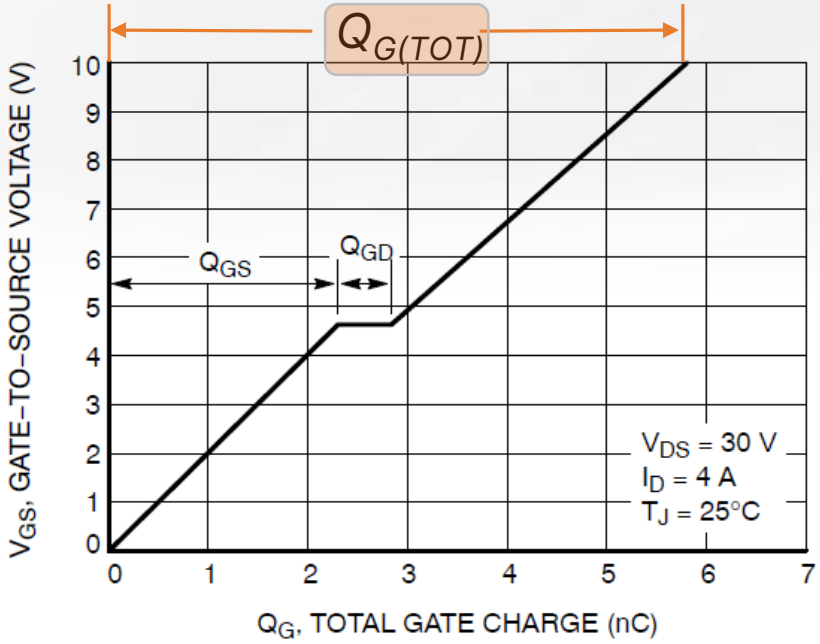
5) The Total Gate Charge $Q_{G(TOT)}$ is the amount of charge (Coulombs) that needs to be injected into the gate electrode to turn On the MOSFET fully.

Gate Drive i_G can be calculated as:

i_G = $Q_{G(TOT)}$ ÷ On/Off Time

CHARGES AND CAPACITANCES

Input Capacitance	C_{ISS}	V_{GS} = 0 V, f = 1 MHz, V_{DS} = 30 V		355		pF
Output Capacitance	C_{OSS}			260		
Reverse Transfer Capacitance	C_{RSS}			4.9		
Total Gate Charge	$Q_{G(TOT)}$	V_{GS} = 10 V, V_{DS} = 30 V, I_D = 4 A		5.8		nC
Threshold Gate Charge	$Q_{G(TH)}$			1.4		
Gate–to–Source Charge	Q_{GS}			2.3		
Gate–to–Drain Charge	Q_{GD}			0.53		

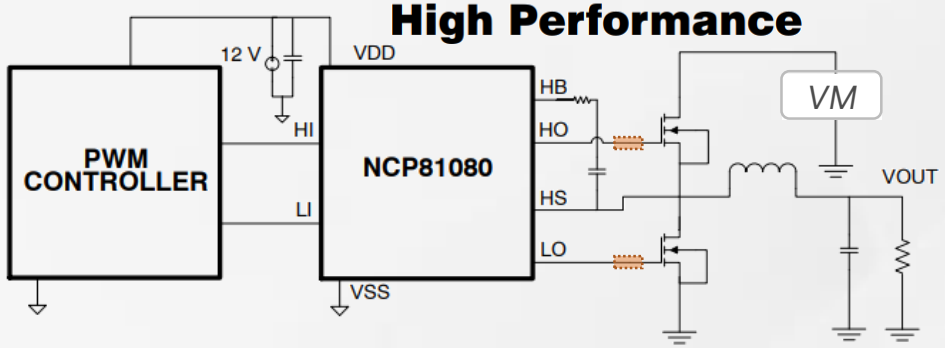


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MOSFET Gate Drive i_G Calculation

Given:
1/4HP, 186W, Motor w/ 24V Rail

NCP81080 Dual MOSFET Gate Driver, High Performance



Selection Criterion (conservative):

Gate Drive (HS/LS):

1) HS Voltage Rating V_{HS}: ~2x VM
2) Gate Drive i_G: >116mA (see below)

Parameter		Min	Nom	Max	Unit
V_{DD}	Supply Voltage Range	5.5	12	20	V
V_{HS}	Voltage on HS (DC)	−10		180	
V_{HB}	Voltage on HB	V_{HS} + 5.5		V_{HS} + 20	

Total Gate charge $Q_{G(TOT)}$ is the amount of charge (Coulombs) that needs to be injected into the gate electrode to turn ON the MOSFET.

Gate Drive i_G can be calculated as
$i_G = QG \div$ *On/Off Time*

50ns ON/Off Example:
$i_G = \frac{5.8\ nC}{50\ ns}$, *then* $i_G =$ *116mA*

Source Current: Turn FET ON

Sink Current: Turn FET OFF

Unless otherwise stated: $T_A = T_J = -40°C$ to $140°C$; VDD = VHB = 12 V, VHS = VSS = 0 V, No load on LO or HO

	Parameter	Test Condition	Min	Typ	Max	Units
LO GATE DRIVER	Peak Pull−Up Current *(Source)*	V_{LO} = 0 V		0.55		A
	Peak Pull−Down Current *(Sink)*	V_{LO} = 12 V		0.8		
HO GATE DRIVER	Peak Pull−Up Current *(Source)*	V_{HO} = 0 V		0.55		A
	Peak Pull−Down Current *(Sink)*	V_{HO} = 12 V		0.8		

OUTPUT RISE AND FALL TIME

t_R	LO, HO	C_{LOAD} = 1000 pF		19		ns
t_F	LO, HO	C_{LOAD} = 1000 pF		17		

Series gate resistors can be placed between the NCP81080 LO/HO and the respective MOSFET Gate inputs to control the rise/fall times for EMI considerations, as well as switching losses.

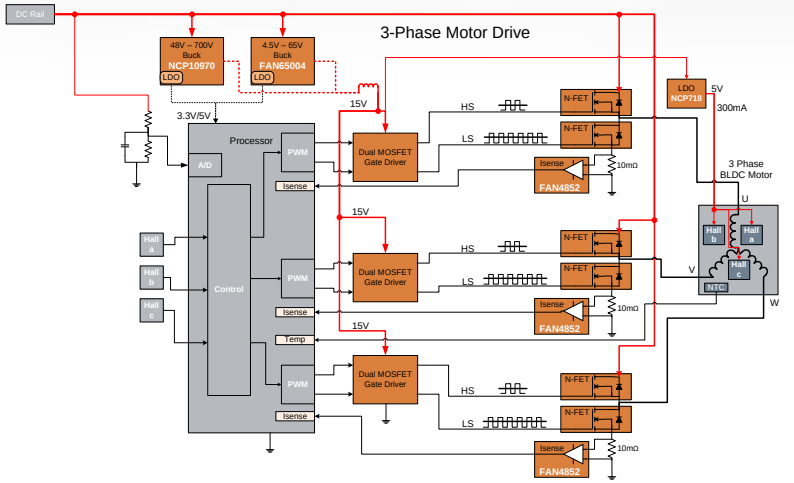
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3-PH BLDC Gate Driver/FET Guidance, 1st Order Approximation

Motor HP:	Power:	DC Rail (VM):	DC Motor Current (I_{PHASE}) RMS:	N-FET Examples:	Rdson @ VGS =10V	Total Gate Charge QG_{TOT}:	Calculated FET Gate Drive (i_G) 50ns:	N-FET Package:	Heat Sink:	Gate Driver (source / sink):	Gate Driver Example:
1/8	93W	12V	9.55A	NTTFS4929 (30V)	11mΩ	16.3 nC	0.326 A	3.3 x 3.3mm	No	0.35A/0.65A	FAN7888 (1x)
1/4	186W		19.09A	NTMFS4821N (30V)	6.95mΩ	25nC	0.5A	5 x 6mm		0.5A/0.8A	NCP81080 (3x)
1/2	372W		38.18	NTMFS4C022N (30V)	1.7mΩ	45.2nC	0.904A			2.5A/2.5A	FAN73933 (3x)
1/4	186W	24V	9.55A	NTMFS020N06C (60V)	19.6mΩ	5.7nC	0.114A			0.25A/0.5A	NCP5109 (3x)
1/2	372W		19.09A	NTMFS5844NL (60V)	12mΩ	30nC	0.6A			2.5A/2.5A	FAN73933 (3x)
1	745W		38.18A	NTMFS5C628NL (60V)	2.4mΩ	52nC	1.04A			2.5A/2.5A	FAN73933 (3x)
1 1/4	931.25W		47.73A	NTMFS5C612NL (60V)	1.5mΩ	91nC	1.82A			2.5A/2.5A	FAN73933 (3x)
1 1/2	1117.5W		57.27A	NTMFS5C604NL (60V)	1.2mΩ	120nC	2.4A			3.5A/3A	NCP51530 (3x)

1st Order Approximation Considerations (conservative):

1. Trapezoidal Commutation (15kHz): 33% Duty Cycle for each FET
2. Junction Isolated Gate driver, 85^{0}C Max Ambient Temp.
3. Matching Gate Drive (i_G) Amps, to FET Gate Charge (QG_{TOT}) nC, for a worst case 50ns On/Off Time.
4. FET Power Dissipation Max = ~25^{0}C below max operating die temp (no Heat Sink), ~50^{0}C w/ Heat Sink
5. FET V_{DSS} Voltage = 2-3x Motor Voltage.
6. FET I_D Rating 3x I_{PHASE}



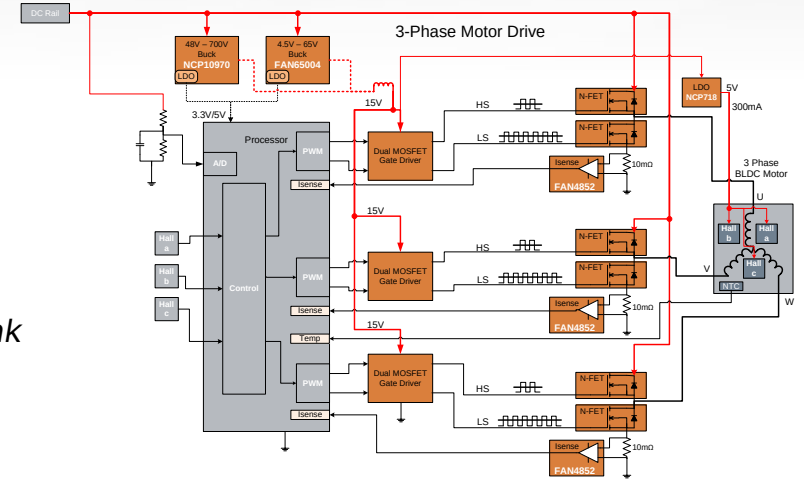
Public Information

3-PH BLDC Gate Driver/FET Guidance, 1st Order Approximation

Motor HP:	Power:	DC Rail (VM):	DC Motor Current (I_{PHASE}) RMS:	N-FET Examples:	Rdson @ VGS =10V	Total Gate Charge QG_{TOT}:	Calculated FET Gate Drive (i_G) 50ns:	N-FET Package:	Heat Sink:	Gate Driver (source / sink):	Gate Driver Example:
1/4	186.25W	48V	4.77A	NTMFS015N10MCL (100V)	12.2mΩ	19nC	0.38A	5 x 6mm	No	0.5A/0.8A	NCP81080 (3x)
1/2	372.5W		9.55A	NTMFS015N10MCL (100V)	12.2mΩ	19nC	0.38A			0.5A/0.8A	NCP81080 (3x)
1	745W		19.09A	NTMFS005N10MCL (100V)	5.1mΩ	55nC	1.1A			2.5A/2.5A	FAN73933 (3x)
2	1490W		38.18A	NTMTSC002N10MC (100V)	2mΩ	89nC	1.78A	8 x 8mm		2.5A/2.5A	FAN73933 (3x)
1/4	186.25W	60V	3.82A	NTMFS008N12MC (120V)	8mΩ	33nC	0.66A	5 x 6mm		2.5A/2.5A	FAN73933 (3x)
1/2	372.5W		7.64A	NTMFS008N12MC (120V)	8mΩ	34nC	0.68A			2.5A/2.5A	FAN73933 (3x)
1	745W		15.27A	NTMFS008N12MC (120V)	8mΩ	34nC	0.68A			2.5A/2.5A	FAN73933 (3x)
2	1490W		30.55A	NTBGS4D1N15MC (150V)	4.1mΩ	88.9nC	1.778A	D2PAK7		2.5A/2.5A	FAN73933 (3x)

1st Order Approximation Considerations (conservative):

1. Trapezoidal Commutation (15kHz): 33% Duty Cycle for each FET
2. Junction Isolated Gate driver, 85^{0}C Max Ambient Temp.
3. Matching Gate Drive (i_G) Amps, to FET Gate Charge (QG_{TOT}) nC, for a worst case 50ns On/Off Time.
4. FET Power Dissipation Max = ~25^{0}C below max operating die temp (no Heat Sink), ~50^{0}C w/ Heat Sink
5. FET V_{DSS} Voltage = 2-3x Motor Voltage.
6. FET I_D Rating 3x I_{PHASE}



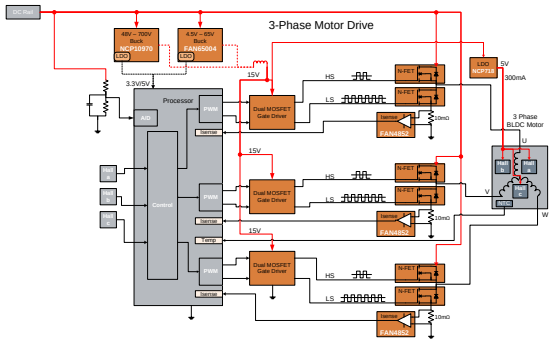
Public Information

3-PH BLDC Gate Driver/FET Guidance, 1st Order Approximation

Motor HP:	Power:	DC Rail (VM):	DC Motor Current (I_{PHASE}) RMS:	N-FET Examples:	Rdson @ VGS =10V	Total Gate Charge QG_{TOT}:	Calculated FET Gate Drive (i_G) 50ns:	N-FET Package:	Heat Sink:	Gate Driver (source / sink):	Gate Driver Example:
1/4	186.25W	120V	1.91A	FQB11N40C (400V)	530mΩ	15nC	0.3A	D2PAK	No	0.5A/0.8A	NCP81080 (3x)
¾	558.75W		5.73A	FDP24N40 (400V)	175mΩ	46nC	0.92A	TO-220	Yes	2.5A/2.5A	FAN73933 (3x)
1 1/2	1.117kW		11.45A	FDPF44N25TRDTU (250V)	69mΩ	47nC	0.94A	TO-220F		2.5A/2.5A	FAN73933 (3x)
2 1/2	1.862kW		19.09A	FDPF44N25TRDTU (250V)	69mΩ	47nC	0.94A	TO-220F		2.5A/2.5A	FAN73933 (3x)
¼	186.25W	200V	1.15A	FDD6N50 (500V)	900mΩ	12.8nC	0.256A	DPAK	No	0.5A/0.8A	NCP81080 (3x)
1/2	372.5W		2.29A	FDP7N50 (500V)	900mΩ	12.8nC	0.256A	TO-220	Yes	0.5A/0.8A	NCP81080 (3x)
1	745W		4.58A	FCP190N65S3R0 (650V)	190mΩ	33nC	0.66A	TO-220		2.5A/2.5A	FAN73933 (3x)
1 ½	1.117kW		6.87A	FCPF190N60-F154 (600V)	199mΩ	57nC	1.14A	TO-220F		2.5A/2.5A	FAN73933 (3x)
2	1.49kW		9.16A	NTPF095N65S3H (600V)	95mΩ	58nC	1.16A	TO-220F		2.5A/2.5A	FAN73933 (3x)
4	2.98kW		18.33A	NTH4LN067N65S3H (650V)	67mΩ	80nC	1.6A	TO-247		2.5A/2.5A	FAN73933 (3x)

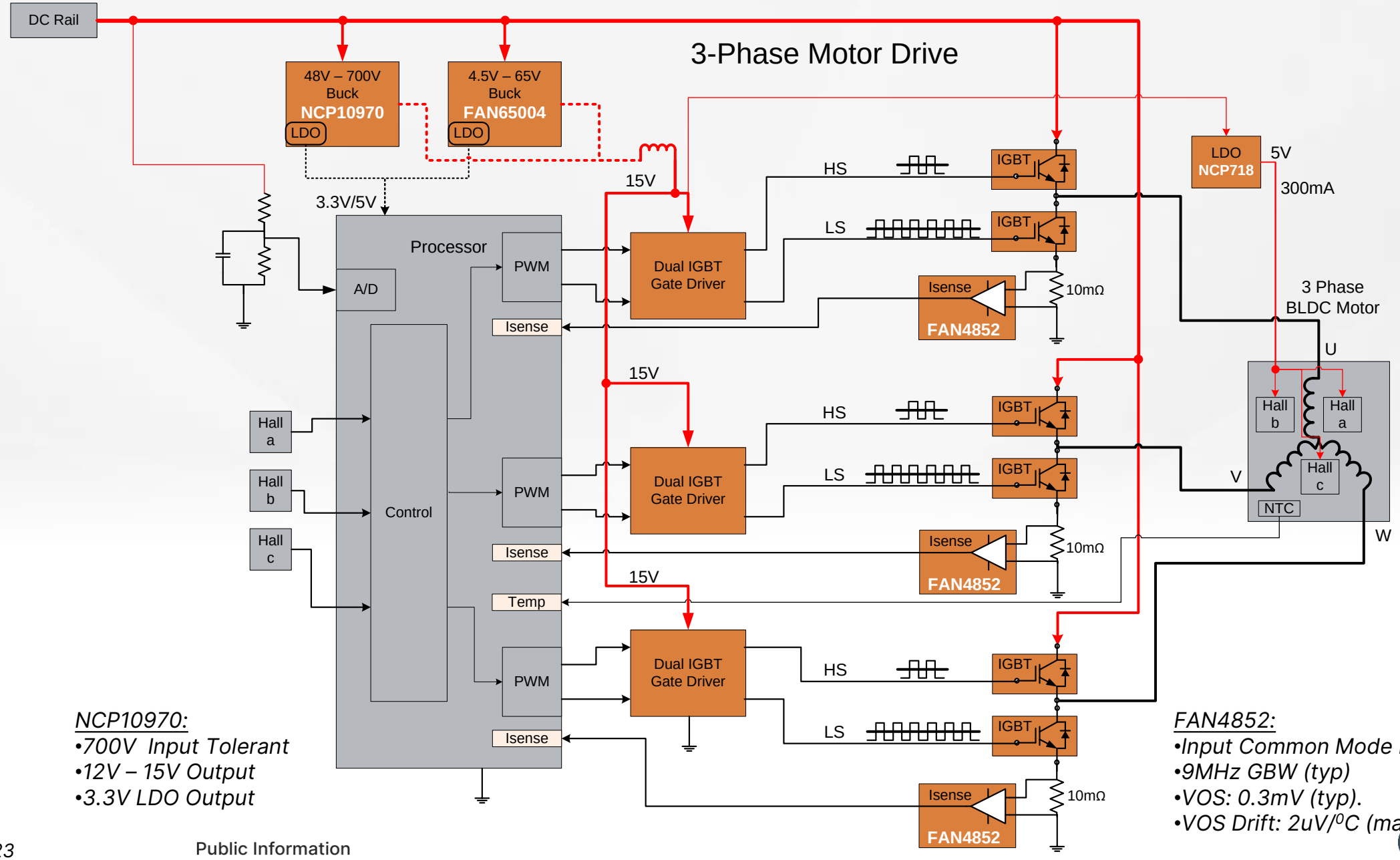
1st Order Approximation Considerations (conservative):

1. Trapezoidal Commutation (15kHz): 33% Duty Cycle for each FET
2. Junction Isolated Gate driver, 85^{0}C Max Ambient Temp.
3. Matching Gate Drive (i_G) Amps, to FET Gate Charge (QG_{TOT}) nC, for a worst case 50ns On/Off Time.
4. FET Power Dissipation Max = ~25^{0}C below max operating die temp (no Heat Sink), ~50^{0}C w/ Heat Sink
5. FET V_{DSS} Voltage = 2-3x Motor Voltage.
6. FET I_D Rating 3x I_{PHASE}



Public Information

3-Phase Block Diagram IGBT's: VM ≥ 300V



NCP10970:
- *700V Input Tolerant*
- *12V – 15V Output*
- *3.3V LDO Output*

FAN4852:
- *Input Common Mode Range: -0.2V to 3.8V*
- *9MHz GBW (typ)*
- *VOS: 0.3mV (typ).*
- *VOS Drift: 2uV/^{0}C (max).*

Public Information

IGBT & Gate Drive Selection Guidance

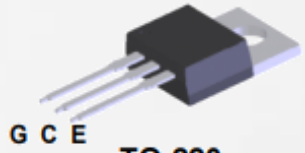
3-Phase BLDC (1st order Approximation)

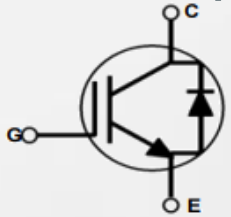
Public Information

IGBT V_{CES}, I_{PHASE}, Packaging and Max J_T @ 85^{0}C Case (Heat Sink)

Given:
1/2HP, 372.5W, Motor w/ 300V Rail

FGP10N60UNDF
600 V, 10 A
Short Circuit Rated IGBT





Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Unit
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction to Case	-	0.9	°C/W
$R_{\theta JC}$(Diode)	Thermal Resistance, Junction to Case	-	3.5	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (PCB Mount)(2)	-	62.5	°C/W

Notes:
2: Mountde on 1" square PCB (FR4 or G-10 material)

Symbol	Description	Ratings	Unit
T_J	Operating Junction Temperature	-55 to +150	°C

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
E_{ts}	Total Switching Loss		-	0.3		mJ
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 10 A, V_{GE} = 15 V	-	2	2.45	V
		I_C = 10 A, V_{GE} = 15 V, T_C = 125°C	-	2.3	-	V

Selection Criterion (1st order approximation) Example:

IGBT:

1) Voltage Rating V_{CES}: ~ 2x Motor Voltage (300V), or ~600V

2) IGBT Current Rating (I_C): ~3x I_{PHASE} @ 25C (Motor Stall Condition).

Where:

$I_{PHASE} = (2 \times P_{OUT} \times \sqrt{2}) / 3 \times V_{BUS} \times MI$

I_{PHASE} = Motor Phase Current, Amps
P_{OUT} = Electrical Power Output of Inverter to Motor, or 372.5W
PF = Motor Power Factor, 0.0 – 1.0, 1.0 is ideal
V_{BUS} = Motor Bus Voltage, VDC, or 300V
MI = Modulation Index, 0.0 – 1.0, typical is 0.9

I_{PHASE} (A):	3 x I_{PHASE} (A):	V_{BUS} (V):	Motor Power (W):	PF:	MI:
1.53	4.59	300	372.5	0.85	0.9

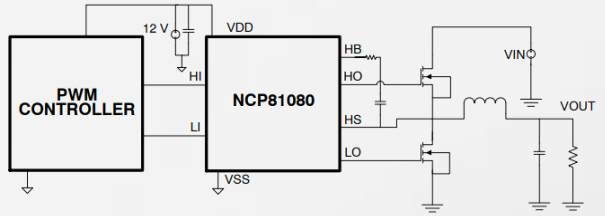
3) Packaging: Customer choice based on many factors like allowable space, through hole vs. smt rules, heatsink design capabilities, etc. We selected the optimal package for size, cost and a common pcb footprint (convenient drop in replacement).

4) Max T_J during normal operation, @ 85^{0}C Case Temp (w/ heat sink):

$P_{DISS(TOT)}$ = Switching Loss + Conduction Loss + Diode Loss
Switching Loss = E_{ts} (J) x PWM Freq. (Hz)
Switching Loss = 0.3 mJ x 15 kHz = 4.5W
Conduction Loss = I_{PHASE} (A) x $V_{CE(SAT)}$ (V)
Conduction Loss = 1.53 A x 2.3V = 3.512W
Diode Loss = ~25% of Switching Loss + Conduction Loss, or 2W
$P_{DISS(TOT)}$ = 10.02W (4.5W + 3.521W + 2W)
T_J @ 85^{0}C Ambient= P_{DISS} x $R_{\theta JC}$ + 85
T_J = (10.02W x 0.33) x 0.9 + 85
T_J = 88^{0}C
Head Room: 62^{0}C (150^{0}C – 88^{0}C)

Public Information

Gate Driver UVLO Warning

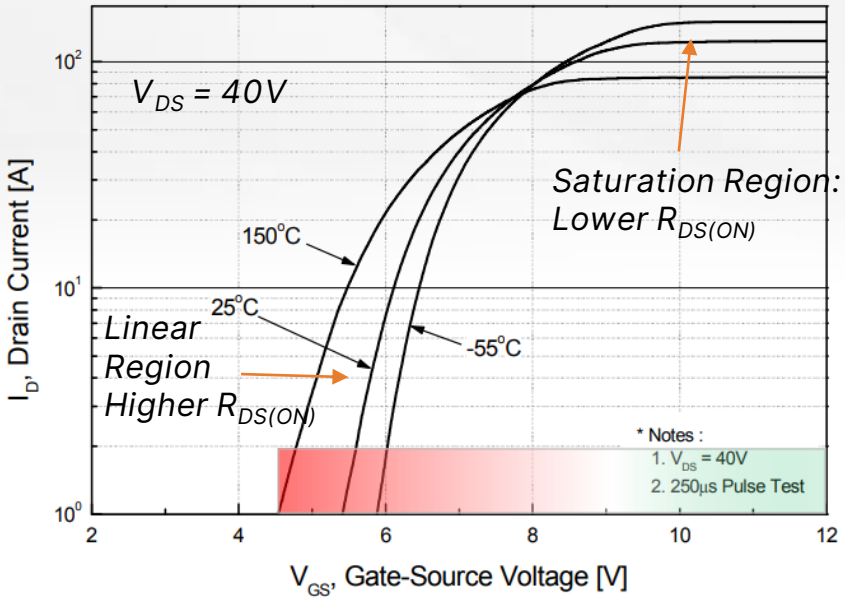


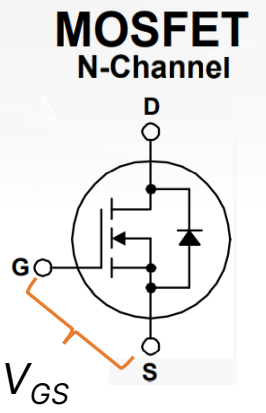
Gate Drivers UVLO (typical):

- *MOSFET: ~3.5V to 7.5V*
- *IGBT: ~ 8V to 13V*

Gate Drive VOH is a function of its VCC

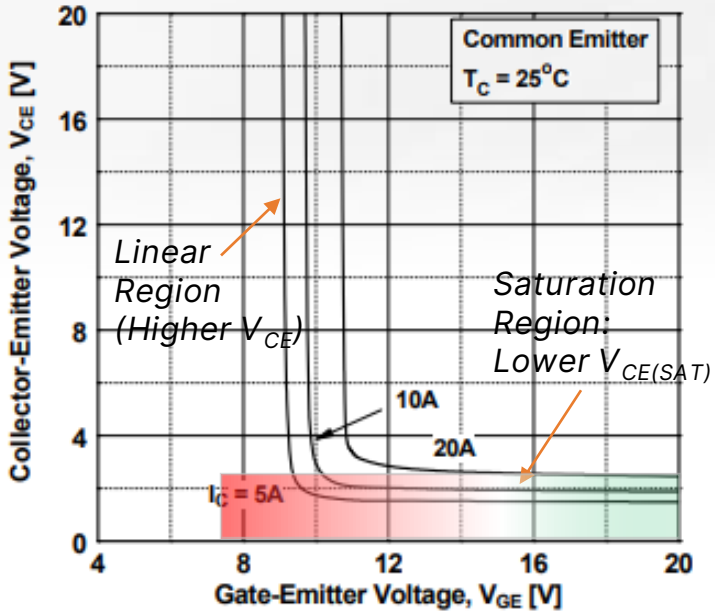
Switch:	*Channel Saturation Starts to Occur:*	*Gate Driver Type:*	*UVLO:*	*Switch Condition if Gate Driver Nears UVLO:*
MOSFET	*~ 5V*	*MOSFET*	*~3.5V to 7.5V*	*Saturation*
		IGBT	*~ 8V to 13V*	*Potentially Overdrive the Switch*
IGBT	*~ 8V*	*IGBT*	*~ 8V to 13V*	*Saturation*
		MOSFET	*~3.5V to 7.5V*	*Linear*

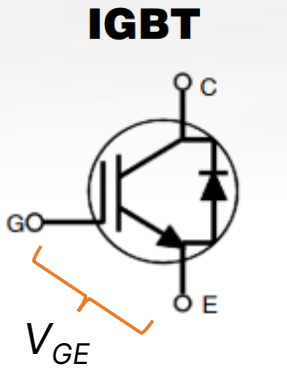




FDPF44N25T

Gate Threshold Voltage $V_{GS(th)}$: ~5V
Conduction Loss: I^2 x $R_{DS(ON)}$





FGP10N60UNDF

Gate Threshold Voltage $V_{GE(th)}$: ~ 8V
Conduction Loss: I x $V_{CE(SAT)}$

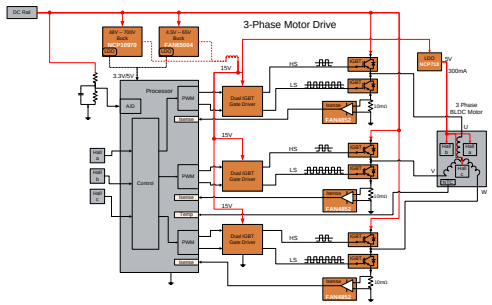
Public Information

3-PH BLDC Gate Driver/IGBT Guidance, 1st Order Approximation

Motor HP:	Power:	DC Rail (VM):	DC Motor Current (I_{PHASE}) RMS:	IGBT Examples:	Total Loss (W):	Total Gate Charge QG_{TOT} w/ V_{GE} 15V:	Calculated IGBT Gate Drive (i_G) 200ns:	IGBT Package:	Heat Sink:	Gate Driver (source / sink/UVLO):	Gate Driver Example:
½	372.5W	300V	1.53A	FGP10N60UNDF (600V)	10.02	37nC	0.185A	TO-220	Yes	0.35A/0.65A/8.2V	FAN7388 (1x)
1	745W		3.05A	FGP10N60UNDF (600V)	14.41	37nC	0.185A	TO-220		0.35A/0.65A/8.2V	FAN7388 (1x)
2	1.49kW		6.11A	FGAF20S65AQ (650V)	22.75	38nC	0.19A	TO-3PF		0.35A/0.65A/8.2V	FAN7388 (1x)
4	2.98kW		12.22A	FGAF40S65AQ (650V)	38.27	75nC	0.375A	TO-3PF		2.5A/2.5A/9V	FAN73933 (3x)
6	4.47kW		18.33	FGHL75T65MQDT (650V)	126.8	149nC	0.745A	TO-247-3L		2.5A/2.5A/9V	FAN73933 (3x)
½	372.5W	400V	1.15A	FGP10N60UNDF (600V)	10.02	37nC	0.185A	TO-220		0.35A/0.65A/8.2V	FAN7388 (1x)
1	745W		2.29A	FGP10N60UNDF (600V)	14.41	37nC	0.185A	TO-220		0.35A/0.65A/8.2V	FAN7388 (1x)
2	1.49kW		4.58A	FGAF20S65AQ (650V)	22.75	38nC	0.19A	TO-3PF		0.35A/0.65A/8.2V	FAN7388 (1x)
4	2.98kW		9.16A	FGAF30S65AQ (650V)	35.07	58nC	0.29A	TO-3PF		0.35A/0.65A/8.2V	FAN7388 (1x)
6	4.47kW		13.75A	FGHL50T65MQDT (650V)	80.23	99nC	0.495A	TO-247		2.5A/2.5A/9V	FAN73933 (3x)
8	5.96kW		18.33A	FGA6065ADF (650V)	114.4	84nC	0.420A	TO-3P-3L		2.5A/2.5A/9V	FAN73933 (3x)

1st Order Approximation Considerations (conservative):

1. Trapezoidal Commutation (15kHz): 33% Duty Cycle for each IGBT
2. Junction Isolated Gate driver, 85^{0}C Max Ambient Temp.
3. Matching Gate Drive (i_G) Amps, to IGBT Gate Charge (QG_{TOT}) nC, for a worst case 200ns On/Off Time.
4. IGBT Power Dissipation Max = Switching Loss (15Khz) x Conduction Loss x Diode loss
5. IGBT Power Dissipation Max = ~50^{0}C below max operating die temp w/ Heat Sink
6. IGBT V_{CES} = 2-3x Motor Voltage.
7. IGBT I_C Rating 3x I_{PHASE}



Public Information

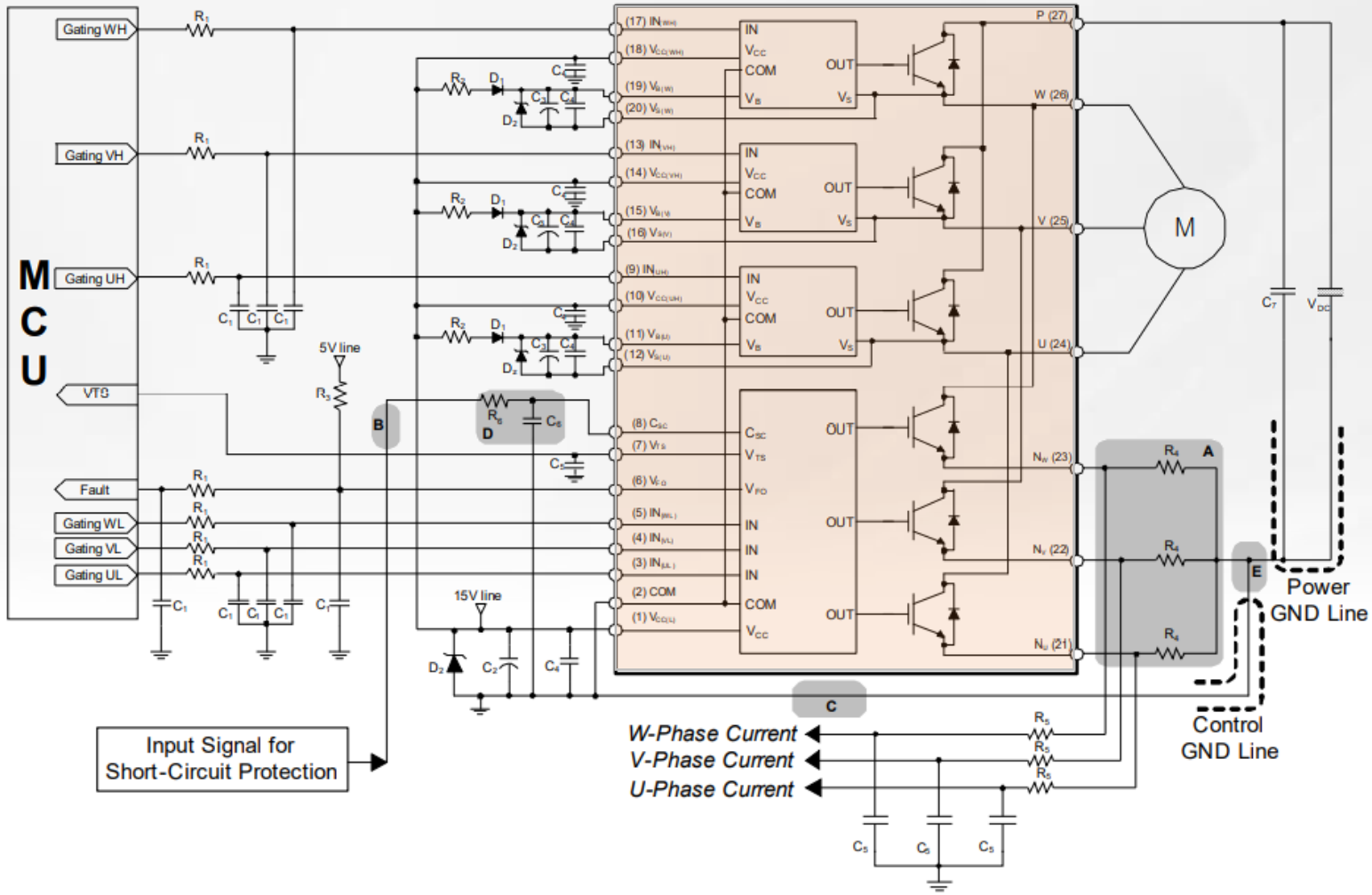
IPM (Intelligent Power Module) Example

FSBB10CH120D

Motion SPM® 3 Series

Features

- UL Certified No. E209204 (UL1557)
- 1200 V - 10 A 3-Phase IGBT Inverter with Integral Gate Drivers and Protection
- Low-Loss, Short-Circuit Rated IGBTs
- Very Low Thermal Resistance Using Al_2O_3 DBC Substrate
- Dedicated Vs Pins Simplify PCB Layout
- Separate Open-Emitter Pins from Low-Side IGBTs for Three-Phase Current Sensing
- Single-Grounded Power Supply
- LVIC Temperature-Sensing Built-In for Temperature Monitoring
- Isolation Rating: 2500 V_{rms} / 1 min.



Public Information

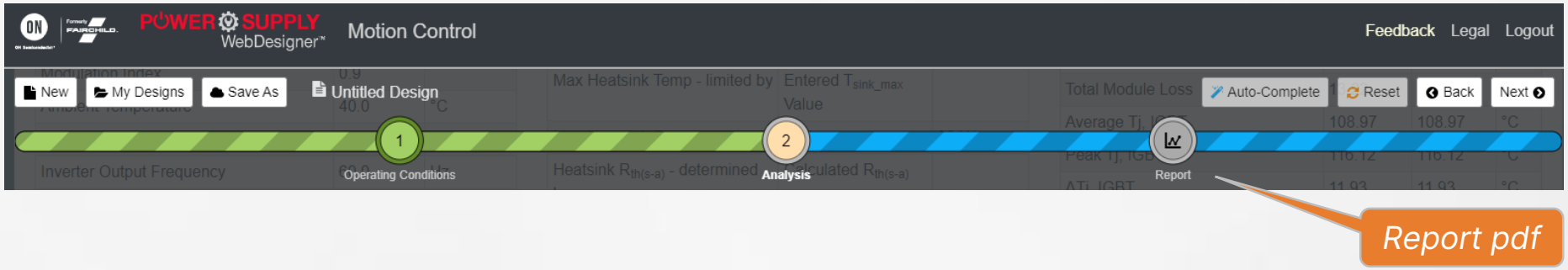
3-PH BLDC IPM Guidance, 1st Order Approximation

Motor HP:	Power:	DC Rail (VM):	DC Motor Current (I_{PHASE}) RMS:	IPM Examples:	V_{CES} Rating:	I_C Rating:	$V_{CE(SAT)}$:	IPM Package:
½	372.5W	300V	1.53A	NFAQ0860L36T	600V	8A	2.4V	DIP-S6
1	745W		3.05A	NFAQ0860L36T		8A	1.9V	DIP-S6
2	1.49kW		6.11A	FNA41560T2		15A	1.6V	SPM45
4	2.98kW		12.22A	FNB33060T		30A	1.6V	SPM3V
6	4.47kW		18.33	FNB34060T		40A	1.5V	SPM3V
½	372.5W		1.15A	STK5C4U332J-E		3A	1.3V	DIP-S
1	745W		2.29A	NFAQ0860L36T		8A	2.4V	DIP-S6
2	1.49kW	400V	4.58A	NFAQ0860L36T		8A	1.9V	DIP-S6
4	2.98kW		9.16A	FSBB20CH60D		20A	2V	SPM3V
6	4.47kW		13.75A	FNB33060T		30A	1.6V	SPM3V
8	5.96kW		18.33A	FNB34060T		40A	1.5V	SPM3V
½	372.5W	650V	0.7A	FSBB10CH120D	1200V	10A	2.2V	SPM3
1	745W		1.41A	FSBB10CH120D		10A	2.2V	SPM3
2	1.49kW		2.82A	FSBB10CH120D		10A	2.2V	SPM3
4	2.98kW		5.64A	FSBB15CH120D		15A	2V	SPM3
6	4.47kW		8.46A	FSBB20CH120D		20A	2.2V	SPM34
8	5.96kW		11.28A	FNA22512A		25A	1.9V	SPM34

Public Information

onsemi

“On Line” Tool: Building BLDC w/ IPM’s



Enter up to 15 Operating Conditions:

- *Package*
- *RMS Phase Current*
- *Motor Voltage*
- *PWM Switching Frequency*
- *Inverter Output frequency*
- *Ambient Temp*
- *Max Tj*
- *Overload %*
- *Etc.*



Analyze Design

Analysis Tables Format:

Input

Selected SPM - NFAQ0860L36T 8A 600V 3shunt

Input Parameter	Value	Unit
DC Bus Voltage	400.0	V DC
RMS Motor Phase Current	2.29	A RMS
Motor Power Factor	0.95	
PWM Method	SPWM	
Modulation Index	0.9	
Ambient Temperature	85.0	°C
Switching Frequency	15.0	kHz
Inverter Output Frequency	60.0	Hz

Output

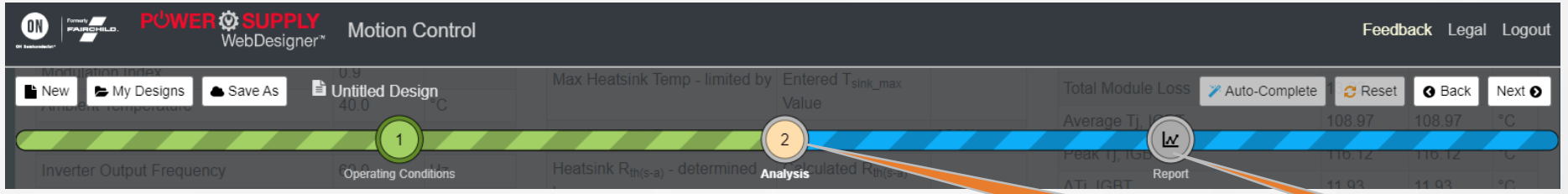
Output Parameter	Value	Unit
Drive Output Power	1.11	Horsepower
Drive Output Power	830.69	W
Inverter Output Line-to-Line Voltage	220.45	V RMS
Max Heatsink Temperature	100.0	°C
Max Case Temperature	101.05	°C
Max Heatsink Temp - limited by	Entered T_{sink_max} Value	
Max Heatsink $R_{th(s-a)}$	0.86	°C/W
Heatsink $R_{th(s-a)}$ - determined by	Calculated $R_{th(s-a)}$	

Output Parameter (Loss and Tj)	High-side	Low-side	Unit
Conduction Loss per IGBT	1.45	1.45	W
Switching Loss per IGBT	0.98	0.98	W
Total Loss Per IGBT	2.43	2.43	W
Conduction Loss per Diode	0.2	0.2	W
Switching loss per Diode	0.27	0.27	W
Total Loss Per Diode	0.48	0.48	W
Total Module Loss	17.44		W
Average Tj, IGBT	111.05	111.05	°C
Peak Tj, IGBT	119.5	119.5	°C
ΔTj, IGBT	14.3	14.3	°C
Average Tj, Diode	104.63	104.63	°C
Peak Tj, Diode	106.86	106.86	°C
ΔTj, Diode	3.84	3.84	°C

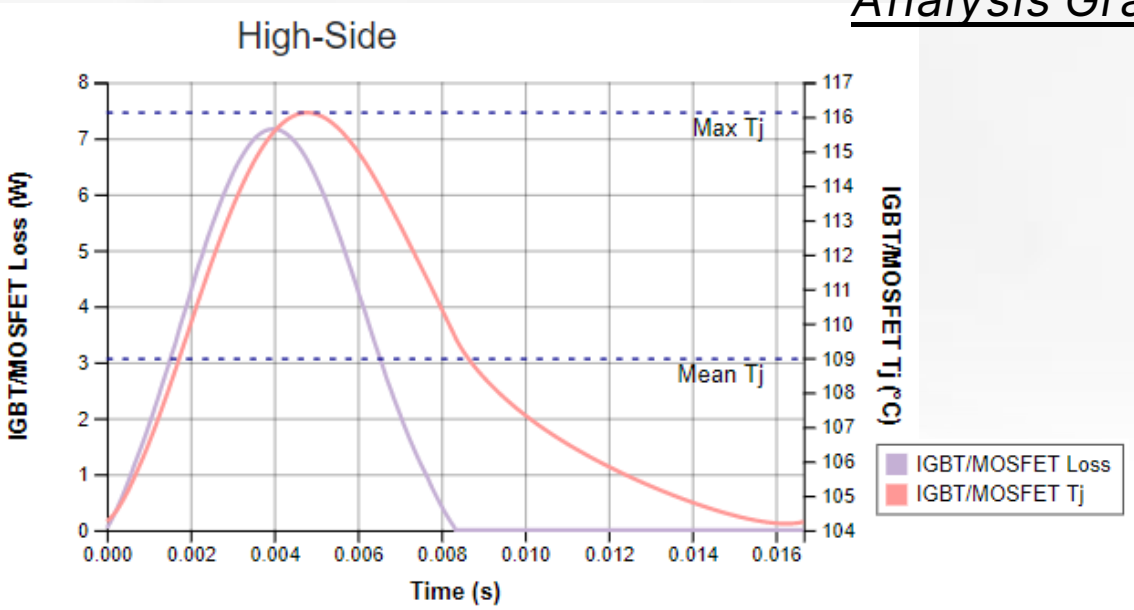
Link:
https://www.onsemi.com/site/design-tools/motion-control/

Public Information

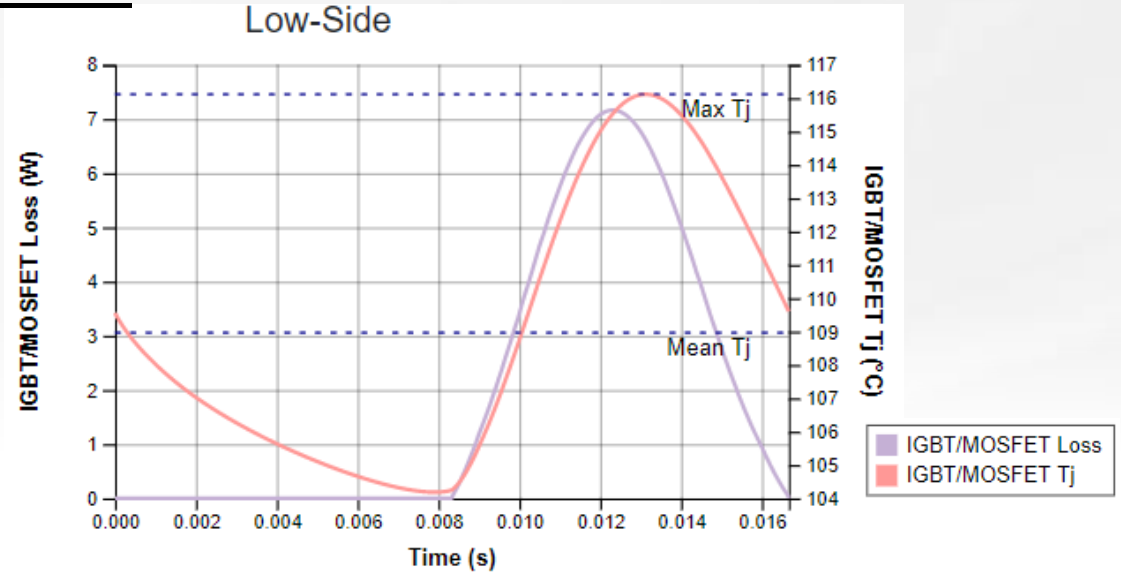
“On Line” Tool: Building BLDC w/ IPM’s



Analysis Graphical Format:



Graph 1 — IGBT or MOSFET losses and junction temperature vs. time for full load conditions specified above. MOSFET losses include body diode losses for MOSFET-based modules.



Graph 2 — IGBT or MOSFET losses and junction temperature vs. time for full load conditions specified above. MOSFET losses include body diode losses for MOSFET-based modules.

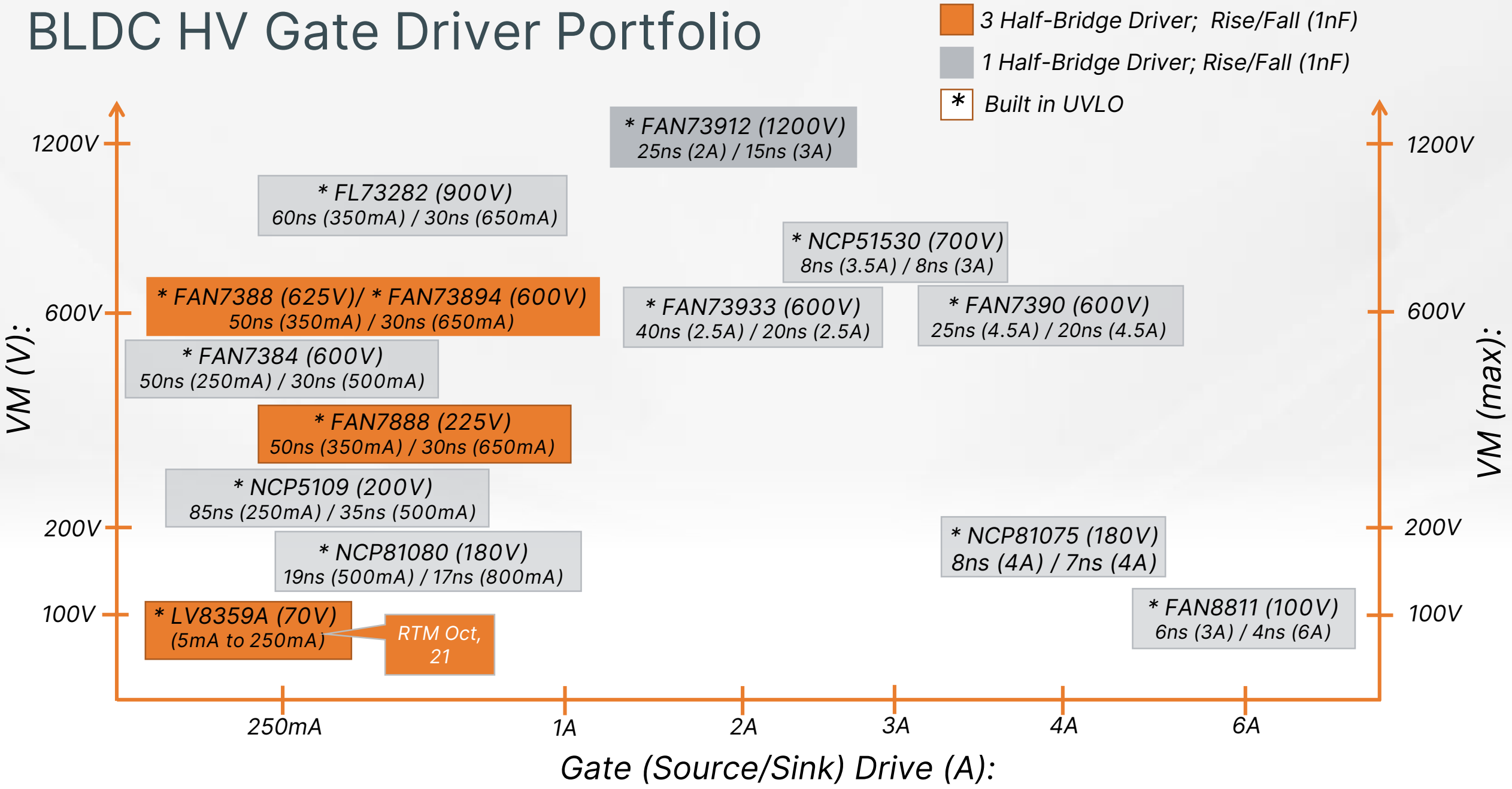
Link:
https://www.onsemi.com/site/design-tools/motion-control/

Public Information

BLDC Gate Drivers

Public Information

BLDC HV Gate Driver Portfolio



Public Information

Turn-ON Rise time (Source I) / Turn-Off Fall time (Sink I), assuming 1nF

High Voltage Gate Driver Products

Type	Product	In - Out	Offset Voltage(V)	Output Current		Delay Time		Shut Down	OCP	DT(ns)	PKG
				SRC (mA)	SNK (mA)	Ton (ns)	Toff (ns)				
High & Low-Side	FAN7382	2 to 2	600	350	650	170	200	No	No	No	8DIP, 8SOP, 14SOP
	FAN7390	2 to 2	600	4500	4500	140	140	No	No	No	8SOP, 14SOP
	FAN7390A	2 to 2	600	4500	4500	140	140	No	No	No	14SOP
	FAN73901	2 to 2	600	2500	2500	140	140	No	No	No	8SOP
	FAN7391	2 to 2	600	4500	4500	150	150	No	No	No	14SOP
	FAN73912A	2 to 2	1200	2000	3000	500	550	Yes	No	No	16 WSOP
	FAN7392	2 to 2	600	3000	3000	130	150	Yes	No	No	16 WSOP
	FAN7842	2 to 2	200	350	650	170	200	No	No	No	8SOP
	FAN8811	2 to 2	100	3000	6000	30	28	No	No	No	10WDFN
	NCP5106A	2 to 2	600	250	500	100	100	No	No	No	8DIP, 8SOP, 10DFN
	NCP5109A	2 to 2	200	250	500	100	100	No	No	No	8SOP, 10DFN
	NCP5181	2 to 2	600	1400	2200	100	100	No	No	No	8DIP, 8SOP
	NCP5183	2 to 2	600	4300	4300	120	120	No	No	No	8SOP
	NCP51530B	2 to 2	700	3500	3000	25	25	No	No	No	8SOP, 10DFN
Half Bridge	TND525SS	2 to 2	600	200	400	100	100	No	No	No	8SOP
	FAN7380	2 to 2	600	90	180	135	130	No	No	100	8SOP
	FAN7383	1 to 2	600	350	650	500	170	Yes	No	Variable	14SOP
	FAN7387	1 to 2	600	350	650	550	160	Yes	No	Variable	8SOP
	FAN73832	1 to 2	600	350	650	580	180	Yes	No	Variable	8SOP
	FAN73833	2 to 2	600	350	650	150	140	No	No	450	8SOP
	FAN7384	2 to 2	600	250	500	180	170	Yes	Yes	120	14SOP
	FAN73912	2 to 2	1200	2000	3000	500	550	Yes	No	330	16 WSOP

Type	Product	In - Out	Offset Voltage (V)	Output Current		Delay Time		Shut Down	OCP	DT(ns)	PKG
				SRC (mA)	SNK (mA)	Ton (ns)	Toff (ns)				
Half Bridge	FAN7393A	1 to 2	600	2500	2500	530	130	Yes	No	Variable	14SOP
	FAN73932	1 to 2	600	2500	2500	600	200	Yes	No	400	8SOP
	FAN73933	2 to 2	600	2500	2500	160	160	No	No	Variable	14SOP
	FL73282	2 to 2	900	350	650	150	150	No	No	170	8SOP
	NCP1392B	1 to 2	600	500	1000	N/A	N/A	No	No	610	8SOP
	NCP1392D	1 to 2	600	500	1000	N/A	N/A	No	No	305	8SOP
	NCP1393B	1 to 2	600	1000	1500	N/A	N/A	No	No	610	8SOP
	NCP5104	1 to 2	600	250	500	620	100	Yes	No	520	8DIP, 8SOP
	NCP5106B	2 to 2	600	250	500	100	100	No	No	100	8DIP, 8SOP, 10DFN
	NCP5109B	2 to 2	200	250	500	100	100	No	No	100	8SOP, 10DFN
	NCP5111	1 to 2	600	250	500	750	100	No	No	650	8DIP, 8SOP
	NCP5304	2 to 2	600	250	500	100	100	No	No	100	8DIP, 8SOP
3-Phase Half-Bridge	FAN7388	6 to 6	600	350	650	130	150	No	No	270	20SOP
	FAN73893 FAN73894	6 to 6 (inverting)	600	350	650	500	500	Yes	Yes	320	28SOP
	FAN73895 FAN73896	6 to 6	600	350	650	500	500	Yes	Yes	320	28SOP
	FAN7888	6 to 6	200	350	650	130	150	No	No	270	20SOP
WBG	NCP51705	1 to 1	-	6000	6000	25	25	Yes	Yes	Adj	24QFN
	NCP51820	2 to 2	650	1000	2000	25	25	Yes	No	Adj	15QFN

Public Information

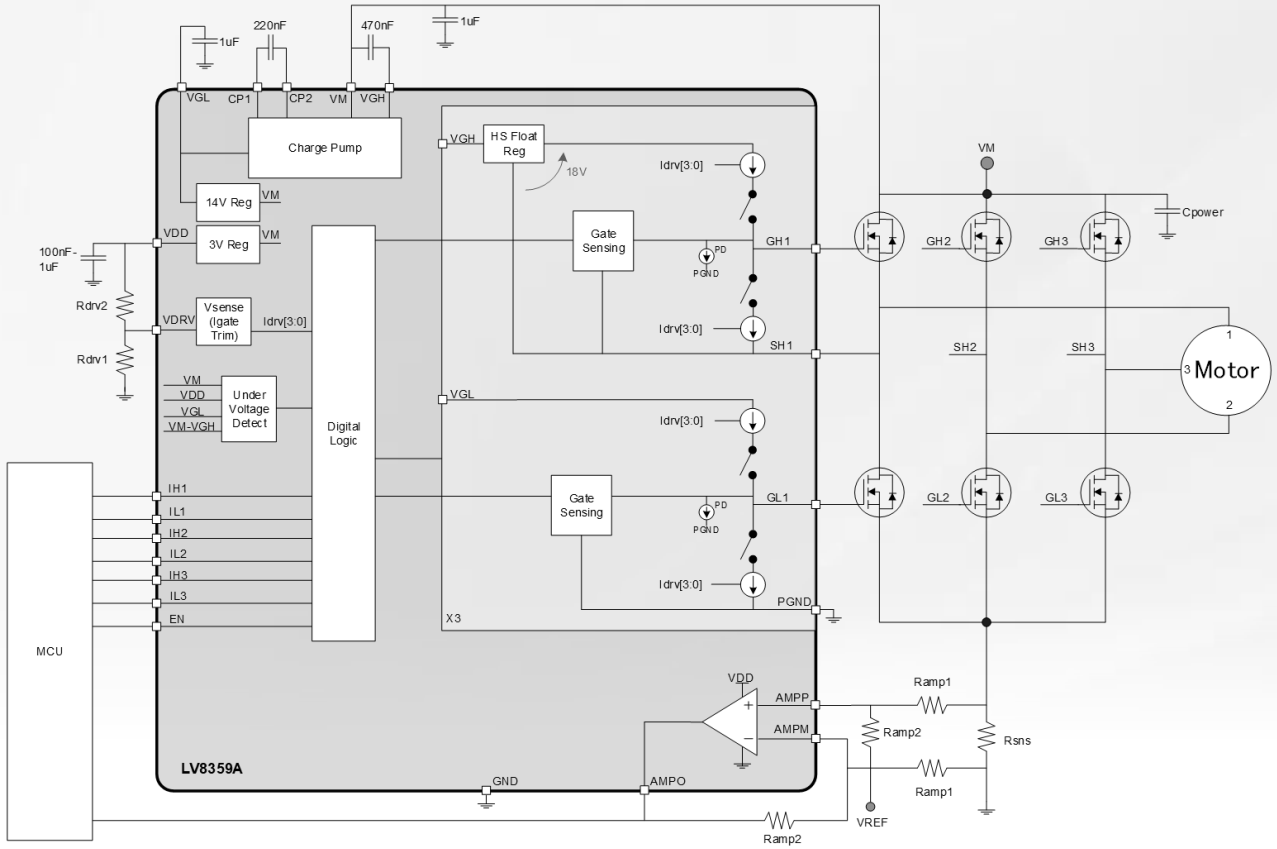
LV8359A 60V 3-Phase Gate Driver

Low Cost Motor Driver IC

Unique Features & Benefits

- Optimized for low BOM cost
- 5V to 60V operational supply voltage with abs max of 70V
- Constant current drive of power FET, configurable from 5 to 250mA
- Internally generated gate drive supply voltages
- Tolerant to -10V DC (-15V transient overshoot) for high side gate and source output pins
- Gate sensing for external FET shoot-through protection
- Embedded high GBW general purpose amplifier with external configurable gain
- Embedded charge pump function allowing DC static drive
- Strong hold-off current preventing self-turn-on
- Internal gate pull-down to GND during loss of VDD (core) power
- Under voltage lock out on VM, VGL, and VGH-VM
- 4kV HBM and 1kV CDM ESD protection
- 5V/3.3V compatible 6 input control plus enable

Typical Application Schematic



Other Features & Specifications

- Up to 30kHz motor PWM with individual six gate control mode
- Junction temperature range of -40°C to +150°C
- Available in a 24-pin QFN 4x4
- RTM OCT 2021, samples and EVB now available

Markets & Applications

- Power Tools
- Industrial Actuators and Cobots
- Automated Guided Robots
- Light Mobility (E-bikes, E-scooters, Hoverboards)

Public Information

MOSFETS

Public Information

30 – 150V MOSFET Technology

25V
30V
40V
60V
80V

T6

- Dramatically Reduced On-resistance
  - 30V, 0.7mΩ in SO8FL : NTMFS4C020N
  - 40V, 0.67mΩ in SO8FL (PQFN56) : NTMFS5C404NL
  - 60V, 1.2mΩ in SO8FL : NTMFS5C604NL
- Increased Power Density

T8

- Optimized Switching performance based on T6 tech
  - 25V, 0.68mΩ in SO8FL: NTMFS4H01N
  - 40V, 0.8mΩ in SO8FL : NTMFS5H400NL
  - 60V, 1.3mΩ in SO8FL : NTMFS5H600NL
- 35~40% lower Qg and Qoss than T6 tech

T10 T10M

- T10 Optimized Switching for AC/DC & DC/DC
- T10M features low Rds with optimized "soft recovery" body diode

80V
100V
120V
150V

MV5

- Much better than older Trench tech. MV MOS
  - Smaller On-resistance
  - Good Qg, Qoss and Qrr vs. rDS balanced technology

PTNG

- Industry's Lowest Qrr and softest Body-Diode
  - 80V, 2.5mΩ: FDMS2D5N08C
  - 100V, 3.2mΩ: FDMS86180
  - 120V, 4.0mΩ: FDMS4D0N12C
  - 150V, 8.8mΩ: FDMS8D8N15C

LowQ & Low RDS PTNG

- LowQ features Optimized Switching performance
  - 100V node in development followed by 80V
- Low Rds PTNG program focus on lower Rds vs PTNG
  - RdsxQoss, RdsxQg FOM's similar with PTNG

Power Tools (Motor)	Power 33/56, D2PAK, D2Pak7Lç	Power 33/56 Dual Cool, TOLL, Power 8x8 SC and DC
Industrial Motor	D²PAK, TO-220	D2Pak7L, TOLL
Battery	D²PAK, TO-220, Power 56	D2Pak7L, TOLL, Power88

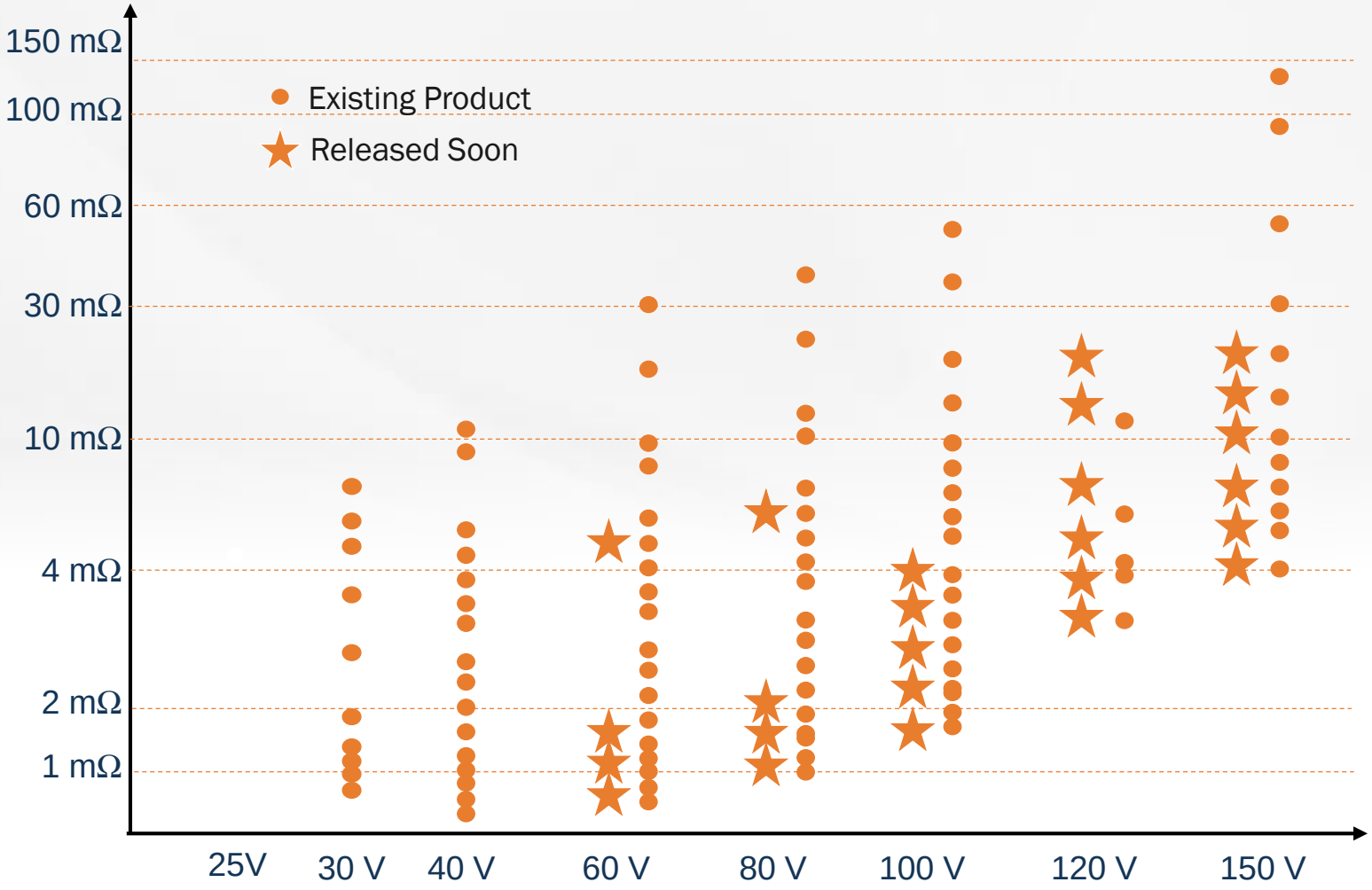


Public Information

onsemi

MV MOSFET Roadmap

A wide power range…



…In a wide variety of packages



And more

See backup slides for complete released product portfolio

Public Information

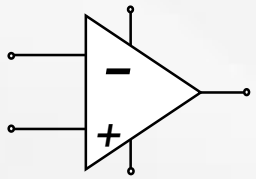
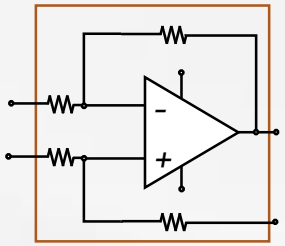
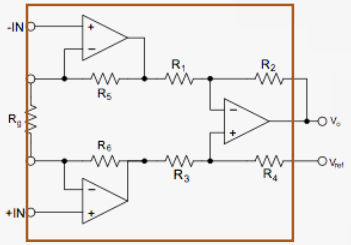
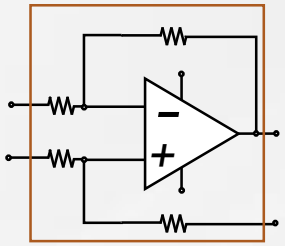
Current Sense Amplifiers

Public Information

Current Sensing Amplifiers

onsemi offers two of the four popular current sensing solutions:

- *Operational Amplifiers which are connected with external gain setting resistors.*
- *Current Sense Amplifiers which have the gain settings resistors integrated on chip for higher resistor matching and sensing accuracy*

Operational Amplifiers	*Difference Amplifiers*	*Instrumentation Amplifiers*	*Current Sense Amplifiers*
			
Low Side Current Sensing	*High/ Low Side Sensing*	*Low Side Current Sensing*	*High/ Low Side Current Sensing*
V_{CM} = 0	*V_{CM} > Vs*	*0< V_{CM} <Vs*	*V_{CM} > Vs*
- Low Cost *- External resistor matching is a big concern*	*- Limited to gain of 1* *- Old Technology* *- CMV dependent on Vs*	*- High CMRR* *- High Performance* *- CMV dependent on Vs*	*- Wide Variety of Gain Options* *- CMV independent of Supply*

Public Information

Current Sense Amplifiers (Integrated Resistors)

5 Families of Current Sense Amplifiers

Supply Current

Common Mode Voltage

Direct Drop-in for TI INA210, INA211, INA213, & INA214

NCS(V)21x (G= 50, 100, 200, 500)
26V CM, 35uV, 1%, 40uA, RRIO
Bi-directional CMOS Family

Improved Direct Drop-in for TI INA180, INA2180 & INA4180

NCS(V)21673/4/5 (G= 20, 50, 100, 200)
40V CM, 500uV, 1%, 300uA, RRIO
Uni-directional CMOS Family

NCS(V)21671 (G= 20, 50, 100, 200)
40V CM, 25uV, 0.3%, 80uA, RRIO
Bi-directional CMOS Family

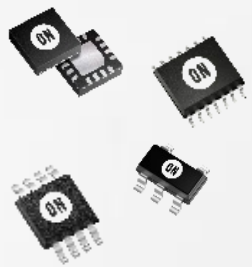
NCS(V)7041 (G= 10, 20, 50, 100)
80V CM, 300uV, 0.3%, 2.3mA, RRIO
Bi-directional CMOS Family

NCS(V)703x (G= 10, 20, 50, 100)
80V CM, 300uV, 0.3%, 2.3mA, RRIO
Uni-directional CMOS Family

Performance

- *Low Input Offset Voltages*
- *Multiple Gain Options*
- *Wide Common-Mode Range*

***AEC Qualified products are available for Automotive applications , NCV prefix*



Space Saving Packages

PRICE

PERFORMANCE

Good Price to Performance Balance

Public Information

onsemi

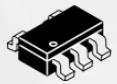
LDO

Public Information

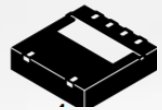
LDO Wide-Input & Low IQ Family

Application	P/N	*Vin (max)*	I_{LOAD} (mA)	T_J Operating Range:	V_{OUT}	I_Q (uA)	Package
Wide-Input & Low Iq	NCP715	*24*	50	-40C to 125C	1.2-5.0	3.2	XDFN-6, SC-70, TSOP-5
	NCP716B	*24*	*150*	*-40C to 125C*	*3.0, 3.3, 5*	*3.2*	*TSOP-5*
	NCP718	*24*	*300*	*-40C to 125C*	*1.5-5.0*	*4*	*WDFN-6, TSOP-5*
	NCP730 New	*38*	*150*	*-40C to 125C*	*1.2- 24 ADJ*	*1.3*	*WDFN-6, TSOP-5*
	NCP786A	*450*	*10*	*-40C to 85C*	*1.27-15*	*10*	*DFN-6*
Low Iq	NCP170	*5.5*	150	-40C to 85C	0.8-3.6	0.5	XDFN4, TSOP5
	NCP171	*5.5*	*80*	*-40C to 85C*	*0.6-3.3*	*0.05*	*XDFN-4, TSOP5 - (Dev)*

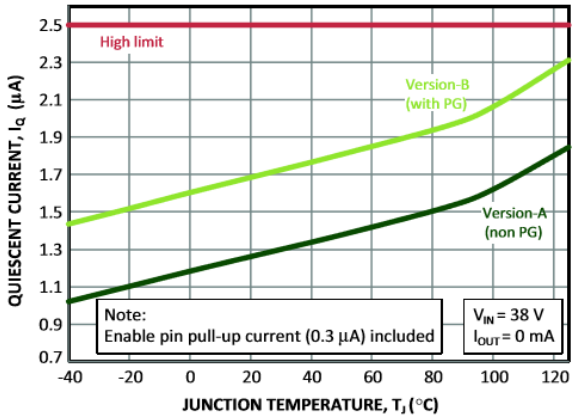

XDFN-6

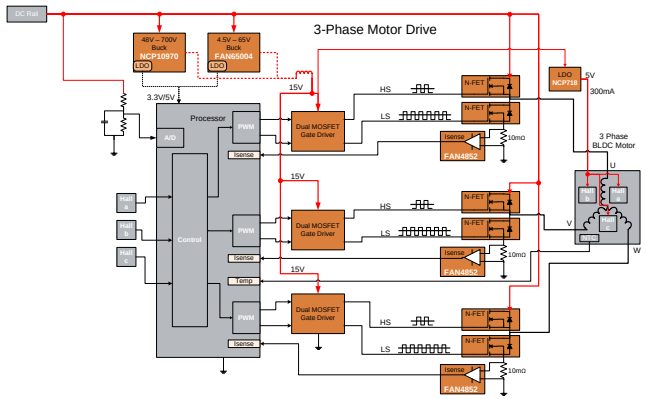

TSOP-5


WDFN (2*2)


DFN-6


XDFN4

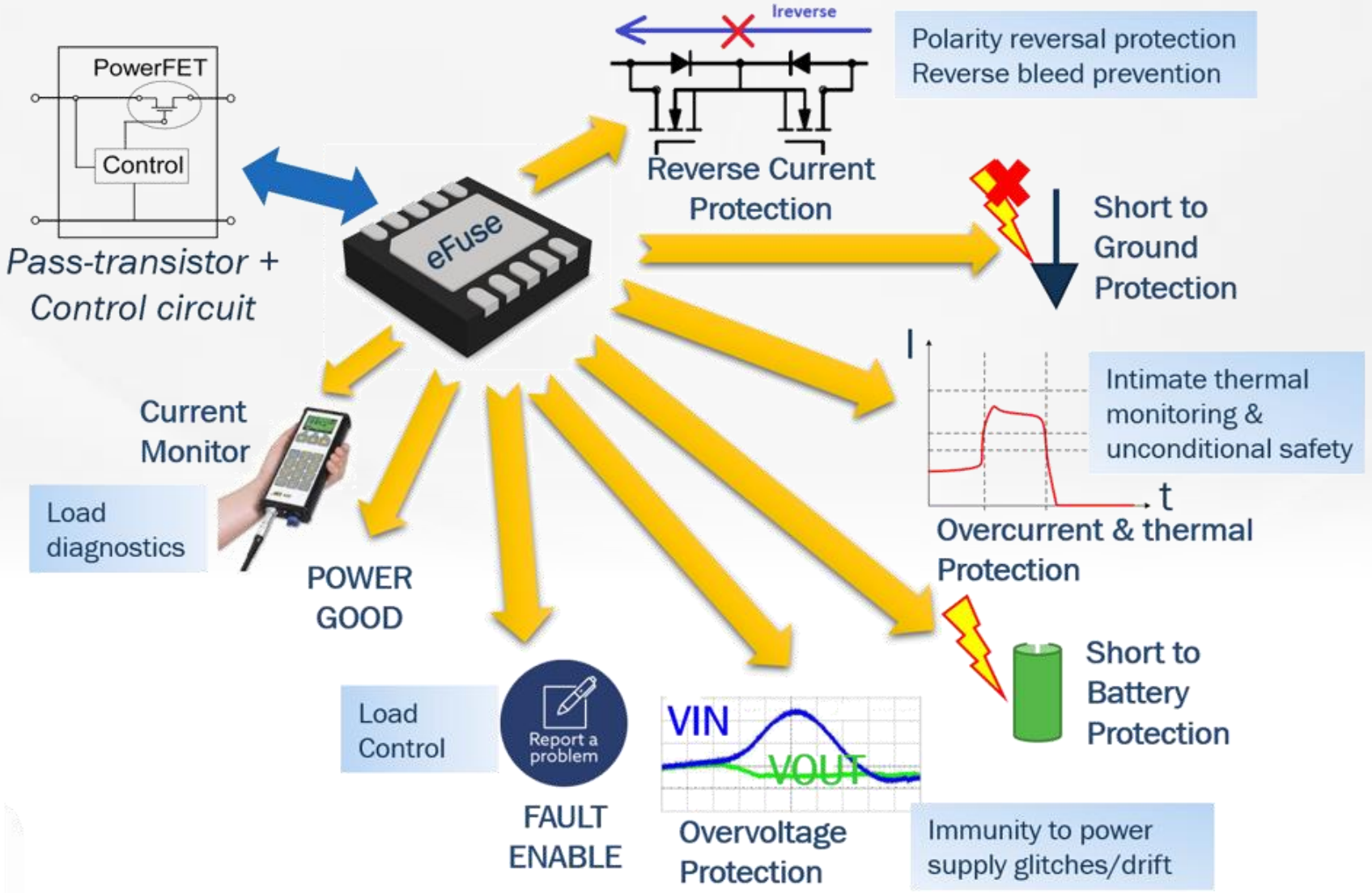




eFuse

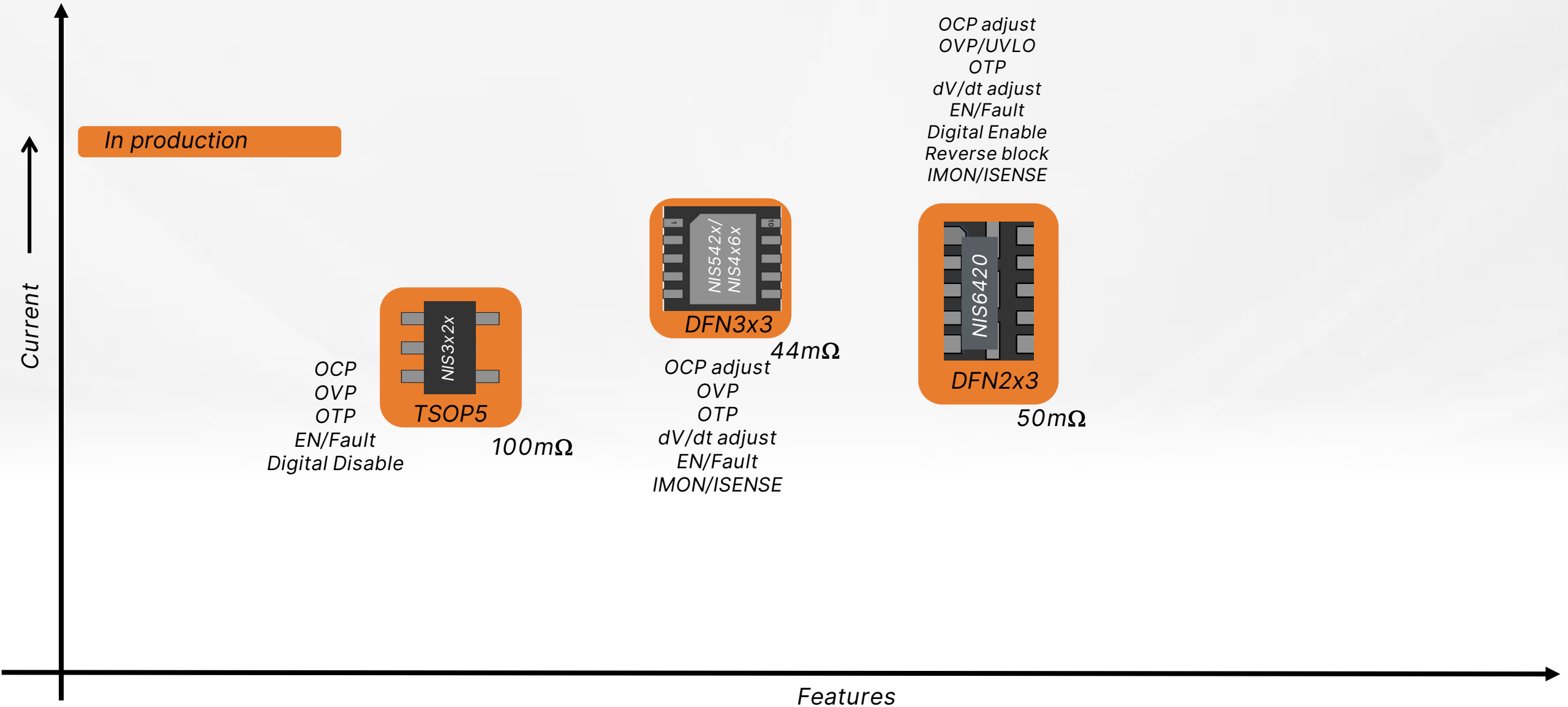
Public Information

eFuse – Why **onsemi**



Public Information

12-24V eFuses



Public Information

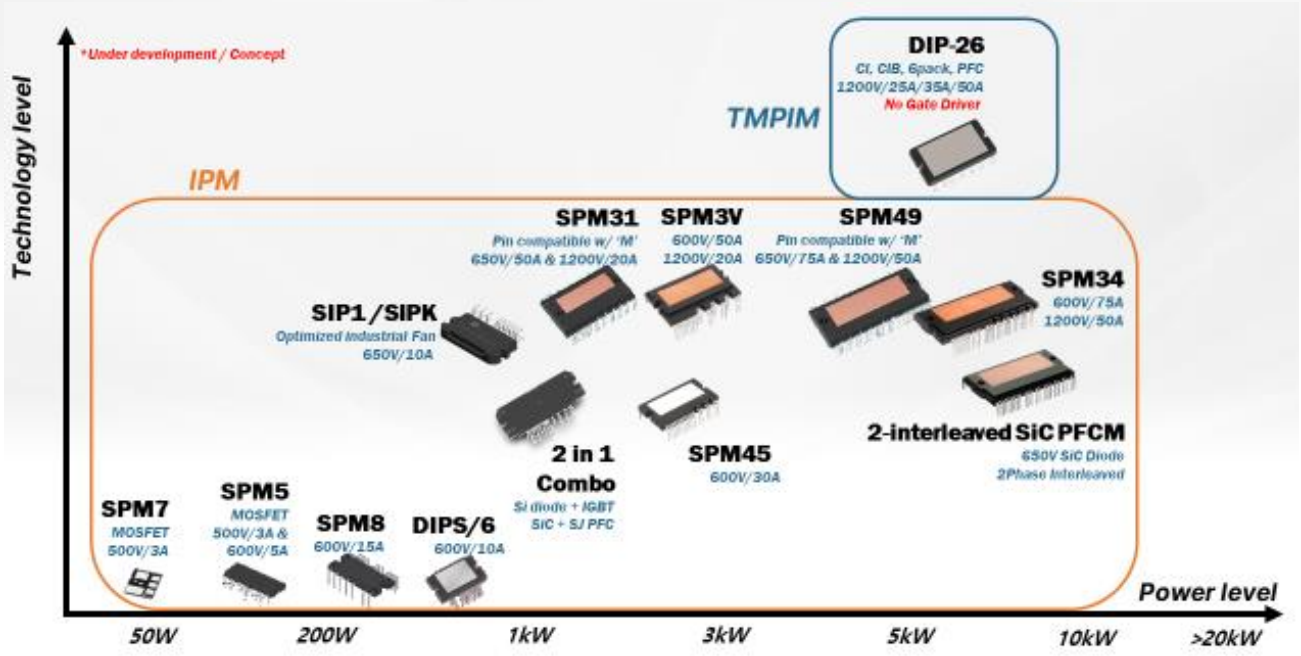
Power Modules

Public Information

Power Modules – Why **onsemi**

With a deep understanding of power module technologies for motion control, ON Semi equips innovators with a broad spectrum of devices that fit most collaborative robot applications.

Devices range from a few watts to kilowatts
Check out our complete power module portfolio below



Highlight Products

IPMs

SPM®31 (Mini)



SPM®49 (Large)

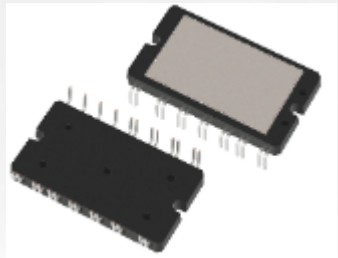


650 V & 1200 V
Advanced Trench IGBT

Superior performance
Wide coverage

TMPIMs

DIP-26 family
Enhanced reliability
Outstanding Power Density



onsemi Value Proposition

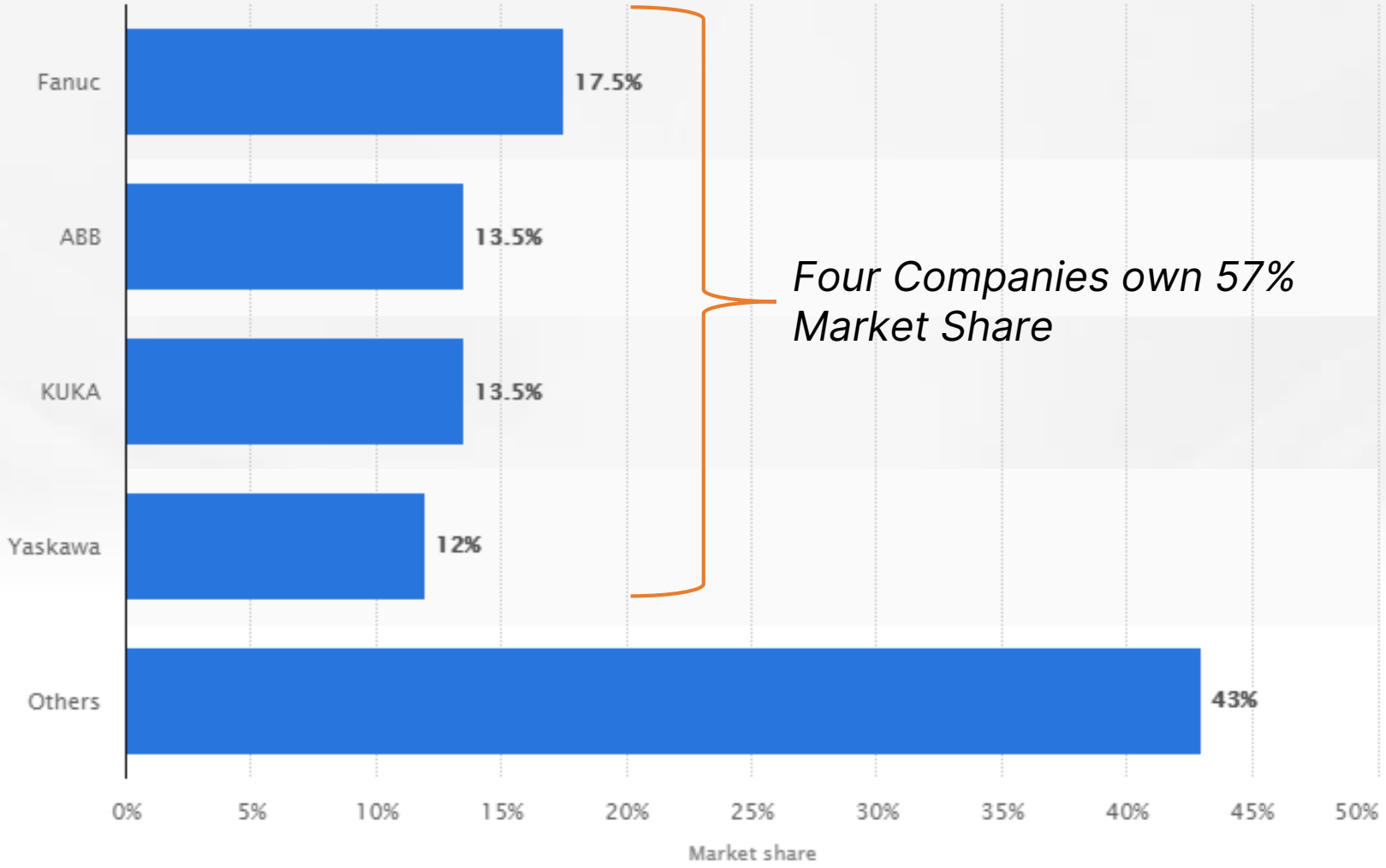
Our advanced packaging technology enables a high level of integration, superior thermal performance and enhanced reliability

Public Information

Robotics Customers

Public Information

Global Industrial Robot Market (2019)



Public Information

Noteworthy AMR Robotics Innovators

PIAGGIO FAST FORWARD™

gita®

HQ: 52 Roland Street | Boston, MA 02129

Factory: 7 Roland Street | Boston, MA 02129





I AM SWIFT™

productive robotics®

Headquartered in Santa Barbara, California,



7 AXIS FLEXIBILITY TO REACH AROUND DOORS AND MORE

Diligent Robotics Inc.

diligent

Moxi helps hospitals run 24/7 by assisting clinical staff with non-patient-facing tasks like:

- Running patient supplies
- Delivering lab samples
- Fetching items from central supply
- Distributing PPE
- Delivering medications



Headquarters location: Austin, TX

IAM ROBOTICS

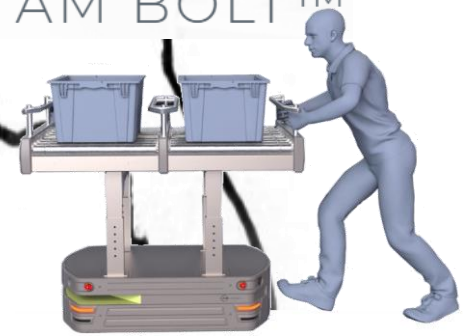
autonomous mobile manipulation robot (AMMR)

250 48th Street, Pittsburgh, PA 15201

info@iamrobotics.com | 412.626.7425

autonomous mobile robot (AMR)

I AM BOLT™





onsemi

Public Information

Noteworthy AMR Robotics Innovators



CARBON ROBOTICS

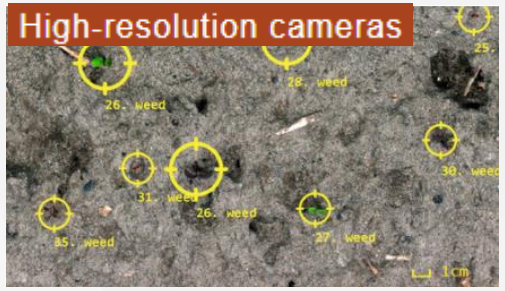
Carbon Robotics
807 Aurora Ave N
Seattle WA 98109

A single robot will weed 15-20 acres per day

Autonomous Weeder



High-resolution cameras



High-powered lasers



LEFT HAND ROBOTICS

Longmont, Colorado

March 2, 2021 The Toro Company Acquires Left Hand Robotics, Inc.



Autonomous Navigation and Telemetry



Head Office

HARVEST AUTOMATION

HV-100

85 Rangeway Rd
Billerica MA 01862

a Real Impact in Agriculture!



SEEGRID

Seegrid HQ:
216 RIDC Park West Drive
Pittsburgh, PA 15275





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Noteworthy AMR Robotics Innovators

RIGHTHAND™ ROBOTICS

Somerville, Massachusetts

The RightPick™ Platform





Reliability
Autonomously fill orders 24/7

Rate
Move up to 1,200 units per hour

Range
Pick and place millions of SKUs

PRECISE AUTOMATION

Precise Automation
47350 Fremont Boulevard
Fremont, CA 94538

PP100 CARTESIAN ROBOT

The World's Only Collaborative Cartesian Robot



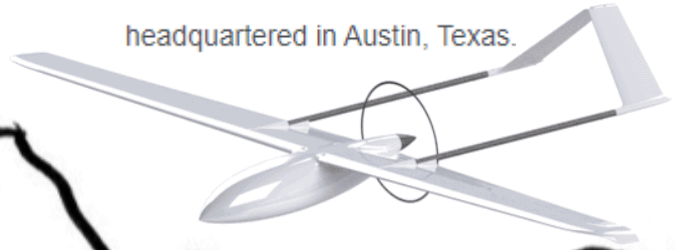


THE ALBATROSS
LONG RANGE

APPLIED AERONAUTICS

The Albatross is entirely electric, has a flight time of up to 4 hours and cruises at 68 km/hr. This gives it max range of over 250 km.

headquartered in Austin, Texas.



Public Information

onsemi

Noteworthy AMR Robotics Innovators

Autonomous Mobile Robot (AMR)

fetch robotics

Fetch Robotics, Inc. 2811 Orchard Parkway San Jose, CA 95134

TagSurveyor



Collecting, locating and tracking RFID tags on products and bins within warehouses and factories



VIRTUAL conveyor

MEET CHUCK

The most capable and collaborative mobile robot on the planet.



shopify

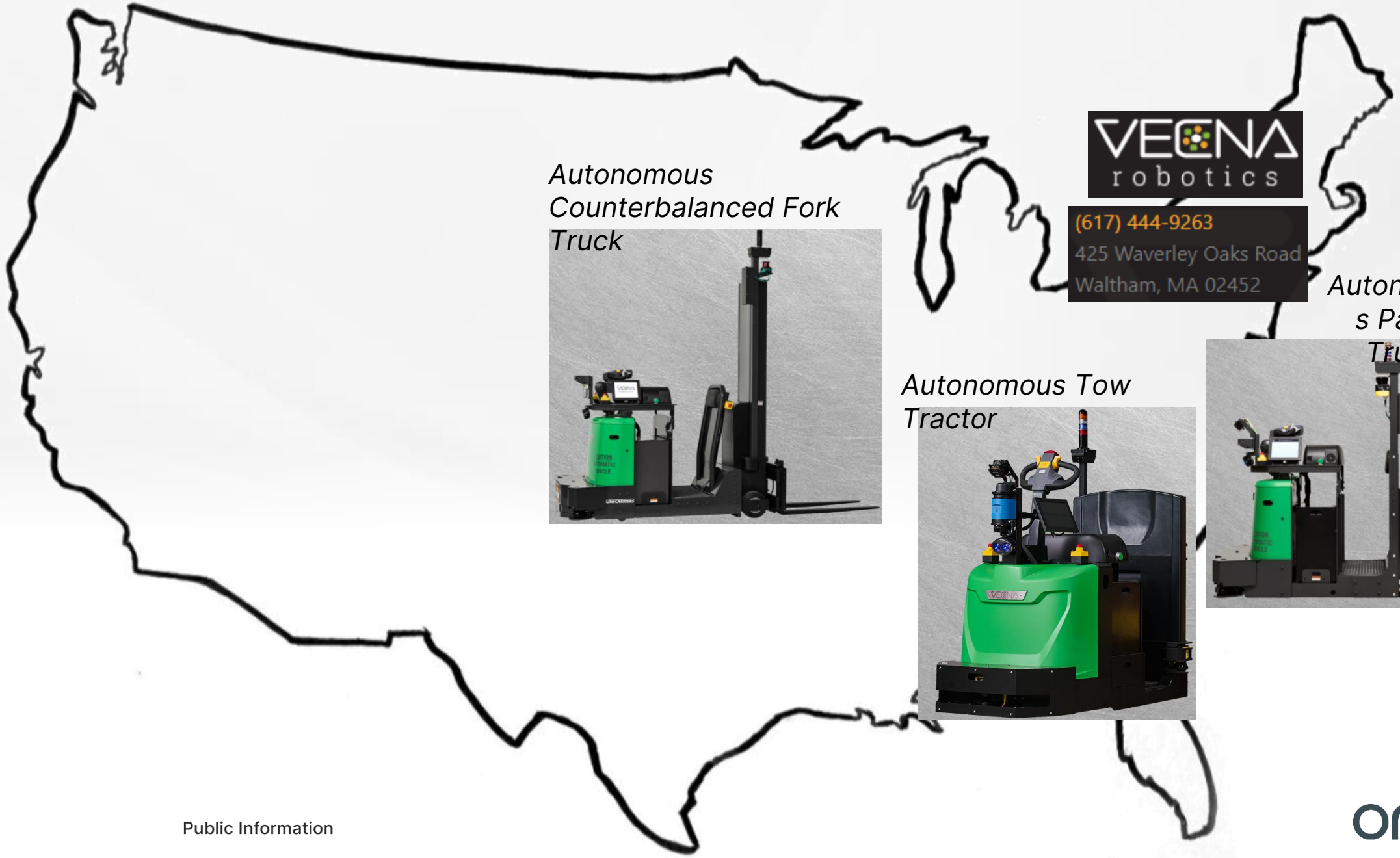
6 RIVER SYSTEMS

307 Waverley Oaks Rd Ste 405, Waltham, MA 02452



onsemi

Noteworthy AMR Robotics Innovators



VECNA robotics

(617) 444-9263
425 Waverley Oaks Road
Waltham, MA 02452

Autonomous Counterbalanced Fork Truck

Autonomous Tow Tractor

Autonomous Pallet Truck

Public Information

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New Starting Point for BLDC Design

Customer Decision (Fractal) Tree

BLDC Electronics Selection:

BLDC is Complicated
Share these Tables w/ your BLDC customers to expedite their BLDC Designs

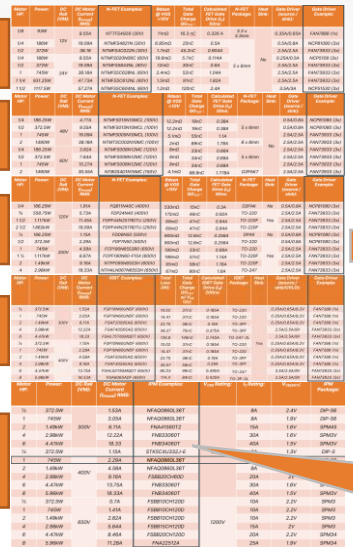
Competition →

Portfolios of FETs/IGBT's/Gate Driver "Old Starting Point"

onsemi →

up to 6kW:

- *12V, 24V*
- *48V, 60V*
- *120V, 200V*
- *300V, 400V*
- *300V, 400V & 650V*



1st Order Approximation "New Starting Point"

Customer A Final Decision

Customer B Final Decision

Many more complex decisions to be made

Customer C Final Decision

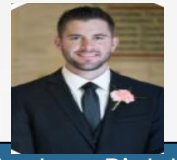
1st Order Approximation Gate Drive to Switch Matching "BLDC Tables"

Public Information

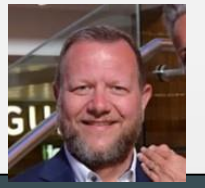
DSM MAP



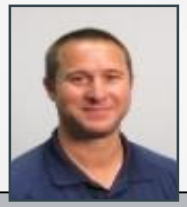
Daniel Fitzpatrick
DSM Pacific NW



Andrew Bielski
DSM- North Central



Eric Dupont
DSM- East Can/Upstate NY



Brody Trejos
DSM CA/NV



Rachael Rodney
DSM Northeast



Luis Verduzco
LATAM Q2-Q3



Jason Meyer
DSM - MidWest



Mel Gipson Jr
DSM Southeast

Lacey Guzman

West Canada
East Canada
Washington
Oregon
Montana
Idaho
Wyoming
North Dakota
South Dakota
Nebraska
Minnesota
Iowa
Wisconsin
Michigan
Illinois
Indiana
Ohio
W. Pen
E. Penn
New York
Maine
Ver
Massachusett
Rhode Islan
Connecticut
Ney Jersey
Delaware
Maryland
D.C.
West Virginia
Virginia
Kentucky
Tennessee
North Carolina
South Carolina
Georgia
Florida
Mississippi
Alabama
Louisiana
Arkansas
Missouri
Kansas
Oklahoma
Texas
Colorado
New Mexico
Arizona
Utah
Nevada
BAY
California
Mexico
Brazil

Public Information

onsemi

Backup Slides

Public Information

FAN8811 - 3A/6A 80 V High/Low Side Gate Driver

Value Proposition

The FAN8811 is a is high side and low side gate-drive IC designer for high speed, high current/voltage driving MOSFET up to 80 V

Features

- *Integrated bootstrap diode*
- *Excellent dynamic*
  - *30 ns prop. delay (typ.)*
  - *2 ns delay matching*
  - *6 ns rise & fall times*
- *DFN10 4mm x 4mm with EP*

Benefits

- *High frequency operating with low power loss*
- *Small package & good thermal char.*

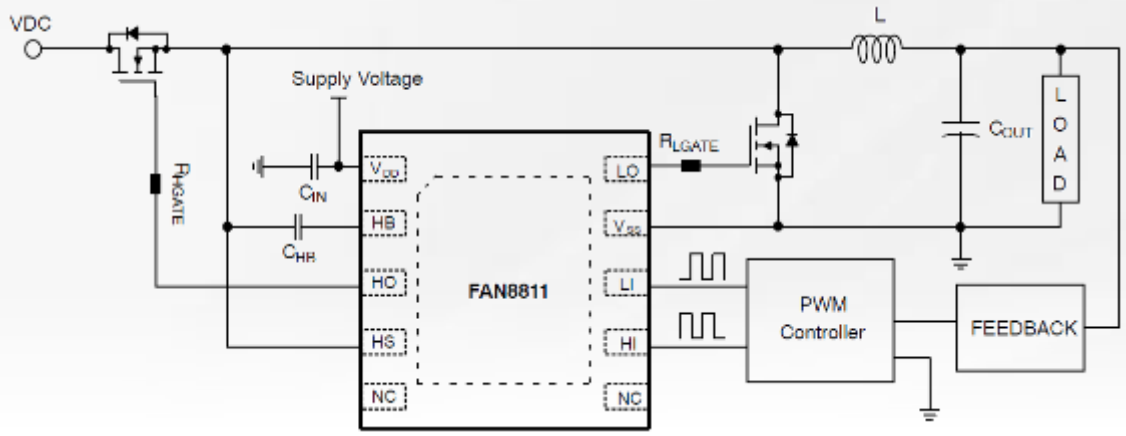
Other Features

- *Dual input logic with TTL compatible*
- *3 A/6 A source/sink currents*
- *Wide supply voltage range up to 18 V max.*
- *50 ns min. pulse width*
- *Under voltage lockout for both inputs*
- *Operating T_J range of 40°C up to 125°C*

Market & Applications

- *Power supplies for telecomm and data communication*
- *Half-bridge and full-bridge converters*
- *Synchronous buck converters*
- *Battery power tools*

Typical Application Schematic



Package Information



WDFN-8

- *FAN8811TMPX : WDFN-10 4mm x 4mm (pin #1 upper left near sprocket holes)*
- *FAN8811MNTXG : WDFN-10 4mm x 4mm (pin #1 upper right near sprocket holes)*

RTM Product

Public Information

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NCP81075 – High Voltage (up to 180V) MOSFET Drivers

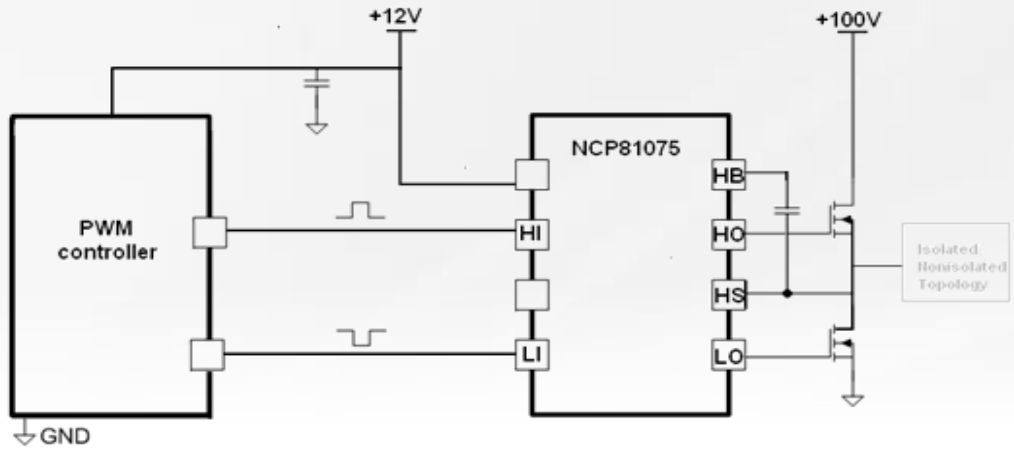
Value Proposition

The NCP81075 is a high performance dual channel MOSFET gate drivers. A bootstrap technique is implemented to ensure proper drive of the high side switch. A high floating top driver is implemented to accommodate voltages as high as 180V

Features

- *Drives two N-Channel MOSFETs in High-Side and Low-Side Configuration*
- *Floating Top Driver Accommodates Boost Voltage up to 180V (SOI process allows VHB to be protected at -20V DC)*
- *Switching Frequency up to 1MHz*
- *27ns Propagation Delay Times*
- *4A Sink, 4A Source Output Currents*
- *8-ns Rise/7-ns Fall Time with 1nF Load*
- *UVLO Protection*
- *Offered in 8-Pin SOIC (D), SON8 (DRM),*
- *SON10 (DRM) Packages*

Typical Application diagram



Market & Applications

- *Telecommunication, Datacenter Power*
- *Isolated and Non Isolated Power Supplies*
- *2 Switch and Active Clamp Forward Converters*

Ordering info & Support

Device	Package	Size:
NCP81075DR2G	SOIC-8	5x6mm
NCP81075MNTXG	DFN8	4x4mm
NCP81075MTTXG	WDFN10	4x4mm

Public Information

FAN73912 – 1200 V Half Bridge Gate- Driver IC

Product Description

The FAN73912/NCV51542 is a monolithic half bridge gate-drive IC designed for high-voltage and high-speed driving for MOSFETs and IGBTs that operate up to +1200 V

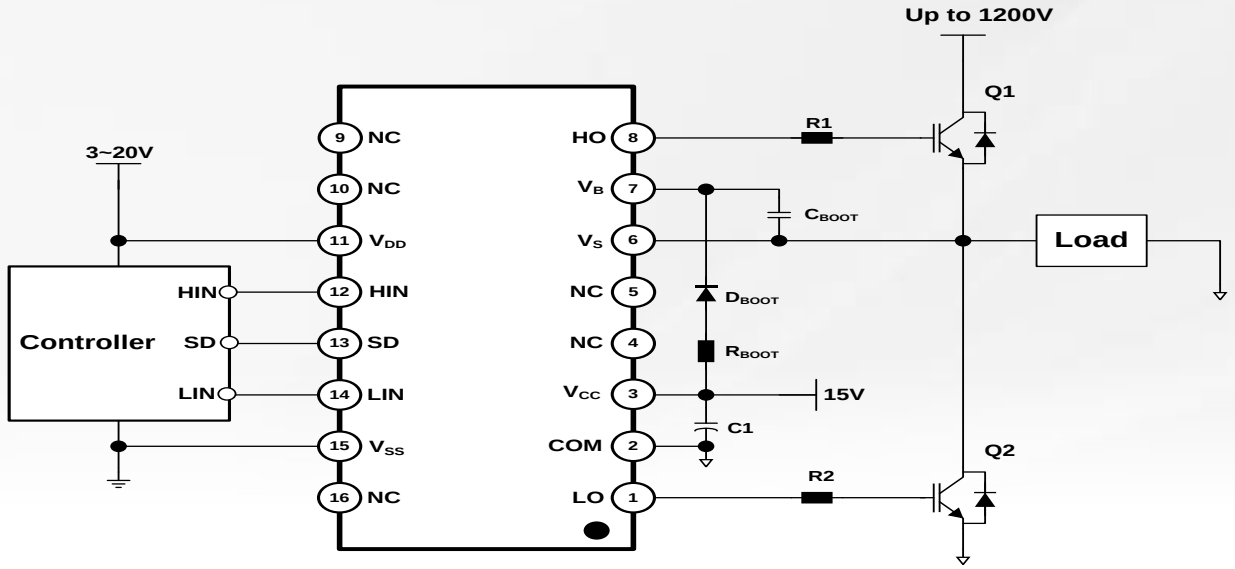
Unique Features

- *Separate Logic Supply (Vdd) from 3V to 20V*
- *Built-in Advanced Input Filter*
- *Shoot-Through Prevention*

Benefits

- *Design flexibility*
- *Protection against short-pulse input signals*
- *Robust design - no cross conduction*
- *AEC-Q100 Qualified(NCV51542)*

Typical Application Schematic



Other Features

- *Gate Driver Supply (VCC) Range from 12 to 20V*
- *Cycle-by-Cycle Edge-Triggered Shutdown Logic*
- *UVLO Functions for VDD/VBS*
- *Matched Propagation Delay Below 35ns*
- *Outputs in-Phase with Input Signal*
- *Logic and power ground +/- 10V offset*

Market Application

- *Industrial & Automotive(NCV51542) Motor Driver*
- *UPS & Solar Inverter*
- *Half-Bridge Converter*

Packaging information

Device	Package	Packaging Method
FAN73912MX	Wide 16-SOIC	Tape & Reel

Public Information

FAN73912A : 1200 V 2A/-3A High & Low Side Gate Driver

Product Description

The FAN73912A is a monolithic high and low-side gate-drive IC designed for high-voltage and high-speed driving for MOSFETs and IGBTs that operate up to +1200 V

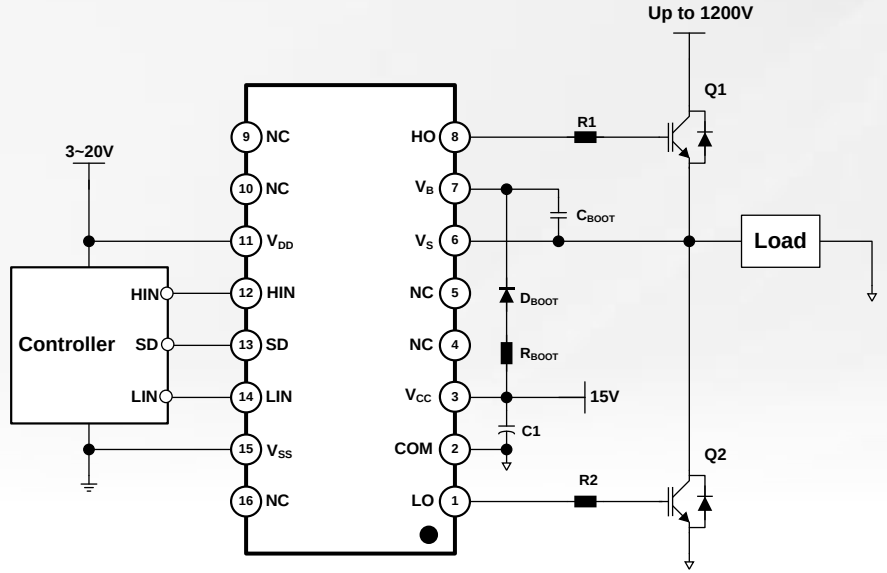
Unique Features

- *Separate logic supply(V_{DD}) from 3 V to 20 V*
- *Built-in advanced input filter*

Benefits

- *Strong immunity for dVs/dt*
- *Adjustable input threshold*
- *Reliable design*

Typical Application Schematic



Other Features

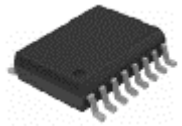
- *Typically IO+ 2A / IO- 3A capability for both channels*
- *Gate driver supply (V_{CC}) range from 12 to 20 V*
- *Cycle-by-cycle edge-triggered shutdown logic*
- *UVLO functions for V_{DD}/V_{BS}*
- *Matched propagation delay below 60ns*
- *Outputs in-phase with input signal*
- *Logic and power ground +/- 10 V offset*

Market Application

- *Electrical Contactor*
- *Industrial Motor Driver*
- *UPS & Solar Inverter*
- *Ballast*
- *Half-bridge Converter*

Packaging information

RTM Product



SOICW-16

- *FAN73912AMX : SOICW-16*

Public Information

NCP51530 – High and Low Side, High Performance 700V

Value Proposition

The NCP51530 are 700 V high frequency high-side and low-side drivers with very low and matched propagation delays for direct drive of 2 N-channel power MOSFETs in High Performance SMPS & Digital High power converters

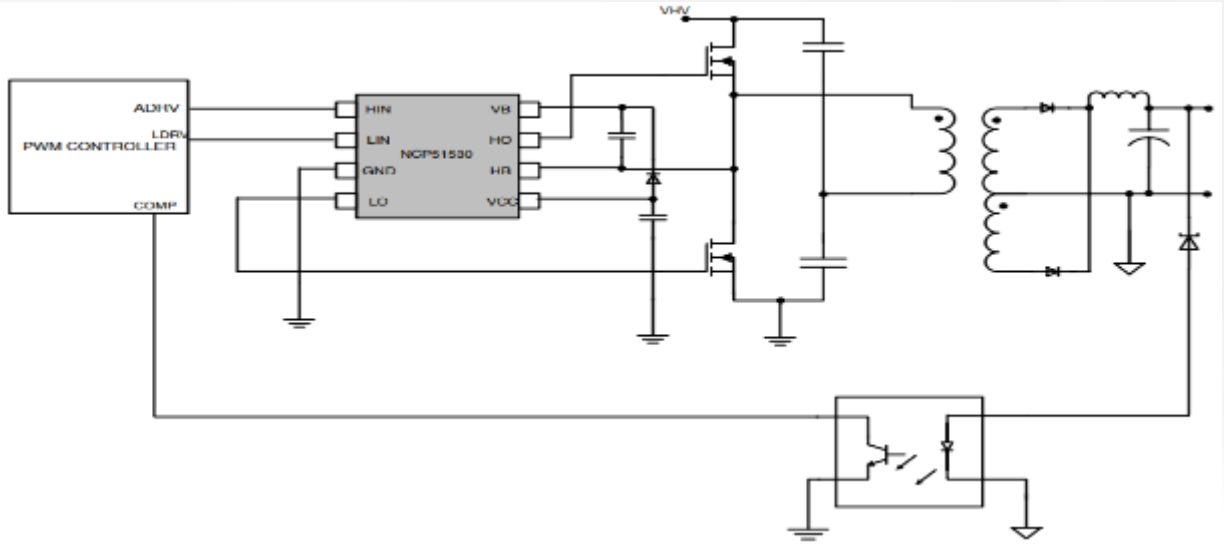
Unique Features

- *Input range: up to 700 V*
- *Excellent dynamic*
  - *60/25 ns Typ Prop delay (A/B)*
  - *7 ns Max Delay matching*
  - *8/15 ns Typ/Max Rise & Fall Times*
- *Negative bridge pin voltage up to -10 Volts*

Benefits

- *Off-line applications*
- *Well suited for high frequency operations*
- *Robust design*

Typical Application Schematic



Other Features

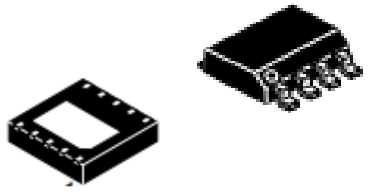
- *Dual input logic*
- *3/3.5 A Source/Sync currents*
- *Max Vcc : 20 V*
- *100 ns Min pulse width*
- *Under voltage lockout for both inputs*

Market Application

- *Server & Telecom Off-line Power Supplies*
- *Industrial High Power Converters*

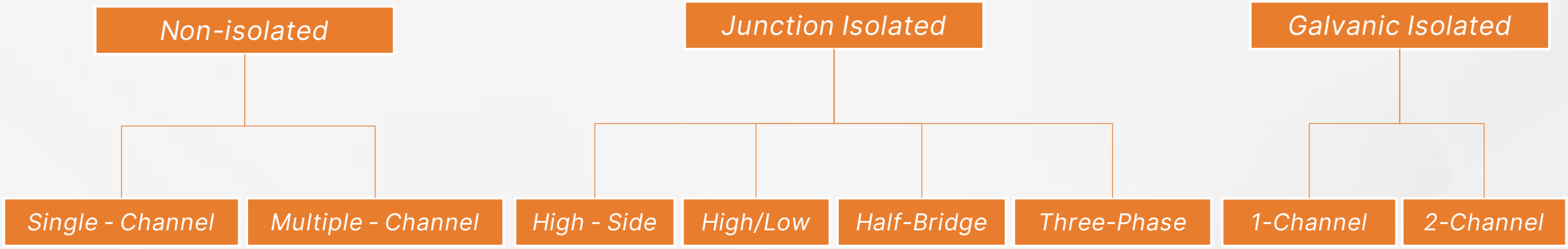
Packaging Information

- *NCP51530A/BDR2G : SOIC8*
- *NCP51530A/BMNTWG : DFN10 4mm x 4mm*



Public Information

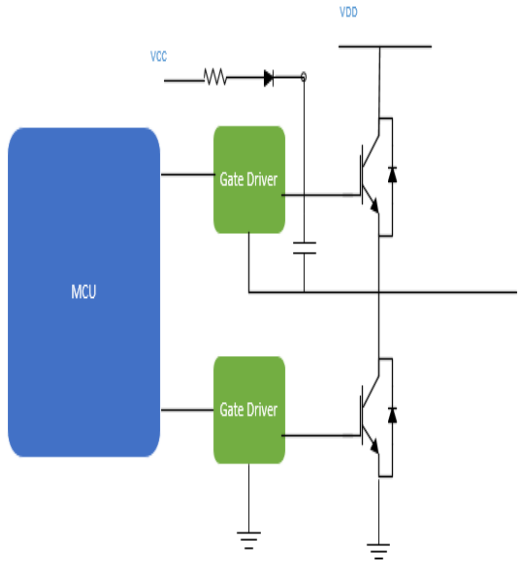
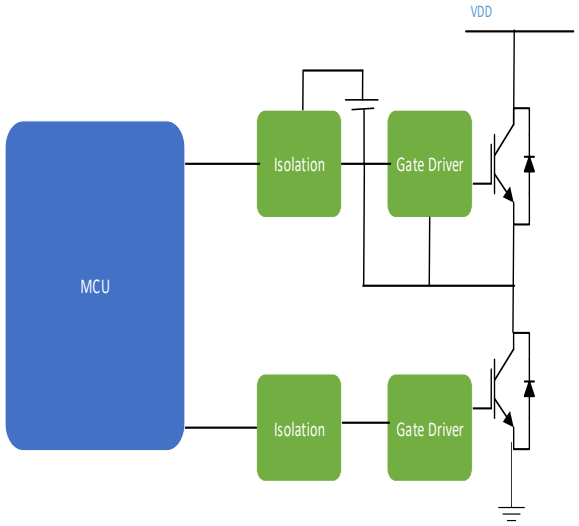
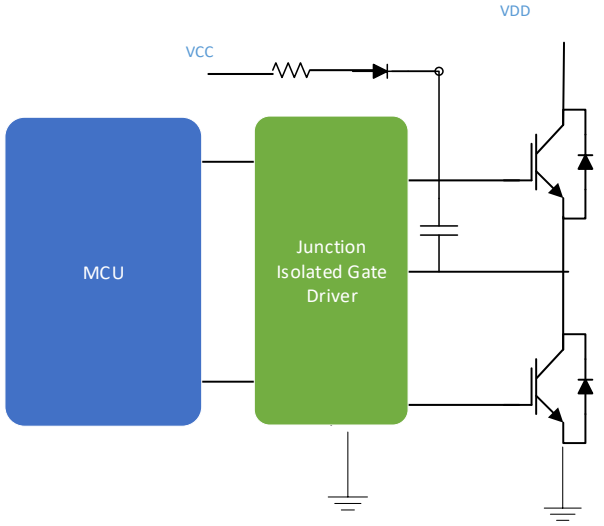
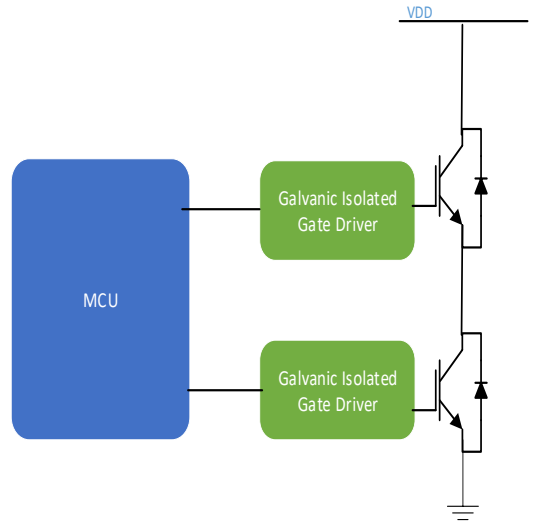
Gate Driver Category Definition



Non-isolated	Junction Isolated	Galvanic Isolated
• Single or multiple channel • Cheapest, simple solution for many applications where only a low-side driver is needed	• High Side, High/Low and Half Bridge • Floating HV well • From LV to 1200V breakdown voltage	• Normally needed in very high power/high voltage systems. • Three options: Optical, Inductive, Capacitive
Applications		
• Automotive • Industrial Systems • Consumer Devices	• Appliances • Consumer Devices & Power Tools • Auxiliary Automotive & Motors Drives • Offline Power	• Automotive traction inverters • Industrial Drive • Server Rack Power • Solar and Energy Storage
Products		
FAN3100/11 FAN3181 FAN312x NCD5700/1/2/3	FAN321x FAN322x	FAN73611	FAN8811 FAN7392 NCP51530 NCP5183	FAN7382 FAN73833 FAN73912 NCP5106B	FAN7382 FAN73833 FAN73912 NCP5106B	NCD57000/1 NCP5708x NCP51157	NCD57252 NCP51561

Public Information

Gate Driver Topologies

Non-isolated	Signal Isolated	Junction Isolated	Galvanic Isolated
			
• *Very simple* • *Minimal features* • *Layout critical to prevent crosstalk and GND currents* • *May need extra Cap & Common Mode Choke to decouple noise* • *APPS – Low Power SMPS with Low Cost MCU; Low drive Power*	• *Not commonly used* • *Layout can be complex due to extra IC's* • *Decoupling Caps extra cost* • *GND noise Common Mode choke could be required* • *APPS – Low to Med Power; Afterthought Isolation need it if long cables are used*	• *Low Cost* • *Easy layout* • *Need to select Boost Diode and Cap with care for speed/noise ratio* • *Possible Cap needed for cross - coupling reduction due to NO galvanic Isolation* • *APPS – DC-DC; PFC; Small-Med Motor drivers; Consumer Appliances; Med Power UPS< 3KW*	• *IC is complex; all Integrated* • *Full protection features* • *Higher cost/Highest safety* • *Ease of Layout, no extra components* • *APPS – High Power AC/BLDC Motors; Industrial SMPS; Solar Inverters; High Power UPS > 3KW*

Public Information

Quick High Voltage Gate drivers X-Ref

Topology	IN-OUT	ON SEMI	Infineon	STM	Mitsubishi	Note
High-Side Only	1-1	FAN7361	IR2117			
	1-1	FAN73611	IRS21171			
	2-2	FAN7385	IRS21853 (2A)		M81707FP	
	1-1	FAN7371	IRS21851			
	1-1	FAN73711	IRS21850			
High & Low Side	2-2	FAN7382 – NCP5106	IR2106	L6387		FAN7842 (200V)
	2-2	FAN7390 – NCP5181 FAN7390A FAN7391	IRS2181 IRS21814 IRS21864		M81709FP	
	2-2	FAN7392	IRS2110		M81702FP M81737FP	R2113 (500V) M81737FP(No SD, Low Current)
Half-Bridge	2-2	FAN7380 – NCP5304	IR2304	L6385		
	1-2	FAN7383	IR21094			SD and DT
	1-2	FAN73832 – NCP5111	IR2109 (2111)	L6384		
	2-2	FAN73833	IR2304	L6388		
	2-2	FAN7384		L6386		SD, DT, CS and FO
	1-2	FAN7393	IRS21844			SD and DT
	1-2	FAN7393A				
	1-2	FAN73932	IRS2184			
	2-2	FAN73933	IRS21834			IRS21834 : LIN (Active Low)
3-Phase	6-6	FAN7388	IR2136			FAN7888 (200V)
		FAN7389	IRS2336		M63993FP	6ED003L06-F (Infineon)
		FAN73893/4/5/6	IR21363SPbF, IR2136SPbF			

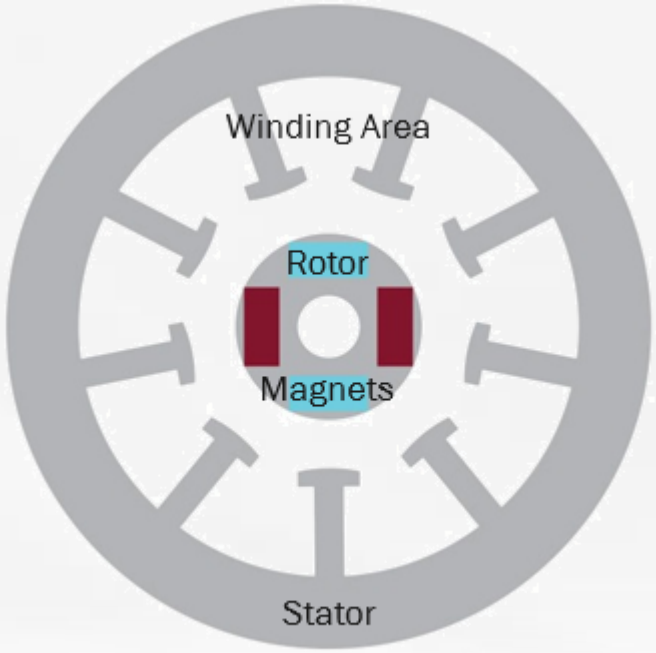
Public Information

Disclaimer

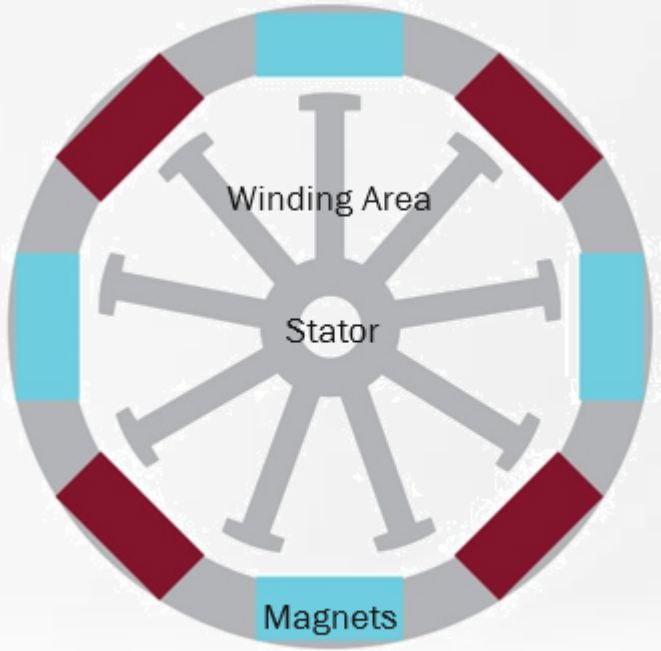
1st Order Approximation is typically on the conservative side. BLDC design is very complicated, and every customer has a different tolerance level for cost vs. performance. This 1st Order Approximation should be treated only as a starting point, not a final solution to a customer's BLDC Gate Driver and FET/IGBT design selection.

Public Information

BLDC Mechanical Structure - Types

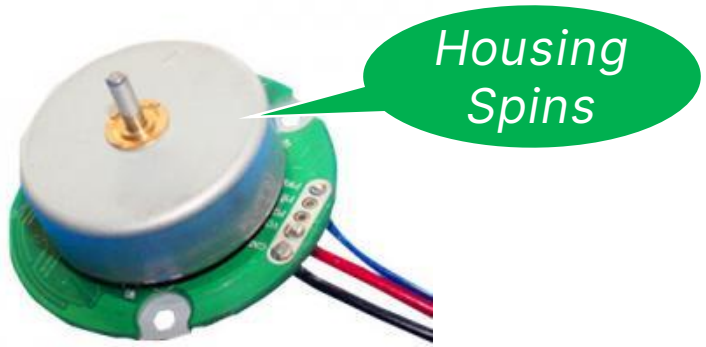


Inrunner



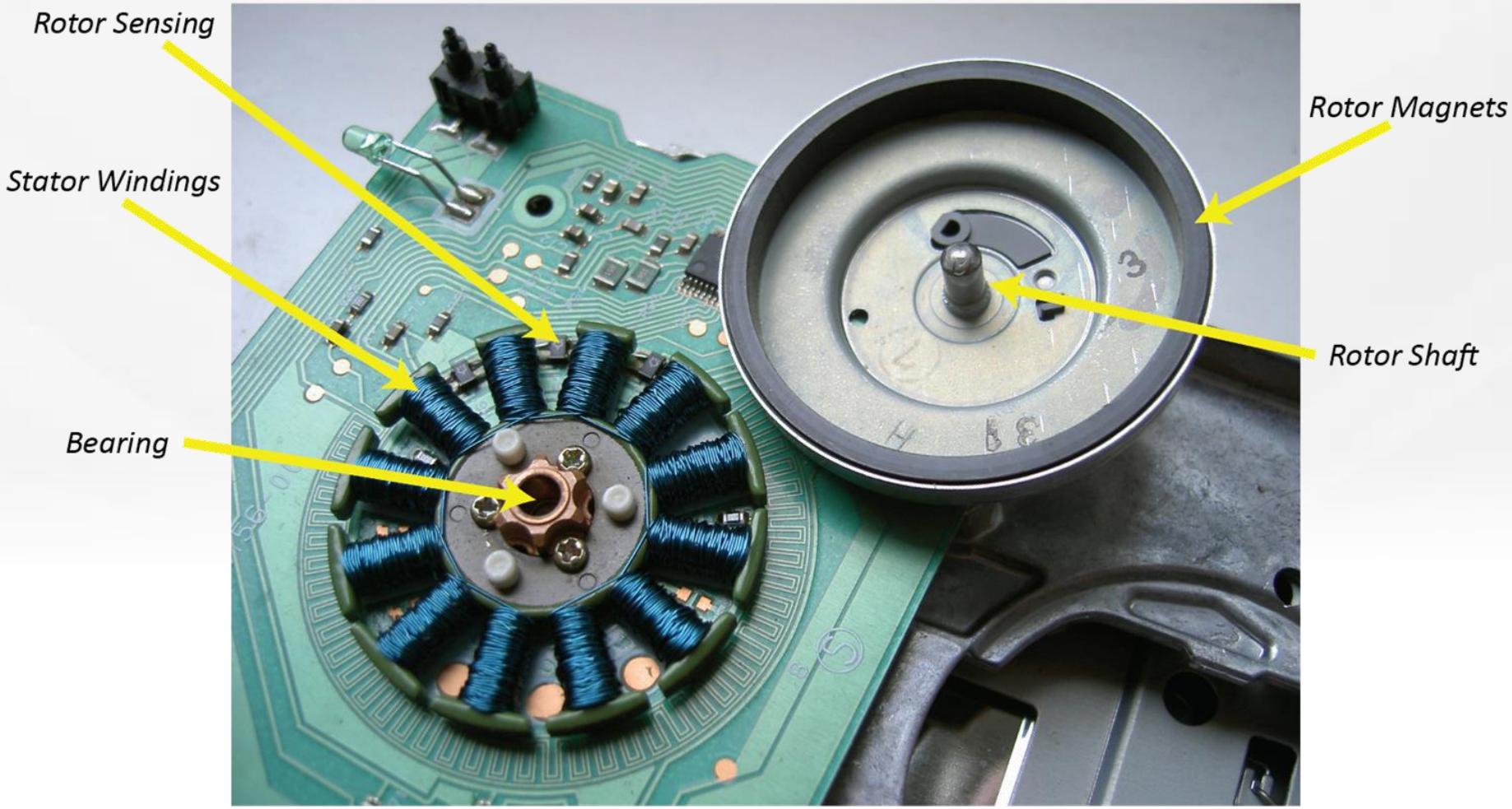
Outrunner





Public Information

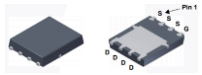
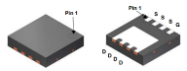
BLDC Mechanical Structure - Internals

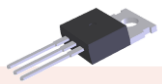
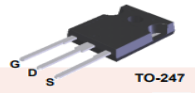
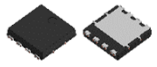
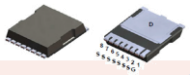
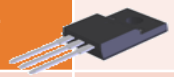


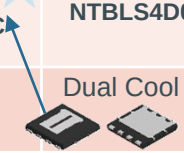
BLDC Motor (Out-Runner Style), 12 Stator Slots, 4 Poles, 3-Phase

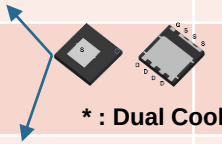
Public Information

New 150V product portfolio

Rds(on)	Power56	Power33
RDS(on)		
7.5mΩ	NTMFS7D5N15MC ★	
8.8mΩ	FDMS8D8N15C ★	
11.0mΩ	NTMFS011N15MC ★	
12.4mΩ	FDMS86255	
15.0mΩ	NTMFS015N15MC	
17mΩ	FDMS86200DC (Dual Cool) ★	
18mΩ	FDMS86200	
22.0mΩ	NTMFS022N15MC	NTTFS022N15MC
25mΩ	FDMS86250 ★	
34.0mΩ	NTMFS034N15MC	NTTFS034N15MC FDMC86260
51mΩ	FDMS86252 ★	FDMC86240
56mΩ	FDMS86252L	
90mΩ		FDMC86248
134mΩ		FDMC86244

Rds(on)	TO220	D2PAK	TO247	D2PAK-7L	Power88	TOLL
RDS(on)						
4.0~4.5mΩ				NTBGS4D1N15MC ★	NTMTS4D3N15MC ★ NTMTSC4D3N15MC	NTBLS4D0N15MC ★
5.0mΩ	NTP5D0N15MC ★	NTB5D0N15MC	FDH055N15A (5.9mΩ)			
6.0~6.5mΩ				NTBGS6D5N15MC ★ FDB0630N1507L FDB0690N1507L	NTMTS6D0N15MC FDMT800150DC *	FDBL0630N150
7.3~7.5mΩ	NTP7D3N15MC FDP075N15A	NTB7D3N15MC FDB075N15A				
8.2~8.3mΩ	FDP083N15A	FDB082N15A			FDMT800152DC * (9mΩ)	
11.0mΩ	NTP011N15MC ★	NTB011N15MC FDB110N15A	DPAK 			
15.0mΩ	TO220F 		NTDS015N15MC			
19mΩ	FDPF190N15A **					
22mΩ			FDD86250			
39~42mΩ	FDPF390N15A **	FDB390N15A	FDD390N15A FDD390N15ALZ			
52mΩ			FDD86252			
77mΩ	FDPF770N15A **		FDD770N15A			

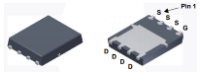
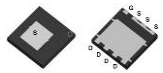
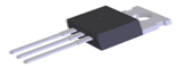




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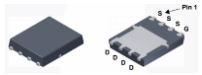
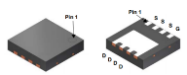
New 120V product portfolio

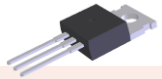
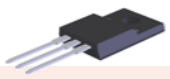
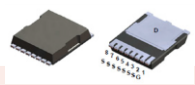
Rds(on)	Power56		Power88	TO220
				
RDS(on)	MV5	★ PTNG	MV5	★ PTNG
2.9~3.2mΩ			* : Dual Cool	FDP2D9N12C
4mΩ		FDMS4D0N12C		
4.2mΩ			FDMT800120DC *	
6mΩ		NTMFS006N12MC		
7.2mΩ	FDMS86202			
8mΩ		NTMFS008N12MC		
11.5mΩ	FDMS86201			

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Public Information

New 100V product portfolio

Rds(on)	Power56	Power33
RDS(on)		
2mΩ 3.2mΩ 3.6mΩ	FDMS86180 NTMFS3D6N10MCL (Logic Level)	
4.2mΩ	FDMS86181 NTMFSC4D2N10MC NTMFS4D2N10MD (Dual Cool)	
4.8mΩ 4.85mΩ 5mΩ	FDMS86150 NTMFS6B03N NTMFS005N10MCL (Low Q 100V)	
6mΩ	FDMS86152	
7.2mΩ	FDMS86182	
7.5mΩ	FDMS86101DC *	* : Dual Cool
8, 8.5mΩ	FDMS86101 FDMS86103L NTMFS6B05N	FDMC86184 (8.5mΩ)
10.6mΩ	Logic Level	NTTFS010N10MCL
12.2/12.8mΩ	NTMFS015N10MCL FDMS86183	
15mΩ	NTMFS6B14N	
24mΩ	FDMS86104	
25mΩ	FDMS86102LZ	
34mΩ	FDMS86105	
56mΩ	FDMS8622	

Rds(on)	TO220	TO220F	D2PAK	D2PAK-7L	Power88	TOLL
RDS(on)						
1.6~2.0mΩ				FDB1D7N10CL7	NTMTS1D6N10MC NTMTSC1D6N10MC NTMTS002N10MC NTMTSC002N10MC 	FDBL0200N100 (2mΩ)
2.3~2.6mΩ	FDP2D3N10C	FDPF2D3N10C		FDB0260N1007L (2.6mΩ)		FDBL0260N100
2.8~3.0mΩ				FDB0300N1007L	FDMT800100DC*	FDBL0240N100 (2.8mΩ)
3.5~3.6mΩ	FDP036N10A		FDB035N10A			
4.5mΩ	FDP4D5N10C FDP045N10A	FDPF4D5N10C FDPF045N10A				
8.5~9.0mΩ	FDP8D5N10C FDP085N10A	FDPF8D5N10C FDPF085N10A	NTBS9D0N10MC	DPAK 		
10.2mΩ				FDD86110		
15mΩ	FDP150N10A					
22.5mΩ				FDD86102LZ		
24mΩ			FDB86102LZ	FDD86102		

★ New Release and New Technology / Latest Technology

Public Information

New 80V product portfolio

★ New Release and New Technology / Latest Technology

Rds(on)	Power56			Power33	
RDS(on)	MV7	PTNG	★ T8	MV7 / T8	PTNG
2.2mΩ			NTMFS6H800N NTMFS6H800NL		
2.4~2.5mΩ	FDMS86350	FDMS2D5N08C			
2.8mΩ		* : Dual Cool	NTMFS6H801N / NL		
2.9~3.1mΩ	FDMS86300DC *	FDMS003N08C			
3.5, 3.7mΩ	FDMS037N08B	FDMS3D5N08LC	NTMFS6H818N / NL		
3.9~4.0mΩ	FDMS039N08B FDMS86300	FDMS004N08C			
4.3~4.8mΩ	FDMS86310	FDMS4D4N08C FDMS4D5N08LC	NTMFS6H824N / NL		
6.5~6.7mΩ		NTMFS006N08MC FDMS007N08LC	NTMFS6H836N / NL	FDMC86340	
7~7.8mΩ	FDMS86322			NTTFS8D1N08H (T8 / 8.3mΩ)	FDMC007N08LC FDMC007N08LCDC * FDMC008N08C
9.4~9.5mΩ			NTMFS6H848N / NL		NTTFS6H850N (T8) NTTFS6H850NL
10mΩ		NTMFSC010N08M7			FDMC010N08C FDMC010N08LC
11.7mΩ	FDMS86320		NTMFS6H852N / NL (14.7mΩ)	FDMC86320	NTTFS6H854N / NL (14.5mΩ)
23mΩ			NTMFS6H858N / NL (20.7mΩ)	FDMC86324	NTTFS6H860N / NL (21.1mΩ)
32,55mΩ			NTMFS6H864N / NL		NTTFS6H880N / NL NTTFS6H888N / NL (55mΩ)

Rds(on)	TOLL	D2PAK-7L	Power88
RDS(on)			
1.1~1.7mΩ	NTBLS1D1N08H NTBLS1D7N08H NTBLS1D5N08MC FDBL0150N80		NTMTS1D2N08H NTMTS1D5N08H NTMTS1D5N08MC NTMTSC1D5N08MC FDMT80080DC
1.9~2.0mΩ	NTBLS002N08MC		NTMTS002N08MC
1.6~1.7mΩ		FDB0165N807L FDB0190N807L	
2mΩ	FDBL0210N80		
2.2~2.4mΩ		FDB0250N807L FDB024N08BL7	
3mΩ	FDBL0330N80		* : Dual Cool

Rds(on)	DPAK
RDS(on)	
23mΩ	FDD86326

Rds(on)	TO220
RDS(on)	
2.3mΩ	FDP023N08B
2.7mΩ	FDP027N08B
3.2mΩ	FDP032N08B
3.9mΩ	FDP039N08B
5.3mΩ	FDP053N08B

New 60V product portfolio

Rds(on)	Power56			Power33	
RDS(on)	T6	T8 ★	MV7	T6 / T8	MV5/8
1.2~1.3mΩ	NTMFS5C604NL NTMFS5C604N	NTMFS5H600NL			
1.5mΩ	NTMFS5C612NL NTMFS5C612N				
1.65mΩ			FDMS86550		
1.8~1.9mΩ		NTMFS5H615NL			
2.3mΩ			FDMS86500DC *		
2.4~2.5mΩ	NTMFS5C628NL NTMFS5C628N	* : Dual Cool	FDMS86500L		
3.1mΩ		NTMFS5H630NL			
3.4mΩ			FDMS86540		
4mΩ	NTMFS5C645NL NTMFS5C645N			NTTFS3D7N06HL (T8 / 3.9mΩ)	
4.3mΩ					FDMC86570L
4.7mΩ	NTMFS5C646NL NTMFS5C646N			NTTFS5D1N06HL (T8 / 5.2mΩ)	
6.1mΩ	NTMFS5C670NL NTMFS5C670N				
6.3mΩ				NTTFS5C670NL (6.5mΩ)	FDMC86520DC *
7.2mΩ		NTMFS5H663NL			
7.4mΩ			FDMS86520		
7.9~8.2mΩ			FDMS86520L		FDMC86520L
9.2~9.3mΩ	NTMFS5C673NL NTMFS5C673N			NTTFS5C673NL	
10mΩ		NTMFS5H610NL			

Rds(on)	TOLL	D2PAK-7L	Power88
RDS(on)			
0.6mΩ			NTMTS0D7N06CL
0.7~0.8mΩ	NTBLS0D7N06C		NTMTS0D7N06C
1mΩ	NTBLS001N06C FDBL0110N60	NTBGS001N06C	NTMTS001N06C NTMTS001N06CL FDMT80060DC *
1.4~1.5mΩ	FDBL0150N60	FDB0170N607L NTBGS1D5N06C	
2.0mΩ		NTBGS002N06C	* : Dual Cool
2.5mΩ , 3.5mΩ		NTBGS2D5N06C NTBGS3D5N06C	

Rds(on)	DPAK	TO220	TO220F
2.0~2.2mΩ	NTD5C434N (40V)	FDP020N06B	
3mΩ	NTD5C632NL	FDP030N06B	
3.5~3.6mΩ	NTD5C446N(40V)		FDPF035N06B
4.1mΩ	FDD86540		FDPF041N06BL1
4.6mΩ	NTD5C648NL		
5.7mΩ	NTD5C464N		
9.3mΩ	NTD5C668NL		
17.5mΩ	NTD5C684NL		
30mΩ	NTD5C688NL		

Public Information

Others : NTMFS23D9N06HL (23.9mΩ) & NTMFS5C682NL (21mΩ)

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New 40V product portfolio

Rds(on)	Power56		Power33	
RDS(on)	T6	T8 ★	MV5/8	T6/T8	MV5/8
0.75/0.8mΩ	NTMFS5C404NL	NTMFS5H400NL			
0.85mΩ			FDMS8350L		
0.9~0.92 /1.1~1.2mΩ	NTMFS5C410NL NTMFS5C410N	NTMFS5H409NL (1.1mΩ)	FDMS8320LDC * FDMS8320L (1.1mΩ)		
1.5~1.7/1.4mΩ	NTMFS5C430NL NTMFS5C430N	NTMFS5H414NL	FDMS015N04B (1.5mΩ)		
2/2.1mΩ	NTMFS5C423NL	NTMFS5H419NL	FDMS8460 (2.2mΩ)		FDMC8360L
2.3~2.5mΩ	NTMFS5C442NL NTMFS5C442N				FDMC8321LDC FDMC8321L
2.75~3.3mΩ	NTMFS5C450NL NTMFS5C450N	NTMFS5H425NL NTMFS5H431NL	FDMS8333L (3.1mΩ)	NTTFS2D8N04HL (T8 / 2.75mΩ) NTTFS5C453NL (T6 / 3.0mΩ)	
3.7/3.8mΩ	NTMFS5C456NL			NTTFS5C454NL (T6 / 3.8mΩ)	
4.5mΩ	NTMFS5C460NL				
5.8mΩ					FDMC8462
9.7mΩ					FDMC8327L
10.3mΩ	NTMFS5C468NL				

* : Dual Cool

Rds(on)	DPAK	D2PAK-7L	Power88	TOLL
RDS(on)				
0.4mΩ			NTMTS0D4N04C	
0.45mΩ			NTMTS0D4N04CL	
0.55mΩ			NTMTS0D6N04C	
0.56mΩ			FDMT80040DC	
0.6mΩ			NTMTS0D6N04CL	
0.65mΩ				FDBL0065N40
0.7mΩ			NTMTS0D7N04C	
0.75mΩ			NTMTS0D7N04CL	
0.8mΩ		FDB0105N407L		
0.9mΩ				FDBL0090N40
1.2mΩ				FDBL0120N40
2.2mΩ	NTD5C434N			
3.6mΩ	NTD5C446N			
5.7mΩ	NTD5C464N			

* : Dual Cool

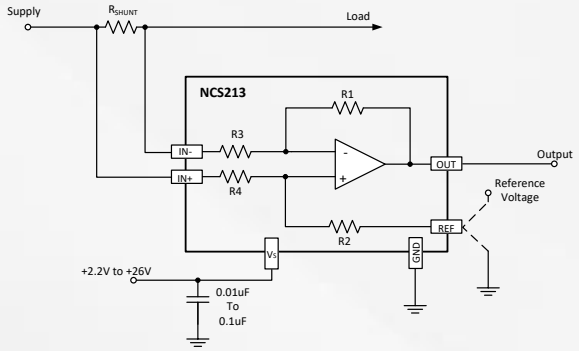
Public Information

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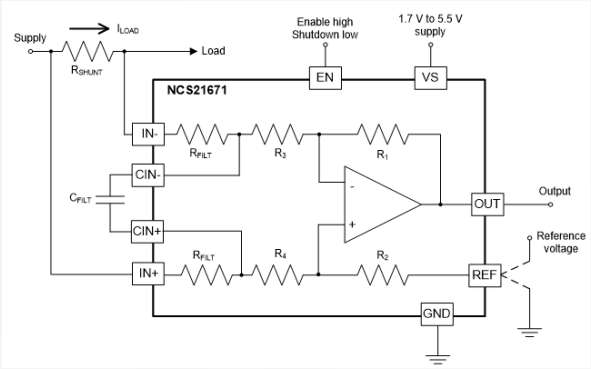
Current Sense Amplifiers (Integrated Resistors)

Monitoring the current consumption provide critical information that can assist in the safety and diagnostic functions in a system. **onsemi** offers current sense amplifiers that integrate external resistors to offer a higher accuracy, smaller solution, in addition to the cost effective stand alone Op Amps.

Current Sense Amplifier with Int. Gain Setting Resistors



Current Sense Amplifier with Integrated input filtering



Unidirectional Current Sense Amplifier

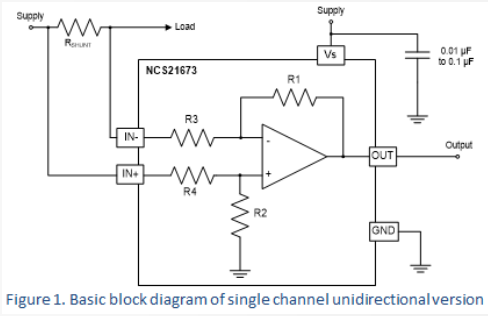
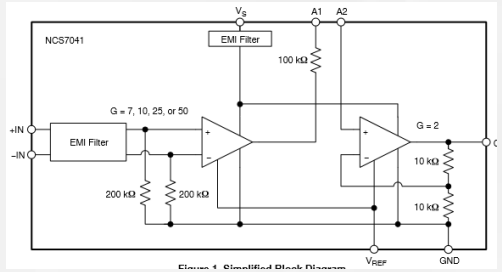


Figure 1. Basic block diagram of single channel unidirectional version

80V Current Sense Amplifier



Zero Drift Current Sense Amplifiers (Integrated and Precision performance)

** Schedules as of 2/16/2021*

Device	Ch.	Min.V_S (V)	Max.V_S (V)	Input CM Range (V)	BW (KHz)	Max. V_{OS} (µV)	V_{OS} Drift (µV/°C)	Gain Error (%)	CMRR (dB)	Package(s)	Features	Samples Status	Release Status
NCS(V)21xR[NEW]	1	2.2	26	2.2 to 26	25- 90	35	0.5	1	105	SC70, UQFN	Low V_{OS} and drift over time and temp.	Available	Released
NCS199AxR*[NEW]	1	2.2	26	2.2 to 26	40-90	150	0.5	1.5	100	SC70, UQFN	Low V_{OS} and drift over time and temp.	Available	Release
NCS(V)21671 *[DEV]	1	1.7	5.5	-0.1 to 40	20-40	25	0.5	0.3	114	SC70, Micro-10	Integrated Input Filters and Enable	Aug 2021	Nov 2021
NCS(V)21673/4/5*[DEV]	1/2/4	2.7	5.5	-0.1 to 40	105-350	100	1	1	100	TSOP-5, Micro-8. TSSop-14	Multiple channel, unidirectional and higher BW	NCS21674 - 5/1/2021 NCS21673 – 7/1/2021 NCS21675 – 10/1/2021	NCS21674 - 8/1/2021 NCS21673 – 12/1/2021 NCS21675 – 3/1/2022
NCS(V)703x/41 *[DEV]	1	4.5	5.5	-5 to 80	100	300	3	0.3	90	SOIC-8, Micro-8	Wide Common Mode Range	Available	May 2021

Public Information