Is Now Part of

ON Semiconductor®

To learn more about ON Semiconductor, please visit our website at www.onsemi.com

Please note: As part of the Fairchild Semiconductor integration, some of the Fairchild orderable part numbers will need to change in order to meet ON Semiconductor's system requirements. Since the ON Semiconductor product management systems do not have the ability to manage part nomenclature that utilizes an underscore (_), the underscore (_) in the Fairchild part numbers will be changed to a dash (-). This document may contain device numbers with an underscore (_). Please check the ON Semiconductor website to verify the updated device numbers. The most current and up-to-date ordering information can be found at www.onsemi.com. Please email any questions regarding the system integration to Fairchild_questions@onsemi.com.

ON Semiconductor™

October 2016

FAM65V05DF1
Auto SPM® Series
Automotive 3-Phase IGBT Smart Power Module

Features

- 27 pin Auto SPM® module
- 650 V-50 A 3-phase IGBT module with low loss IGBTs and soft recovery diodes optimized for motor control applications
- Integrated gate drivers with Internal V_S connection, Under Voltage lockout, Over-current shutdown, Temperature Sensing Unit and Fault reporting
- Electrically isolated AlN substrate with low Rthjc
- Module serialization for full traceability
- Pb-Free and RoHS compliant
- UL Certified No. E209204 (UL 1557)
- Automotive qualified

Applications and Benefits

Automotive high voltage auxiliary motors such as air conditioning compressor and oil pump

- Compact design
- Simplified PCB layout and low EMI
- Simplified Assembly
- High reliability

General Description

FAM65V05DF1 is an advanced Auto SPM® module providing a fully-featured high-performance auxiliary inverter output stage for hybrid and electric vehicles. These modules integrate optimized gate drive of the built-in IGBTs to minimize EMI and losses, while also providing various protection features, in a compact 12cm² footprint.

Applications Note

AN-8422` – *650 V Auto SPM® Series; Automotive 3-Phase IGBT Smart Power Module User's Guide*

Top View **Bottom View**

Figure 1. Package view

Ordering Information

Part Number	Marking	Package	Packing Method	Qty. per tube	Qty. per box
FAM65V05DF1	FAM65V05DF1	APM27-CAA	Tube	10	60

Pin Configuration

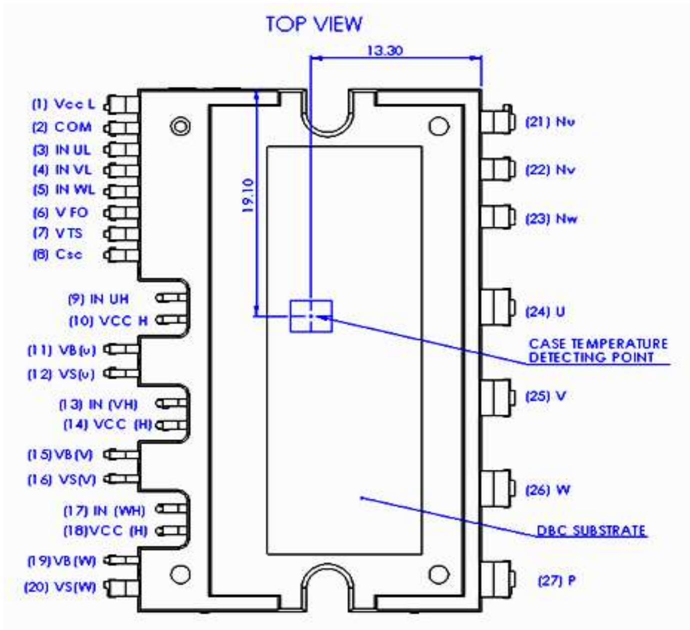


Figure 2. Pin configuration

Pin Description

Pin Number	Pin	Pin Function Description
1	VCC(L)	Low-side Common Bias Voltage for IC and IGBTs Driving
2	COM	Common Supply Ground
3	IN (UL)	Signal Input for Low-side U Phase
4	IN (VL)	Signal Input for Low-side V Phase
5	IN (WL)	Signal Input for Low-side W Phase
6	VFO	Fault Output
7	VTS	Output for LVIC temperature sense
8	CSC	Capacitor (Low-pass Filter) for Short-Current Detection Input
9	IN (UH)	Signal Input for High-side U Phase
10	VCC(H)	High-side Common Bias Voltage for IC and IGBTs Driving
11	VB(U)	High-side Bias Voltage for U Phase IGBT Driving
12	VS(U)	High-side Bias Voltage Ground for U Phase IGBT Driving
13	IN(VH)	Signal Input for High-side V Phase
14	VCC(H)	High-side Common Bias Voltage for IC and IGBTs Driving
15	VB(V)	High-side Bias Voltage for V Phase IGBT Driving
16	VS(V)	High-side Bias Voltage Ground for V Phase IGBT Driving
17	IN(WH)	Signal Input for High-side W Phase
18	VCC(H)	High-side Common Bias Voltage for IC and IGBTs Driving
19	VB(W)	High-side Bias Voltage for W Phase IGBT Driving
20	VS(W)	High-side Bias Voltage Ground for W Phase IGBT Driving
21	NU	Negative DC–Link Input for U Phase
22	NV	Negative DC–Link Input for V Phase
23	NW	Negative DC–Link Input for W Phase
24	U	Output for U Phase
25	V	Output for V Phase
26	W	Output for W Phase
27	P	Positive DC–Link Input

Internal Equivalent Circuit and Input/Output Pins

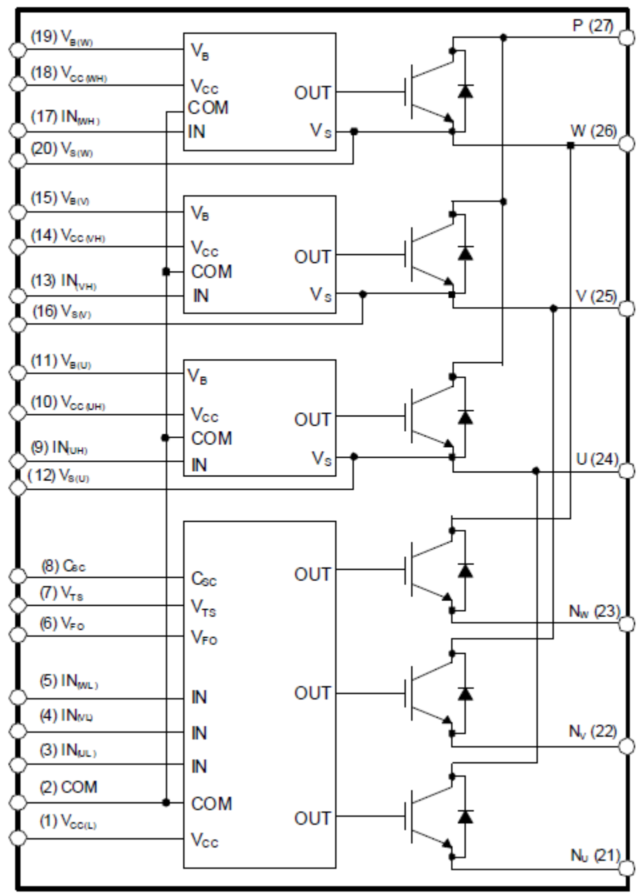


Figure 3. Schematic

Gate drivers block diagram

High side gate driver (x3 single channel):

- Control circuit under-voltage (UV) protection
- 3.3/5 V CMOS/LSTTL compatible, Schmitt trigger input

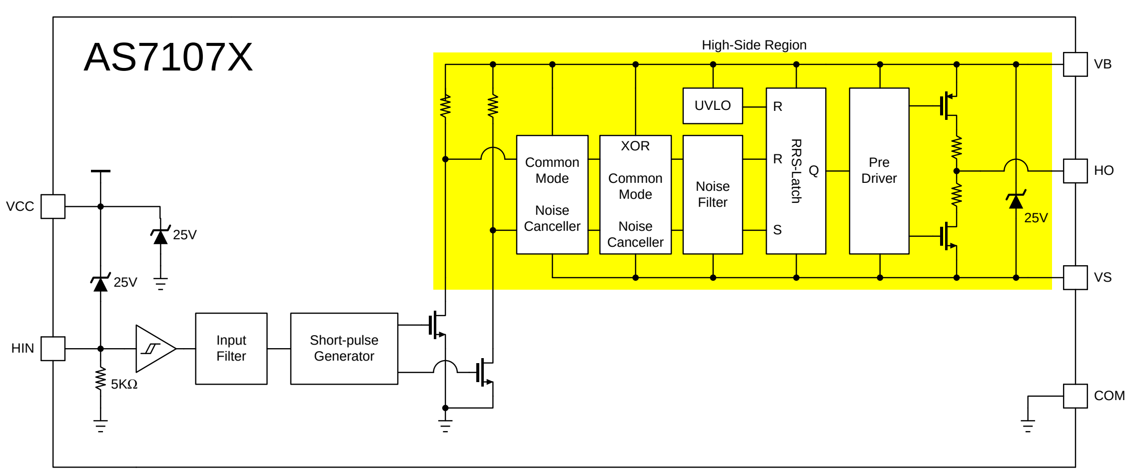


Figure 4. High Side gate drivers (block diagram)

Low side gate driver (x1 monolithic three-channel):

- Control circuit under-voltage (UV) protection
- Short circuit protection (SC)
- Temperature sensing unit
- Fault Output
- 3.3/5 V CMOS/LSTTL compatible, Schmitt trigger input

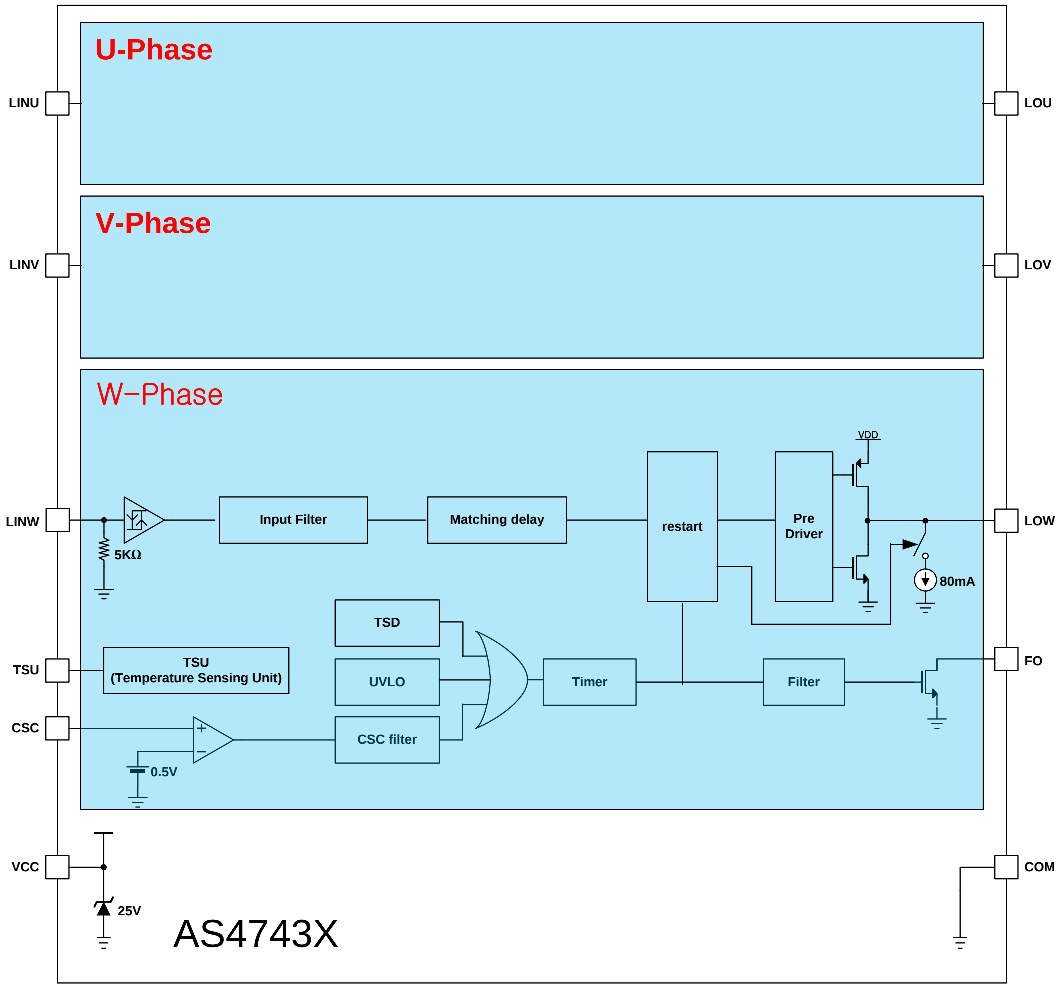


Figure 5. Low Side gate drivers (block diagram)

Absolute Maximum Ratings (T_J = 25°C, Unless Otherwise Specified)

Stresses exceeding the Absolute Maximum Ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability.

Inverter Part

Symbol	Parameter	Condition	Rating	Unit
V_{PN}	Supply voltage	Applied between P- N_U, N_V, N_W	500	V
$V_{PN(Surge)}$	Supply Voltage (surge)	Applied between P- N_U, N_V, N_W dI/dt ≤ 3A/ns	575	V
V_{CES}	Collector-emitter Voltage at the IGBT/diode	T_J=25°C	650	V
± I_C	IGBT continuous collector current	T_C = 100°C, T_{Jmax}=175°C (Note1)	50	A
± I_{CP}	IGBT peak collector pulse current	T_C = 25°C, T_{Jmax}=175°C, V_{CC}=V_{BS}=15V, less than 1ms (Note 6)	150	A
P_C	Collector Dissipation	T_C = 25°C per IGBT	333	W
T_J	Junction Temperature	IGBT/Diode	-40 ~ +175	°C
		Driver IC	-40 ~ +150	°C

Control Part

Symbol	Parameter	Condition	Rating	Unit
V_{CC}	Control Supply Voltage	Applied between $V_{CC(H)}$, $V_{CC(L)}$ - COM	20	V
V_{BS}	High-side Control Bias Voltage	Applied between $V_{B(U)}$ - $V_{S(U)}$, $V_{B(V)}$ - $V_{S(V)}$, $V_{B(W)}$ - $V_{S(W)}$	20	V
V_{IN}	Input Signal Voltage	Applied between $IN_{(UH)}$, $IN_{(VH)}$, $IN_{(WH)}$, $IN_{(UL)}$, $IN_{(VL)}$, $IN_{(WL)}$ - COM	-0.3 ~ V_{CC}+0.3	V
V_{FO}	Fault Output Supply Voltage	Applied between V_{FO} - COM	-0.3 ~ V_{CC}+0.3	V
I_{FO}	Fault Output Current	Sink Current at V_{FO} Pin	5	mA
V_{SC}	Current Sensing Input Voltage	Applied between C_{SC} - COM	-0.3 ~ V_{CC}+0.3	V
V_{TS}	Temperature sense unit		-0.3 ~ 2/3 x V_{CC})	V

Total System

Symbol	Parameter	Condition	Rating	Unit
T_{STG}	Storage Temperature		-40 ~ 125	°C
V_{ISO}	Isolation Voltage	60Hz, Sinusoidal, AC 1 minute, Connection Pins to heat sink plate	2500	V_{rms}
T_{LEAD}	Max lead temperature at the base of the package during pcb assembly	No remelt of internal solder joints	200	°C

Package Characteristics

Symbol	Parameter	Conditions	Typ.	Max.	Units
$R_{th(j-c)Q}$	Junction to Case Thermal Resistance (2)	Inverter IGBT part (per IGBT)	-	0.45	°C/W
$R_{th(j-c)F}$		Inverter FWD part (per DIODE)	-	0.85	°C/W
L_σ	Package Stray Inductance	P to N_U, N_V, N_W (3)	24	-	nH

Notes:

1. Current limited by package terminal, defined by design
2. Case temperature measured below the package at the chip center, compliant with MIL STD 883-1012.1 (single chip heating), DBC discoloration allowed, please refer to application note **AN-9190** *(Impact of DBC Oxidation on SPM® Module Performance)*
3. Stray inductance per phase measured per IEC 60747-15

Electrical Specifications

Inverter part (T_J as specified)

Symbol		Parameters	Conditions	Min	Typ	Max	Unit
$V_{CE(SAT)}$		Collector-Emitter Saturation Voltage	$V_{CC} = V_{BS} = 15$ V, $V_{IN} = 5$ V $I_C = 50$ A, $T_J = 25°C$	-	1.65	-	V
			$V_{CC} = V_{BS} = 15$ V, $V_{IN} = 5$ V $I_C = 50$ A, $T_J = 125°C$	-	1.9	2.4	V
V_F		FWD Forward Voltage	$V_{IN} = 0$ V, $I_F = 30$ A, $T_J = 25°C$	-	2.1	-	V
			$V_{IN} = 0$ V, $I_F = 30$ A, $T_J = 125°C$		1.9	2.5	V
HS	t_{ON}	High Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5V, Ls=55 nH, Inductive Load $T_J = 25°C$ (4 , 5)	-	0.73	-	μs
	$t_{C(ON)}$			-	0.12	-	
	t_{OFF}			-	0.80	-	
	$t_{C(OFF)}$			-	0.14	-	
	t_{rr}			-	0.10	-	
	t_{ON}	High Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5V, Ls=55 nH, Inductive Load $T_J = 125°C$ (4, 5)	-	0.70	-	μs
	$t_{C(ON)}$			-	0.15	-	
	t_{OFF}			-	0.87	-	
	$t_{C(OFF)}$			-	0.19	-	
	t_{rr}			-	0.20	-	
LS	t_{ON}	Low Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls=55 nH, Inductive Load $T_J = 25°C$ (4, 5)	-	0.68	-	μs
	$t_{C(ON)}$			-	0.20	-	
	t_{OFF}			-	0.86	-	
	$t_{C(OFF)}$			-	0.19	-	
	t_{rr}			-	0.14	-	
	t_{ON}	Low Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls=55 nH, Inductive Load $T_J = 125°C$ (4,5)	-	0.64	-	μs
	$t_{C(ON)}$			-	0.24	-	
	t_{OFF}			-	0.88	-	
	$t_{C(OFF)}$			-	0.23	-	
	t_{rr}			-	0.20	-	
SCWT		Short Circuit withstand time (6)	$V_{CC} = V_{BS} = 15$ V, $V_{PN} = 450$ V, $T_J = 25°C$, Non-repetitive	-	5	-	μs
I_{CES}		Collector-Emitter Leakage Current for IGBT and diode in parallel	$T_J = 25°C$, $V_{CE} = 650$ V	-	3	-	μA
			$T_J = 125°C$, $V_{CE} = 650$ V	-	150	1500	μA

Notes:

4. t_{ON} and t_{OFF} include the propagation delay time of the internal drive IC. $t_{C(ON)}$ and $t_{C(OFF)}$ are the switching times of IGBT itself under the given gate driving condition internally. Refer to Figure 6 for detailed information
5. Stray inductance Ls is sum of stray inductance of module & setup
6. Verified by design and bench-testing only

Control Part (T_J = -40°C to 150°C, unless otherwise specified, typical values specified at T_J=125°C)

Symbol	Parameters	Conditions		Min	Typ	Max	Unit
I_{QCCL}	Quiescent V_{CC} Supply Current	V_{CC} = 15 V, $IN_{(UL, VL, WL)}$ = 0 V	$V_{CC(L)}$ – COM	-	-	5	mA
I_{QCCH}		V_{CC} = 15 V, $IN_{(UH, VH, WH)}$ = 0 V	$V_{CC(H)}$ – COM	-	-	150	μA
I_{PCCH}	Operating V_{CC} Supply Current	$V_{CC(UH, VH, WH)}$ = 15 V f_{PWM} = 20 kHz Duty=50%, applied to one PWM signal input for high-side	$V_{CC(UH)}$ – COM $V_{CC(VH)}$ – COM $V_{CC(WH)}$ – COM	-	-	0.30	mA
I_{QCCL}		$V_{CC(UH, VH, WH)}$ = 15 V f_{PWM} = 20 kHz Duty=50%, applied to one PWM signal input for low-side	$V_{CC(L)}$ – COM	-	-	8.5	mA
I_{QBS}	Quiescent V_{BS} Supply Current	V_{BS} = 15 V, $IN_{(UH, VH, WH)}$ = 0V	$V_{B(U)}$ - $V_{S(U)}$ $V_{B(V)}$ -$V_{S(V}$ $V_{B(W)}$ - $V_{S(W)}$	-	-	150	μA
I_{PBS}	Operating V_{BS} Supply Current	V_{CC}=VBC=15 V $IN_{(UH, VH, WH)}$ = 0 V	$V_{B(U)}$ - $V_{S(U)}$ $V_{B(V)}$ -$V_{S(V}$ $V_{B(W)}$ - $V_{S(W)}$	-	-	4.5	mA
V_{FOH}	Fault Output Voltage	V_{SC} = 0 V, V_{FO} Circuit: 4.7 kΩ to 5 V Pull-up		4.5	-	-	V
V_{FOL}		V_{SC} = 1 V, V_{FO} Circuit: 4.7 kΩ to 5 V Pull-up		-	-	0.5	V
$V_{SC(ref)}$	Short-Circuit Trip Level	V_{CC} = 15 V (7)	C_{SC}-COM	0.45	0.52	0.59	V
UV_{CCD}	Supply Circuit Under-Voltage Protection	Detection Level, T_J= 125°C		10.6	-	13.2	V
UV_{CCR}		Reset Level, T_J= 125°C		11.0	-	13.8	V
UV_{BSD}		Detection Level, T_J= 125°C		10.5	-	13	V
UV_{BSR}		Reset Level, T_J= 125°C		10.8	-	13.3	V
t_{FOD}	Fault-out Pulse Width			-	60	-	μs
V_{TS}	LVIC Temperature Sensing Voltage Output	$V_{CC(L)}$ = 15 V, T_{LVIC} =125˚C (8)		-	2.4	-	V
$V_{IN(ON)}$	ON Threshold Voltage	Applied between $IN_{(UH)}$, $IN_{(VH)}$, $IN_{(WH)}$, $IN_{(UL)}$, $IN_{(VL)}$, $IN_{(WL)}$ – COM		-	2.6	3.1	V
$V_{IN(OFF)}$	OFF Threshold Voltage			0.9	1.2	-	V

Notes:
7. Short-circuit current protection is functional only for low side
8. T_{LVIC} is the junction temperature of the LVIC itself

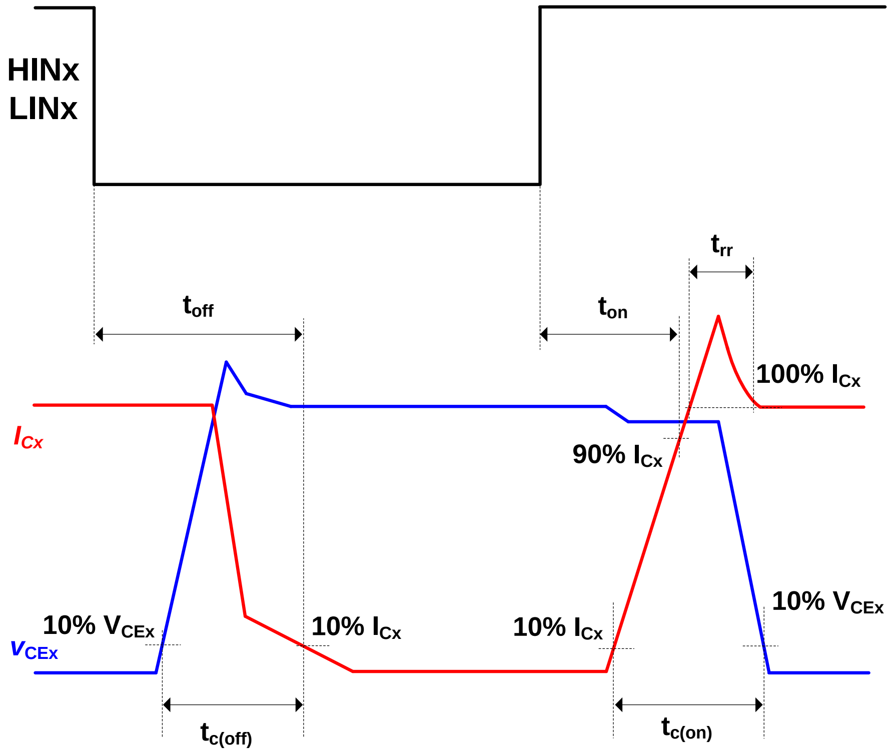


Figure 6a. Switching Time Definition

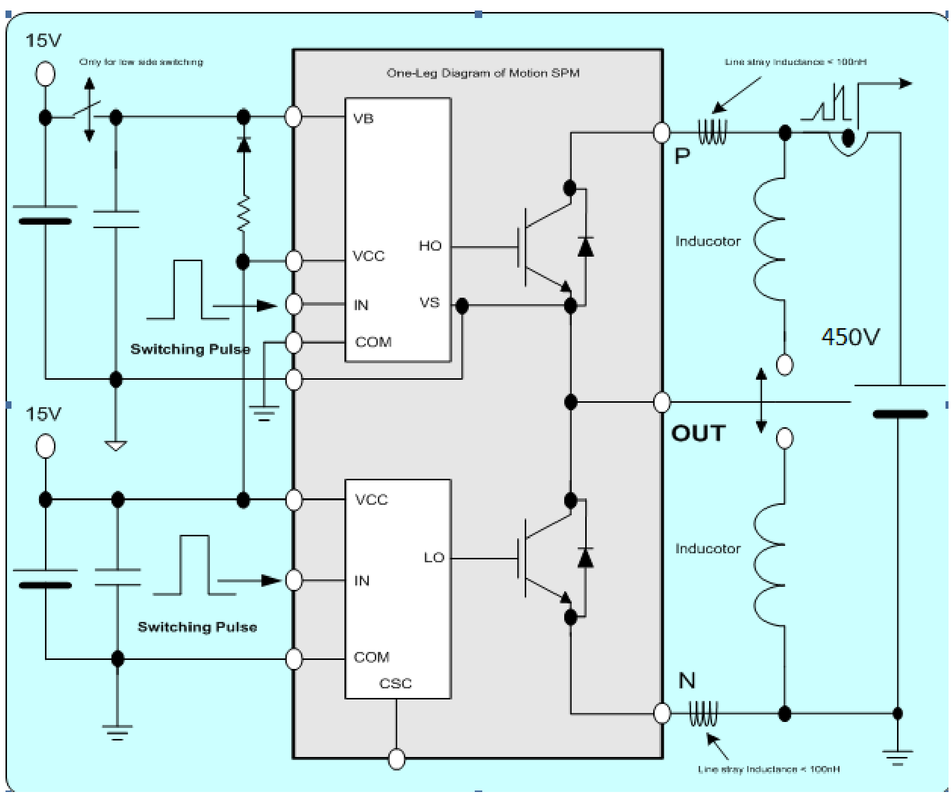


Figure 7b. Switching Evaluation Circuit

Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended Operating Conditions are specified to ensure optimal performance to the datasheet specifications. Fairchild does not recommend exceeding them or designing to Absolute Maximum Ratings.

Symbol	Parameters	Conditions	Min	Typ	Max	Unit
V_{PN}	Supply Voltage	Applied between P - N_U, N_V, N_W	-	450	500	V
V_{CC}	Control Supply Voltage	Applied between $V_{CC(H)}$, $V_{CC(L)}$ - COM	13.5	15	16.5	V
V_{BS}	High-side Bias Voltage	Applied between $V_{B(U)}$ - $V_{S(U)}$, $V_{B(V)}$ - $V_{S(V)}$, $V_{B(W)}$ - $V_{S(W)}$	13.3	15	18.5	V
dV_{CC}/dt, dV_{BS}/dt	Control supply variation		-1	-	1	V/µs
t_{dead}	Blanking Time for Preventing Arm-short	For Each Input Signal	1.0	-	-	µs
f_{PWM}	PWM Input Signal	T_C= 125°C	-	-	20	kHz
V_{SEN}	Voltage for Current Sensing	Applied between N_U, N_V, N_W – COM (Including surge voltage)	-4	-	4	V
T_J	Junction temperature		-40	-	150	°C

Mechanical Characteristics and Ratings

Parameter	Conditions	Conditions	Limits			Units
			Min.	Typ.	Max.	
Mounting Torque	Mounting Screw: - M3	Recommended 0.62N•m	0.51	0.62	0.80	N•m
Device Flatness					+150	µm
Weight				15		g

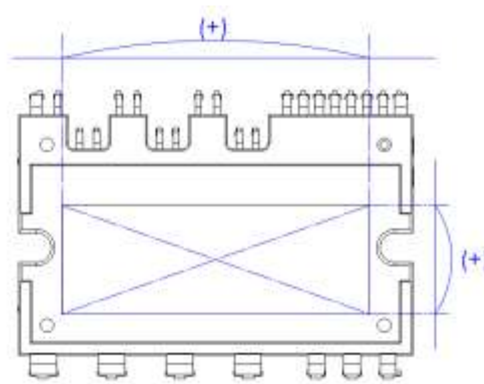


Figure 8. Flatness Measurement Position

Typical Inverter Characteristics

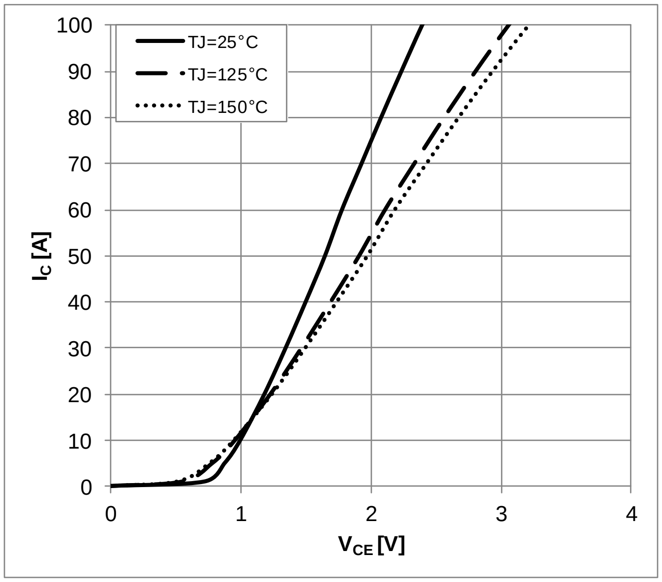


Figure 9. Output characteristics IGBT inverter (typical)
$V_{CC} = V_{BS} = 15$ V, V_{IN}=5 V

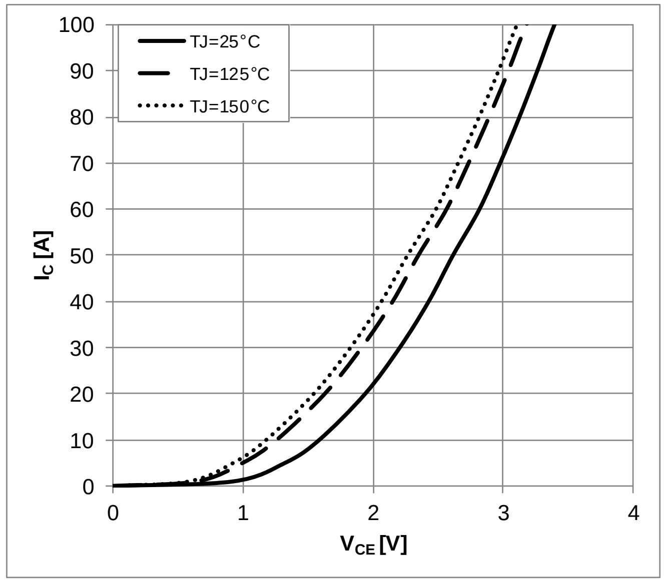


Figure 10. Forward characteristics DIODE inverter (typical)
V_{IN}=0 V

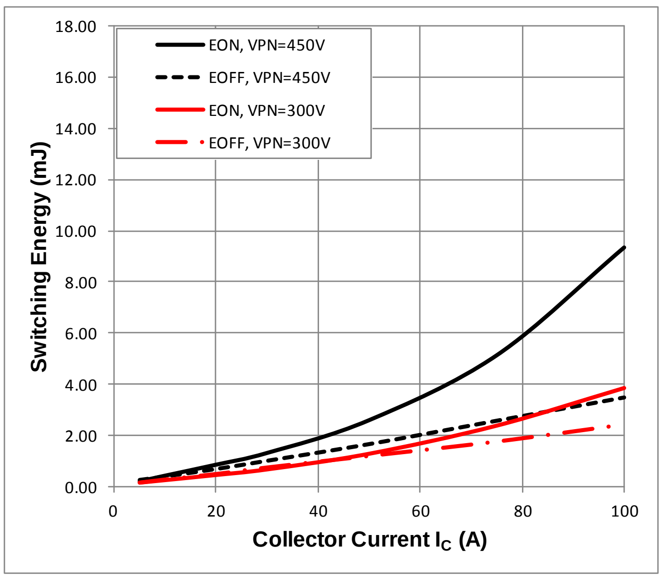


Figure 11. Switching losses IGBT inverter High-Side (typical) versus collector current
VCC = VBS = 15 V
VIN = 0 V ↔ 5 V, Ls=55 nH, Inductive Load, T_J=125°C

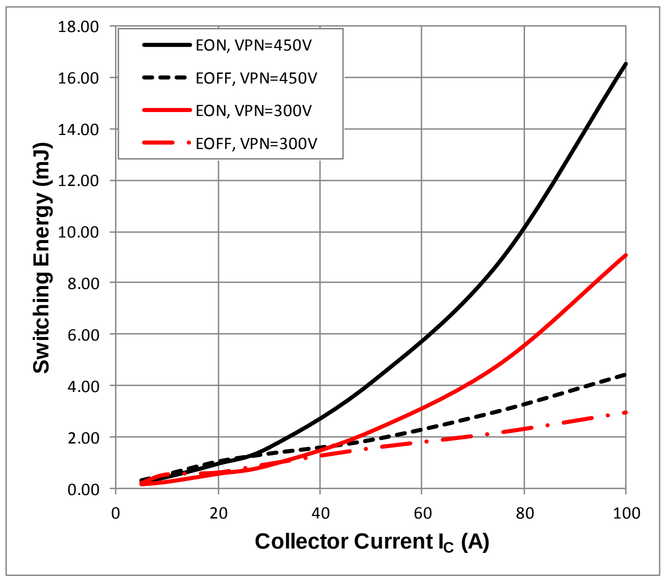


Figure 12. Switching losses IGBT inverter Low-Side (typical) versus collector current
VCC = VBS = 15 V
VIN = 0 V ↔ 5 V, Ls=55 nH, Inductive Load, T_J=125°C

Typical Inverter Characteristics

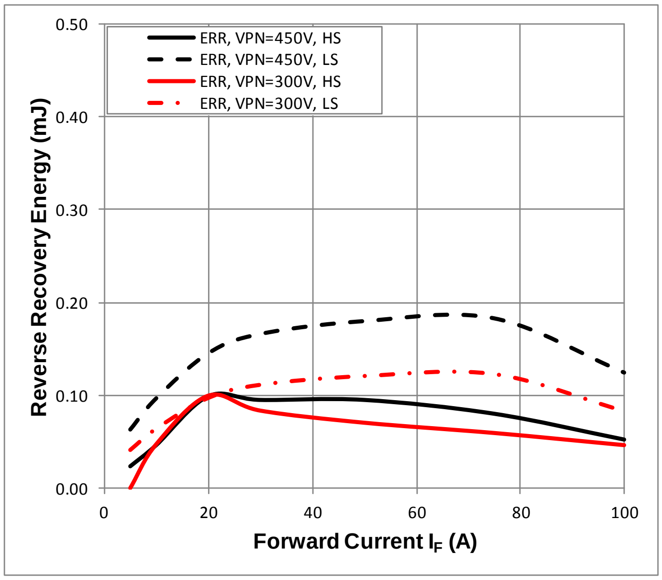


Figure 13. Reverse recovery energy DIODE inverter (typical) versus forward current
VCC = VBS = 15 V
VIN = 0 V ↔ 5 V, Ls=55nH, Inductive Load, T_J=125°C

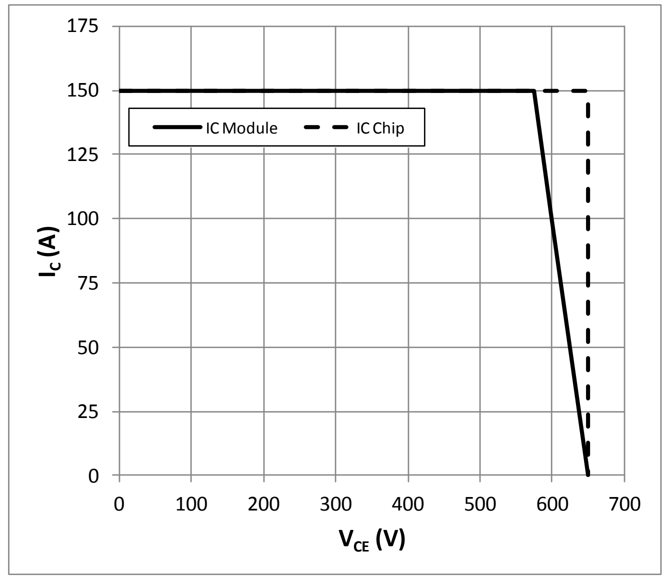


Figure 14. Reverse Bias Safe Operating Area IGBT (RBSOA) inverter
V_{CC} = V_{BS} = 15 V, Tj=150°C

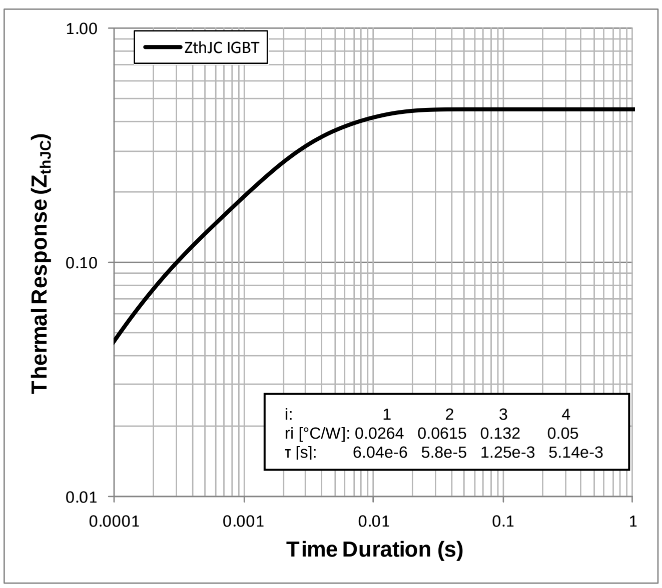


Figure 15. Transient thermal impedance IGBT inverter

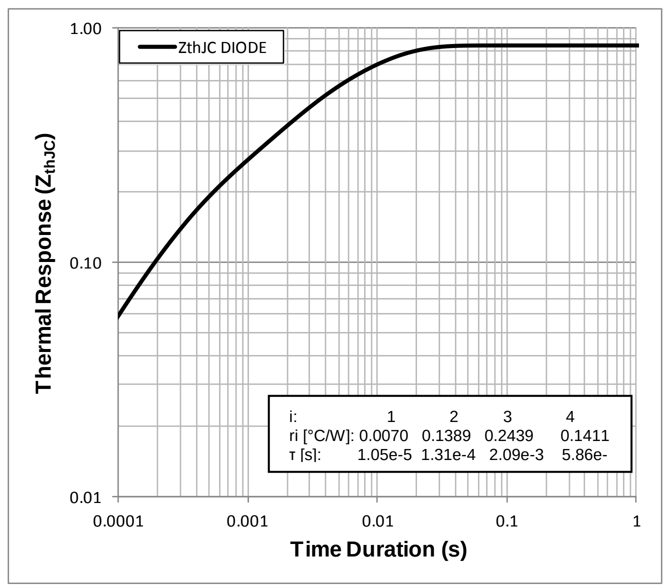


Figure 16. Transient thermal impedance DIODE inverter

Typical Controller Characteristics

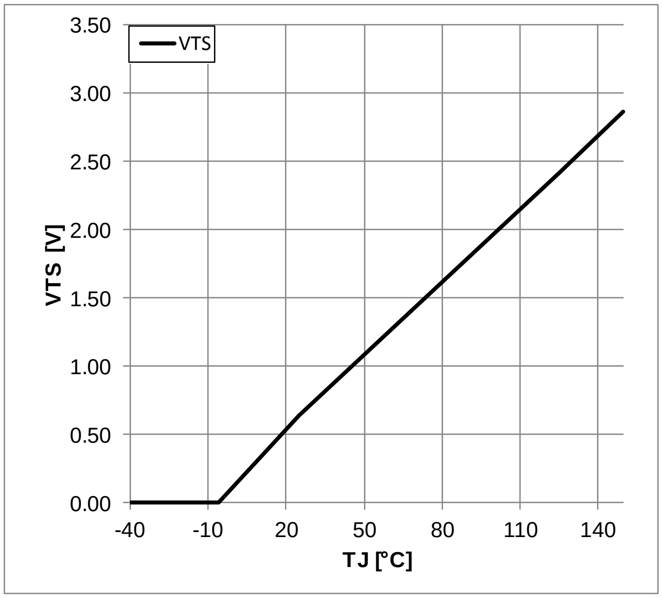


Figure 17. Temperature profile of V_{TS} (typical)

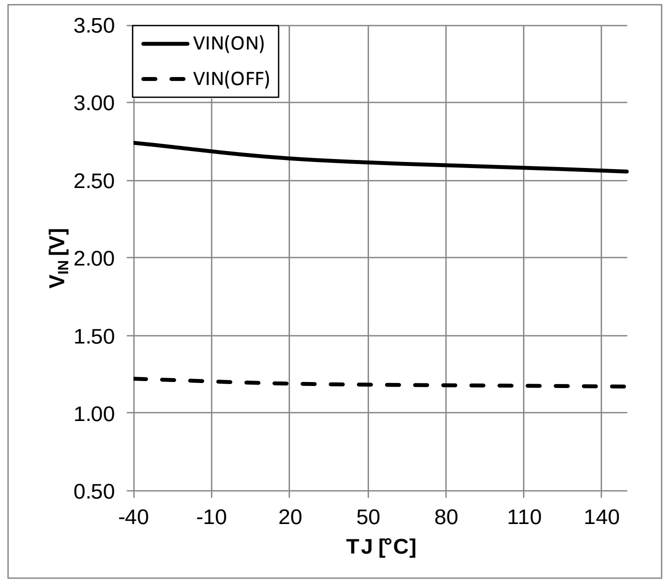


Figure 18. Threshold voltage versus temperature

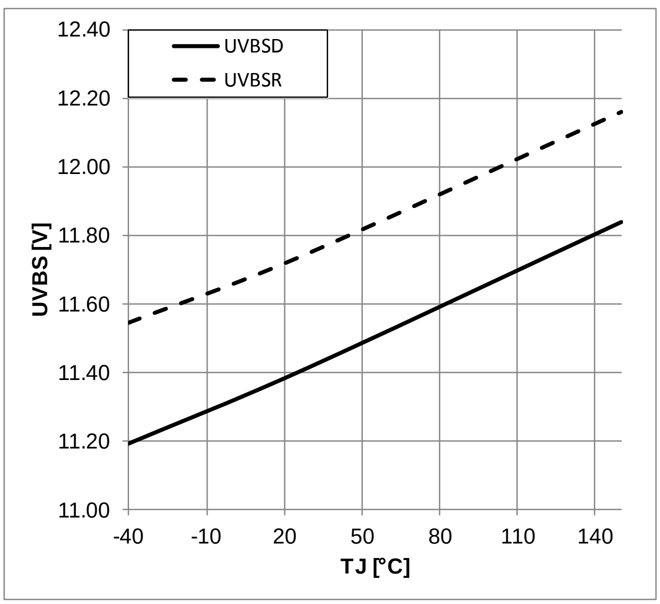


Figure 19. Supply under-voltage protection high-side (typical)

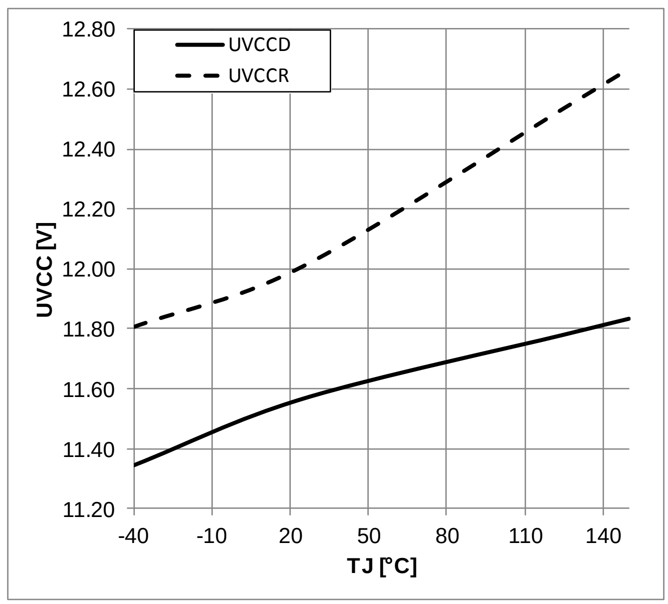
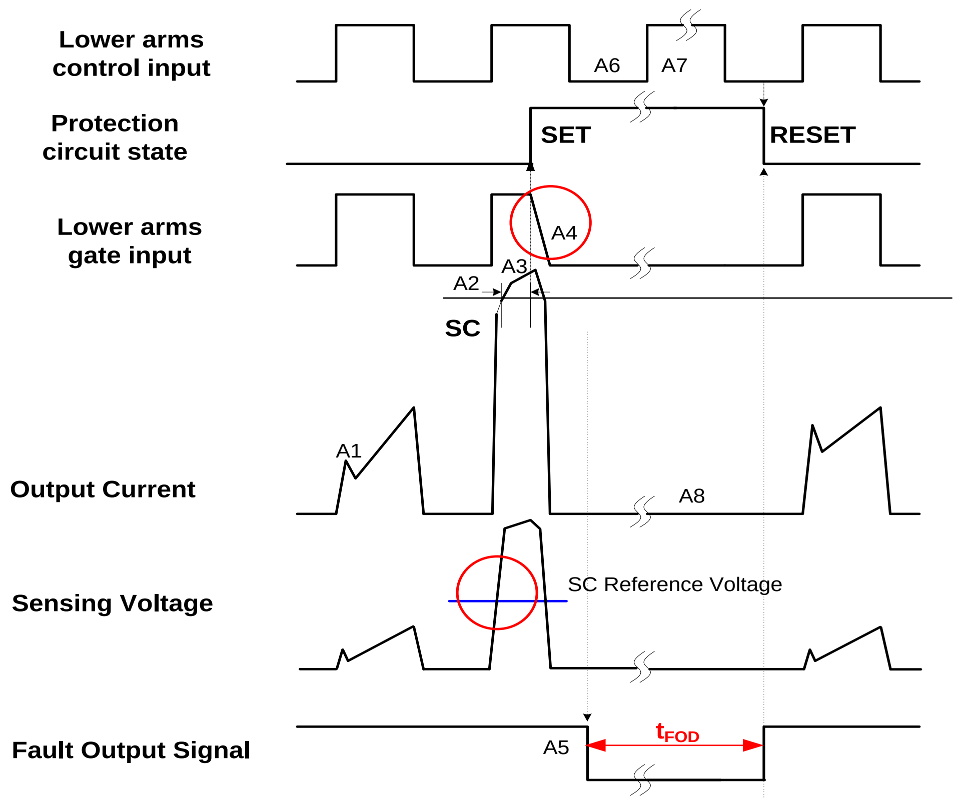


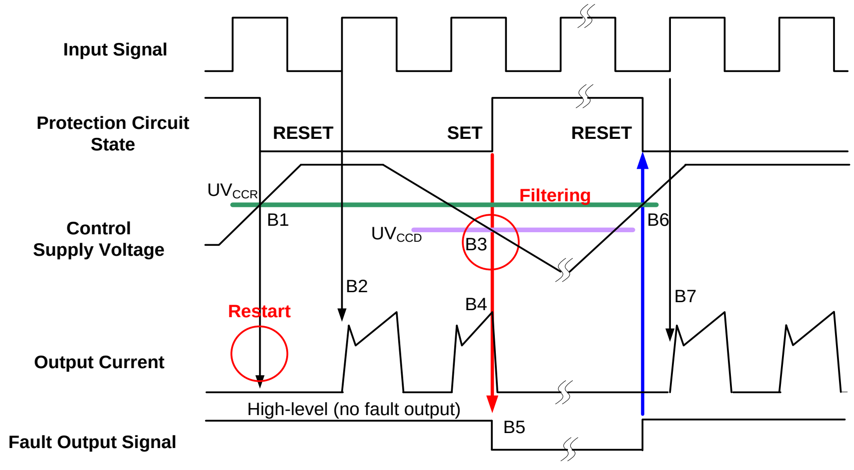
Figure 20. Supply under-voltage protection low-side (typical)

Timing Chart Protective Functions



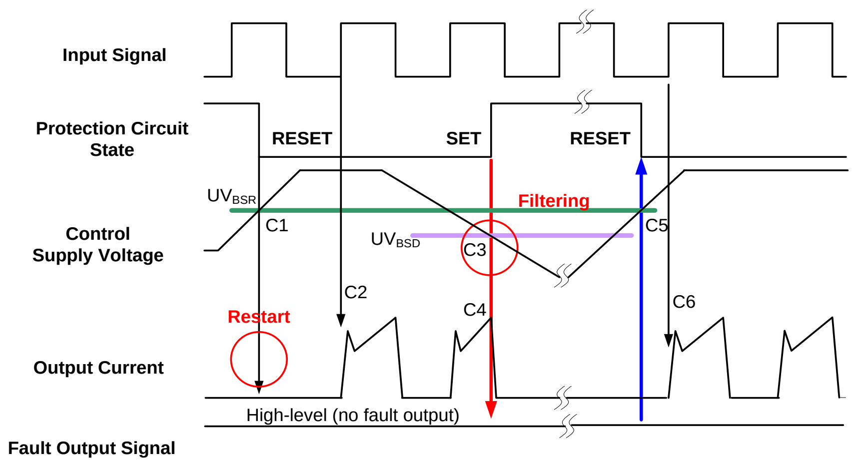
Step	Description
A1	Normal operation. IGBT on and carrying current
A2	Short-circuit current threshold reached
A3	Protection function triggered
A4	IGBT turns off with soft turn-off
A5	Fault output activated (initial delay 2 μs, t_{FOD} min. 50μs)
A6	IGBT “LO” input
A7	IGBT “HI” input is ignored
A8	Current stays at zero during fault state

Figure 21. Short-Circuit Current Protection



Step	Description
B1	Control supply voltage rises above reset voltage UV_{CCR}
B2	Normal operation. IGBT on and carrying current
B3	Control supply voltage falls below detection voltage UV_{CCD}
B4	Filtered supply voltage falls below UV_{CCD} and IGBT turns off
B5	Fault output activated (initial delay 2 μs, t_{FOD} min. 50μs)
B6	Control supply voltage rises above reset voltage UV_{CCR}
B7	IGBT “HI” input is followed after fault output duration and supply voltage rise

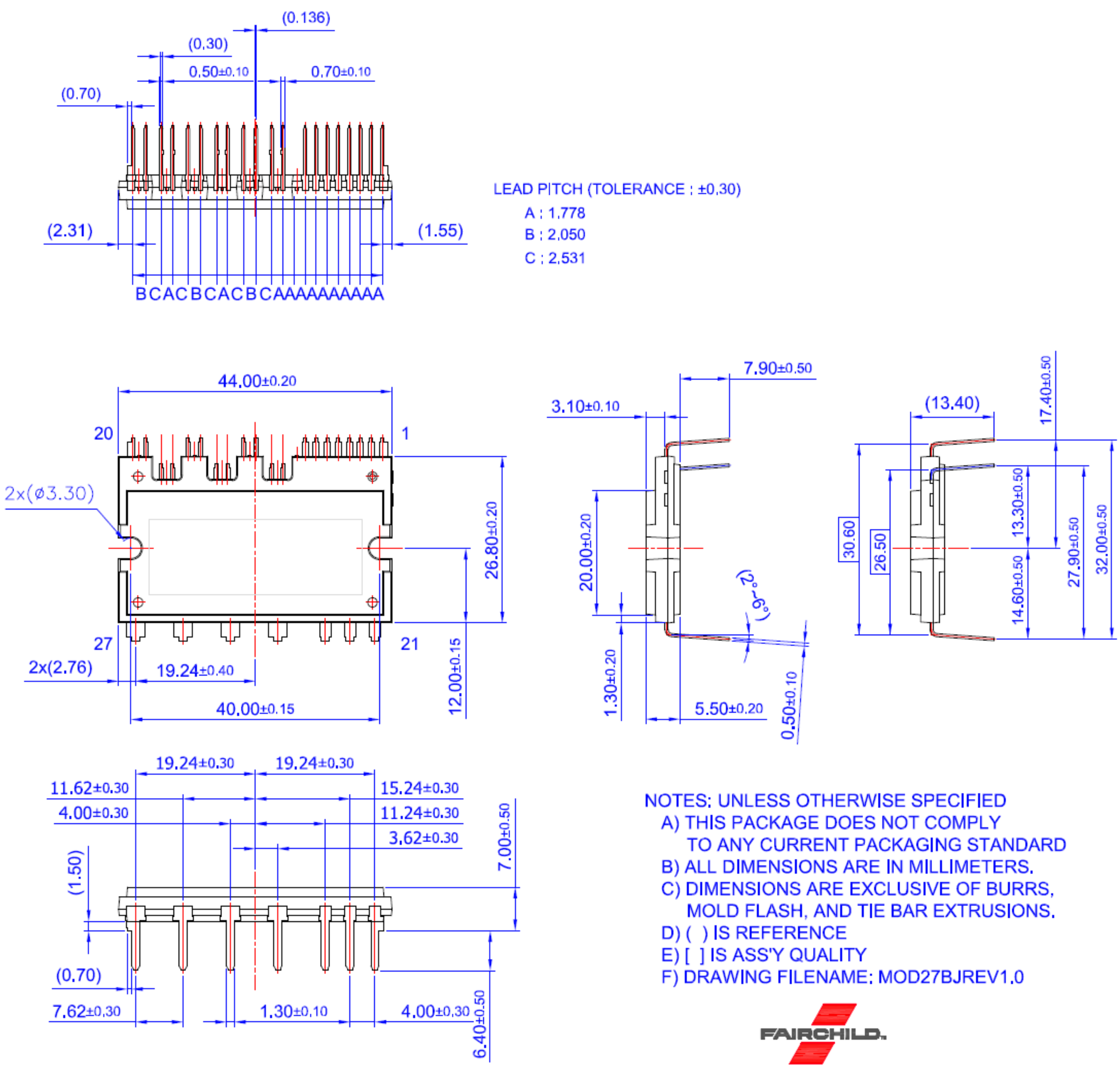
Figure 22. Under-Voltage Protection (Low-side)



Step	Description
C1	Control supply voltage rises above reset voltage UV_{CCR}
C2	Normal operation. IGBT on and carrying current
C3	Control supply voltage falls below detection voltage UV_{CCD}
C4	Filtered supply voltage falls below UV_{CCD} and IGBT turns off
C5	Control supply voltage rises above reset voltage UV_{CCR}
C6	IGBT “HI” input is followed after supply voltage rise

Figure 23 Under-Voltage Protection (High-side)

Physical Dimensions Dimension is in millimeter unless otherwise noted.

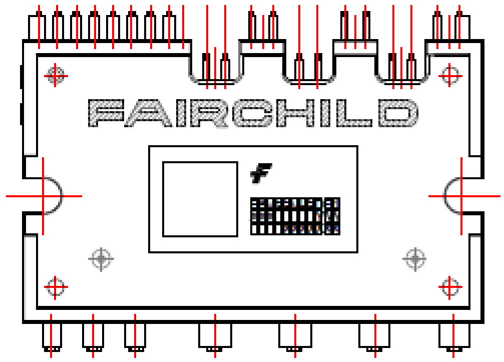


NOTES: UNLESS OTHERWISE SPECIFIED
- A) THIS PACKAGE DOES NOT COMPLY TO ANY CURRENT PACKAGING STANDARD
- B) ALL DIMENSIONS ARE IN MILLIMETERS.
- C) DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS.
- D) ( ) IS REFERENCE
- E) [ ] IS ASS'Y QUALITY
- F) DRAWING FILENAME: MOD27BJREV1.0

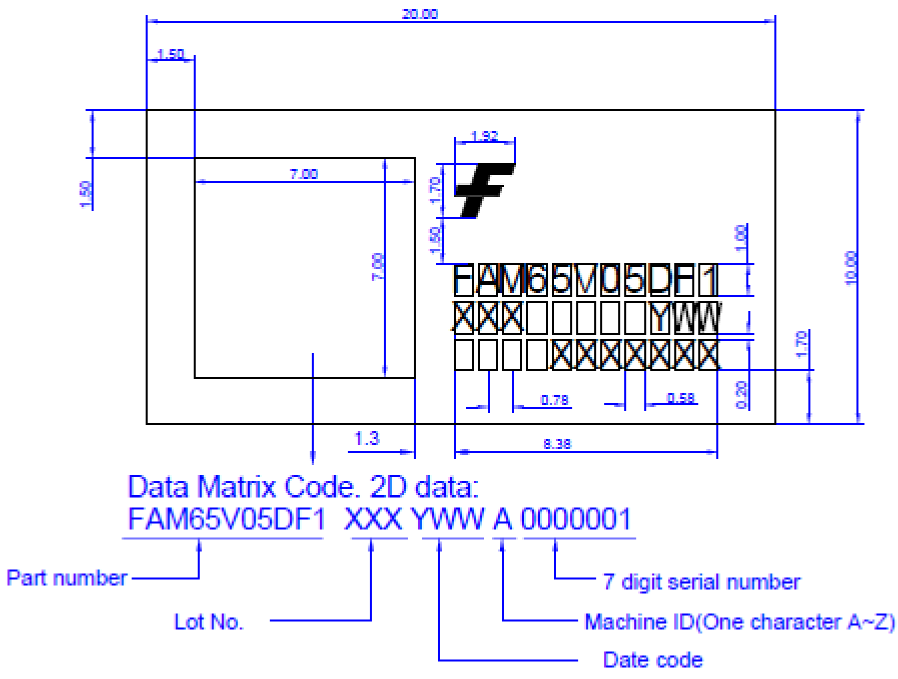
FAIRCHILD.

Physical Dimensions

* MARKING LAY-OUT



* MARKING DIMENSION



X	Alphabet
2010	A
2011	B
2012	C
2013	D
2014	E
2015	F
2016	G
2017	H
2018	J
2019	K
2020	A

Note: Marking pattern shown for final production version, which slightly differ from previous engineering versions.

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:

Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303-675-2175 or 800-344-3860 Toll Free USA/Canada
Fax: 303-675-2176 or 800-344-3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800-282-9855 Toll Free USA/Canada.
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81-3-5817-1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative

PUBLICATION ORDERING INFORMATION

LITERATURE FULFILLMENT:
Literature Distribution Center for ON Semiconductor
19521 E. 32nd Pkwy, Aurora, Colorado 80011 USA
Phone: 303−675−2175 or 800−344−3860 Toll Free USA/Canada
Fax: 303−675−2176 or 800−344−3867 Toll Free USA/Canada
Email: orderlit@onsemi.com

N. American Technical Support: 800−282−9855 Toll Free USA/Canada
Europe, Middle East and Africa Technical Support:
Phone: 421 33 790 2910
Japan Customer Focus Center
Phone: 81−3−5817−1050

ON Semiconductor Website: **www.onsemi.com**

Order Literature: http://www.onsemi.com/orderlit

For additional information, please contact your local Sales Representative