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## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



### 3-PHASE AC Motor Controller IC

#### Features

- Floating channel up to +1200V
- “soft” over-current shutdown turns off output
- Integrated desaturation circuit
- Two stage turn on output for di/dt control
- Integrated brake IGBT driver with protection
- Voltage feedback sensing function
- Separate pull-up/pull-down output drive pins
- Matched delay outputs
- Under voltage lockout with hysteresis band
- Programmable deadtime
- Hard shutdown function

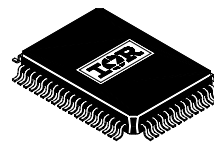
#### Description

The IR2238Q is a high voltage, 3-phase IGBT driver best suited for AC motor drive applications. Integrated desaturation logic provides all mode of overcurrent protection, including ground fault protection. Soft shutdown is predominantly initiated in the event of overcurrent followed by turn-off of all six outputs. A shutdown input is provided for a customized shutdown function. The DT pin allows external resistor to program the deadtime. Output drivers have separate turn on/off pins with two stage turn-on output to achieve the desired di/dt switching level of IGBT. Voltage feedback provides accurate volts \*seconds measurement.

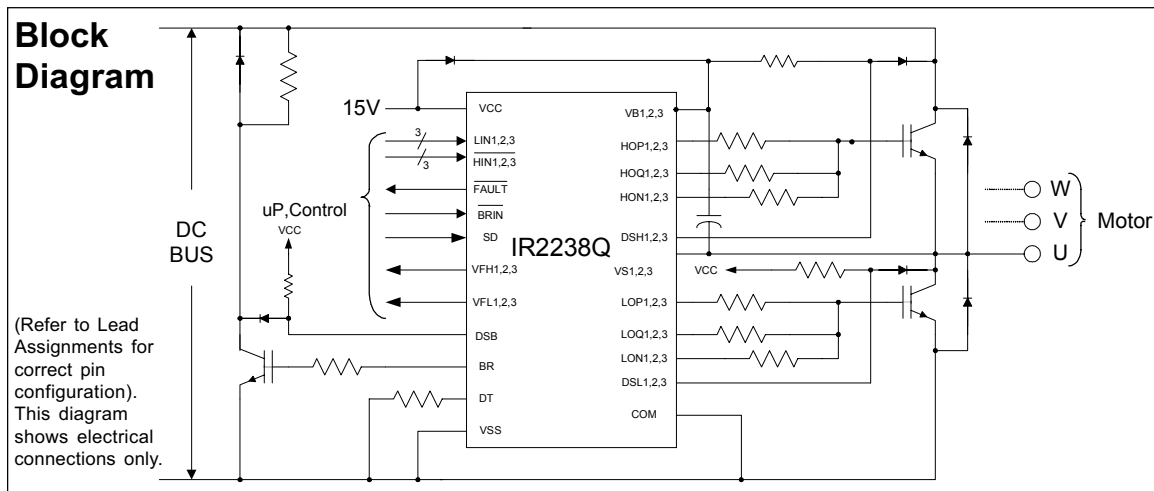
#### Product Summary

$V_{OFFSET}$	1200V max.
$I_{O+/-}$ (min.)	220mA/460mA
$V_{OUT}$	12.5V - 20V
Brake ( $I_{O+/-}$ min)	40mA/80mA
Deadtime Asymmetry Skew (max.)	145nsec
Deadtime (typ. with RDT=39k $\Omega$ )	1 $\mu$ sec
DESAT Blanking time (typ.)	3.0 $\mu$ sec
DSH, DSL input voltage threshold (typ.)	8.0V
Soft shutdown duration time (typ.)	6.0 $\mu$ sec
Voltage feedback matching delay time (max.)	125nsec

#### Package



64-Lead MQFP



## Absolute Maximum Ratings (tentative)

Absolute maximum ratings indicate sustained limits beyond which damage to the device may occur. All voltage parameters are absolute voltages referenced to COM, all currents are defined positive into any lead. The thermal resistance and power dissipation ratings are measured under board mounted and still air conditions.

Symbol	Definition	Min.	Max.	Units	
V <sub>S</sub>	High side offset voltage	V <sub>B1,2,3</sub> -25	V <sub>B1,2,3</sub> +0.3	V	
V <sub>B</sub>	High side floating supply voltage	-0.3	1225		
V <sub>HO</sub>	High side floating output voltage (HOP, HON, HOQ)	V <sub>S1,2,3</sub> - 0.3	V <sub>B1,2,3</sub> + 0.3		
V <sub>CC</sub>	Low side and logic fixed supply voltage	-0.3	25		
V <sub>SS</sub>	Logic ground	V <sub>CC</sub> - 25	V <sub>CC</sub> + 0.3		
V <sub>LO</sub>	Low side output voltage (LOP, LON, LOQ)	-0.3	V <sub>CC</sub> + 0.3		
V <sub>IN</sub>	Logic input voltage (HIN/N,LIN, BRIN/N, SD)	V <sub>SS</sub> - 0.3	V <sub>CC</sub> + 0.3 or V <sub>SS</sub> + 15 which ever is lower		
V <sub>FLT</sub>	FAULT output voltage	V <sub>SS</sub> - 0.3	V <sub>CC</sub> + 0.3		
V <sub>F</sub>	Feedback output voltage	V <sub>SS</sub> - 0.3	V <sub>CC</sub> + 0.3		
V <sub>DSH</sub>	High side desat/feedback input voltage	V <sub>S1,2,3</sub> - 0.3	V <sub>B1,2,3</sub> + 0.3		
V <sub>DSL</sub>	Low side desat/feedback input voltage	- 0.3	V <sub>CC</sub> + 0.3		
V <sub>BR</sub>	Brake output voltage	-0.3	V <sub>CC</sub> + 0.3		
dV <sub>S</sub> /dt	Allowable offset voltage slew rate	—	50		V/ns
P <sub>D</sub>	Package power dissipation @ T <sub>A</sub> ≤ +25°C	—	2.0		W
R <sub>thJA</sub>	Thermal resistance, junction to ambient	—	60	°C/W	
T <sub>J</sub>	Junction temperature	—	125	°C	
T <sub>S</sub>	Storage temperature	-55	150		
T <sub>L</sub>	Lead temperature (soldering, 10 seconds)	—	300		

## Recommended Operating Conditions

For proper operation the device should be used within the recommended conditions. All voltage parameters are absolute voltages referenced to COM. The V<sub>S</sub> offset rating is tested with all supplies biased at 15V differential.

Symbol	Definition	Min.	Max.	Units
V <sub>B1,2,3</sub>	High side floating supply voltage	V <sub>S1,2,3</sub> + 13	V <sub>S1,2,3</sub> + 20	V
V <sub>S1,2,3</sub>	High side floating supply offset voltage	Note 1	1200	
V <sub>HO1,2,3</sub>	High side (HOP/HOQ/HON) output voltage	V <sub>S1,2,3</sub>	V <sub>B1,2,3</sub>	
V <sub>LO1,2,3</sub>	Low side (LOP/LOQ/LON) output voltage	V <sub>COM</sub>	V <sub>CC</sub>	
V <sub>IN</sub>	Logic input voltage (HIN/N,LIN,BRIN/N SD)	V <sub>SS</sub>	V <sub>SS</sub> + 5	
V <sub>CC</sub>	Low side supply voltage	12.5	20	
V <sub>SS</sub>	Logic ground	-5	+5	
V <sub>FLT</sub>	FAULT output voltage	V <sub>SS</sub>	V <sub>CC</sub>	
V <sub>F</sub>	Feedback output voltage	V <sub>SS</sub>	V <sub>CC</sub>	
V <sub>DSH</sub>	High side desat/feedback input voltage	V <sub>S1,2,3</sub> - 0.3	V <sub>B1,2,3</sub>	
V <sub>DSL</sub>	Low side desat/feedback input voltage	- 0.3	V <sub>CC</sub>	
V <sub>BR</sub>	BRAKE output voltage	V <sub>COM</sub>	V <sub>CC</sub>	
T <sub>A</sub>	Ambient temperature	-20	115	°C

Note 1: Logic operational for V<sub>S</sub> of COM-5V to COM+1200V. Logic state held for V<sub>S</sub> of COM-5V to COM-V<sub>BS</sub>.

## Static Electrical Characteristics

$V_{BIAS}$  ( $V_{CC}$ ,  $V_{BS1,2,3}$ ) = 15V and  $T_A$  = 25°C unless otherwise specified. The  $V_{IN}$ ,  $V_{TH}$  and  $I_{IN}$  parameters are referenced to  $V_{SS}$  and are applicable to all six channels (HOP/HOQ/HON1,2,3 and LOP/LOQ/LON1,2,3). The  $V_O$  and  $I_O$  parameters are referenced to COM and  $V_{S1,2,3}$  and are applicable to the respective output leads: HO1,2,3 and LO1,2,3.  $V_{DESAT}$  and  $I_{DESAT}$  parameters are referenced to COM and  $V_{S1,2,3}$

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
$V_{CCUV+}$	$V_{CC1}$ supply undervoltage positive going threshold	10.3	11.2	12.5	V	
$V_{CCUV-}$	$V_{CC1}$ supply undervoltage negative going threshold	9.5	10.2	11.3		
$V_{CCUVH}$	$V_{CC1}$ supply undervoltage lockout hysteresis	—	1.0	—		
$V_{BSUV+}$	$V_{BS}$ supply undervoltage positive going threshold	10.3	11.2	12.5		
$V_{BSUV-}$	$V_{BS}$ supply undervoltage negative going threshold	9.5	10.2	11.3		
$V_{BSUVH}$	$V_{BS}$ supply undervoltage lockout hysteresis	—	1.0	—		
$I_{LK}$	Offset supply leakage current	—	—	50	$\mu A$	$V_{B1,2,3} = V_{S1,2,3} = 1200V$
$I_{QBS}$	Quiescent $V_{BS}$ supply current	—	150	250	mA	$V_{LIN}=0V, V_{HIN}=5V$
$I_{QCC}$	Quiescent $V_{CC}$ supply current	—	3	6		$V_{LIN}=0V, V_{HIN}=5V$ $DT = 1\mu sec$
$V_{IH}$	Logic "0" input voltage (HIN/N, BRIN/N) (OUT=LO)	2.0	—	—	V	$V_{CC} = 12.5$ to 20V
$V_{IL}$	Logic "1" input voltage (HIN/N, BRIN/N) (OUT=HI)	—	—	0.8		
$V_{t+}$	Logic input positive going threshold (HIN/N, LIN, BRIN/N, SD)	1.2	1.6	2.0		
$V_{t-}$	Logic input negative going threshold (HIN/N, LIN, BRIN/N, SD)	0.8	1.2	1.6		
$\Delta V_T$	Logic input hysteresis (HIN, LIN, BRIN, SD)	—	0.4	—		
$V_{OH}$	High level output voltage, $V_{BIAS} - V_O$ (normal switching) HOP, HOQ, LOP, LOQ	—	—	100	mV	$I_o = 1mA$
$V_{OL}$	Low level output voltage, $V_O$ (normal switching) HON, LON	—	—	100		
$I_{IN+}$	Logic "1" input bias current (HIN/N, BRIN/N)	—	5	—	$\mu A$	$V_{IN} = 0V$
	Logic "1" input bias current (LIN, SD)	—	70	—		$V_{IN} = 5V$
$I_{IN-}$	Logic "0" input bias current (HIN/N, BRIN/N)	—	70	—		$V_{IN} = 5V$
	Logic "0" input bias current (LIN, SD)	—	5	—		$V_{IN} = 0V$
$I_{DS+}$	High DSH, DSL, DSB input bias current	—	15	—		$V_{DESAT} = 15V$
$I_{DS-}$	Low DSH, DSL, DSB input bias current	—	0.1	—		$V_{DESAT} = 0V$
$I_{O1+}$	Output high first stage short circuit pulsed current	220	350	—	mA	$V_O = 0V, V_{IN} = 0V$ $PW \leq 200 ns$
$I_{O2+}$	Output high second stage short circuit pulsed current	120	200	—		$V_O = 0V, V_{IN} = 0V$ $PW \leq 10 \mu s$
$I_{O-}$	Output low short circuit pulsed current	460	540	—		$V_O = 15V, V_{IN} = 5V$ $PW \leq 10 \mu s$

## Static Electrical Characteristics cont.

$V_{BIAS}$  ( $V_{CC}$ ,  $V_{BS1,2,3}$ ) = 15V and  $T_A$  = 25°C unless otherwise specified. The  $V_{IN}$ ,  $V_{TH}$  and  $I_{IN}$  parameters are referenced to  $V_{SS}$  and are applicable to all six channels (HOP/HOQ/HON1,2,3 and LOP/LOQ/LON1,2,3). The  $V_O$  and  $I_O$  parameters are referenced to COM and  $V_{S1,2,3}$  and are applicable to the respective output leads:  $HO_{1,2,3}$  and  $LO_{1,2,3}$ .  $V_{DESAT}$  and  $I_{DESAT}$  parameters are referenced to COM and  $V_{S1,2,3}$

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
$I_{OBR+}$	BR output high short circuit pulsed current	40	70	—	mA	$V_{BR}=0V$ , $V_{BRIN}=0V$ $PW \leq 10 \mu s$
$I_{OBR-}$	BR output low short circuit pulsed current	80	125	—		$V_{BR}=15V$ , $V_{BRIN}=5V$ $PW \leq 10 \mu s$
$V_{OHB}$	BR high level output voltage, $V_{CC}-V_{BR}$	—	—	300	mV	$I_{BR} = 1mA$
$V_{OLB}$	BR low level output voltage, $V_{BR}$	—	—	150		
$V_{OLVF}$	VFH or VFL low level output voltage	—	—	0.8	V	$I_{VF} = 10mA$
$R_{ON,VF}$	VFH or VFL output on resistance	—	60	—	$\Omega$	
$R_{ON,SS}$	Soft shutdown on resistance	—	500	—		
$R_{ON,FLT}$	FAULT low on resistance	—	60	—		
$V_{DESAT+}$	High DSH1,2,3 and DSL1,2,3 and DSB input threshold voltage	—	8.0	—	V	
$V_{DESAT-}$	Low DSH1,2,3 and DSL1,2,3 or DSB input threshold voltage	—	7.0	—		
$V_{DSTH}$	DS input voltage hysteresis	—	1.0	—		

## AC Electrical Characteristics

$V_{BIAS}$  ( $V_{CC}$ ,  $V_{BS}$ ) = 15V,  $V_{S1,2,3} = V_{SS}$ ,  $T_A = 25^\circ C$  and  $C_L = 1000$  pF unless otherwise specified.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
<b>Propagation Delay Characteristics</b>						
$T_{on1}$	Turn-on first stage duration time	—	200	—	ns	$V_{IN} = 0$ & 5V $R_L(HOQ/LOQ) = 10\Omega$
$t_{on}$	Turn-on propagation delay	250	550	750		$V_{IN} = 0$ & 5V $V_{S1,2,3} = 0$ to 1200V HOP=HON,LOP=LON Figure 5
$t_{off}$	Turn-off propagation delay	250	550	750		
$t_r$	Turn-on rise time	—	80	—		
$t_f$	Turn-off fall time	—	25	—		
$t_{DESAT1}$	DSH to HO soft shutdown propagation delay at HO turn-on	—	3000	—		$V_{HIN} = 0V$ , $V_{DESAT} = 15V$ , Figure 7
$t_{DESAT2}$	DSH to HO soft shutdown propagation delay after blanking	1000	—	—		
$t_{DESAT3}$	DSL to LO soft shutdown propagation delay at LO turn-on	—	3000	—	$V_{LIN} = 5V$ , $V_{DESAT} = 15V$ , Fig.7	

**AC Electrical Characteristics cont.**

$V_{BIAS} (V_{CC}, V_{BS}) = 15V, V_{S1,2,3} = V_{SS}, T_A = 25^\circ C$  and  $C_L = 1000\text{ pF}$  unless otherwise specified.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
<b>Propagation Delay Characteristics</b>						
t <sub>DESAT4</sub>	DSL to LO soft shutdown propagation delay after blanking	1000	—	—	ns	V <sub>LIN</sub> = 5V, V <sub>DESAT</sub> = 15V, Fig. 7
t <sub>DESAT5</sub>	DSB to HO hard shutdown propagation delay	—	1300	—		V <sub>HIN</sub> = 0V, V <sub>DESAT</sub> = 15V, Fig. 7
t <sub>DESAT6</sub>	DSB to LO hard shutdown propagation delay	—	1300	—		V <sub>LIN</sub> = 5V, V <sub>DESAT</sub> = 15V, Fig. 7
t <sub>DESAT7</sub>	DSB to BR hard shutdown propagation delay	1000	—	—		V <sub>VBRIN</sub> = 0V, V <sub>DSB</sub> = 15V, Fig. 7
t <sub>VFHL1,2,3</sub>	VFH high to low propagation delay	—	550	—		V <sub>DESAT</sub> = 15V to 0V Figure 8
t <sub>VFHHL1,2,3</sub>	VFH low to high propagation delay	—	550	—		V <sub>DESAT</sub> = 0V to 15V Figure 8
t <sub>VFLH1,2,3</sub>	VFL low to high propagation delay	—	550	—		V <sub>DESAT</sub> = 0V to 15V Figure 8
t <sub>VFL1,2,3</sub>	VFL high to low propagation delay	—	550	—		V <sub>DESAT</sub> = 15V to 0V Figure 8
t <sub>PWVF</sub>	Minimum pulse width of VFH and VFL	—	400	—		V <sub>DESAT</sub> = 15V to 0V or 0V to 15V fig. 8
t <sub>DS</sub>	Soft shutdown minimum pulse width of DSx	1000	—	—		C <sub>L</sub> = 1000pF, V <sub>DS</sub> = 15V Figure 6
t <sub>SS</sub>	Soft shutdown duration period	—	6000	—		
t <sub>FLT,DESAT1</sub>	DSH to FAULT propagation delay at HO turn-on	—	3300	—		V <sub>HIN</sub> = 0V, V <sub>DS</sub> = 15V, Fig. 7
t <sub>FLT,DESAT2</sub>	DSH to FAULT propagation delay after blanking	—	1300	—		
t <sub>FLT,DESAT3</sub>	DSL to FAULT propagation delay at LO turn-on	—	3300	—		V <sub>LIN</sub> = 5V, V <sub>DS</sub> = 15V, Fig. 7
t <sub>FLT,DESAT4</sub>	DSL to FAULT propagation delay after blanking	—	1000	—		
t <sub>FLTDSB</sub>	DSB to FAULT propagation delay	—	1000	—	BRIN = 0V, V <sub>DESAT</sub> = 15V, Fig. 7	
t <sub>FLTCLR</sub>	LIN1 = LIN2 = LIN3 = 0 to FAULT	9.0	—	—	V <sub>DESAT</sub> = 15V, Fig. 7	
t <sub>fault</sub>	Minimum FAULT duration period	9.0	15.0	21.0	μs V <sub>DESAT</sub> = 15V, Fig. 11 FLTCLR pending	
t <sub>BL</sub>	DS blanking time at turn-on	—	3000	—	V <sub>IN</sub> = on, V <sub>DESAT</sub> = 15V, Fig. 7	
t <sub>SD</sub>	SD to output shutdown propagation delay	—	600	900	V <sub>IN</sub> = on, V <sub>DESAT</sub> = 0V, Fig. 10	

## AC Electrical Characteristics cont.

$V_{BIAS} (V_{CC}, V_{BS}) = 15V$ ,  $V_{S1,2,3} = V_{SS}$ ,  $T_A = 25^\circ C$  and  $C_L = 1000 \text{ pF}$  unless otherwise specified.

Symbol	Definition	Min.	Typ.	Max.	Units	Test Conditions
<b>Propagation Delay Characteristics</b>						
$t_{EN}$	SD negation to output enable propagation delay	—	600	900		$V_{IN} = 0V$ $V_{DESAT} = 0V$ , Fig.10
$t_{onBR}$	BR output turn-on propagation	—	110	200	ns	Figure 5
$t_{offBR}$	BR output turn-off propagation	—	80	150		
$t_{rBR}$	BR output turn-on rise time	—	235	400		
$t_{fBR}$	BR output turn-off fall time	—	130	200		
<b>Deadtime/Delay Matching Characteristics</b>						
DT	Deadtime	900	1050	1200	ns	Figure 8 external resistor=39k $\Omega$
		76	100	124		Figure 8 external resistor=0k $\Omega$
		4500	5000	5500		Figure 8 external resistor=220k $\Omega$
MDT	Deadtime asymmetry skew, any of DTLoff1,2,3-DTHoff1,2,3	—	—	145		DT=1000nsec. Fig.8
PM	PWM propagation delay matching max {ton/toff} - min {ton/toff}, (ton/toff are applicable to all six channels)	—	—	125		DT=1000nsec. Fig.5
VM	Voltage feedback delay matching,   any of $t_{VFHL1,2,3}$ , $t_{VFHH1,2,3}$ , $t_{VFLL1,2,3}$ , $t_{VFLH1,2,3}$ - any of $t_{VFHL1,2,3}$ , $t_{VFHH1,2,3}$ , $t_{VFLL1,2,3}$ , $t_{VFLH1,2,3}$	—	—	125		Input pulse width >400 nsec Figure 9



Functional Block Diagram

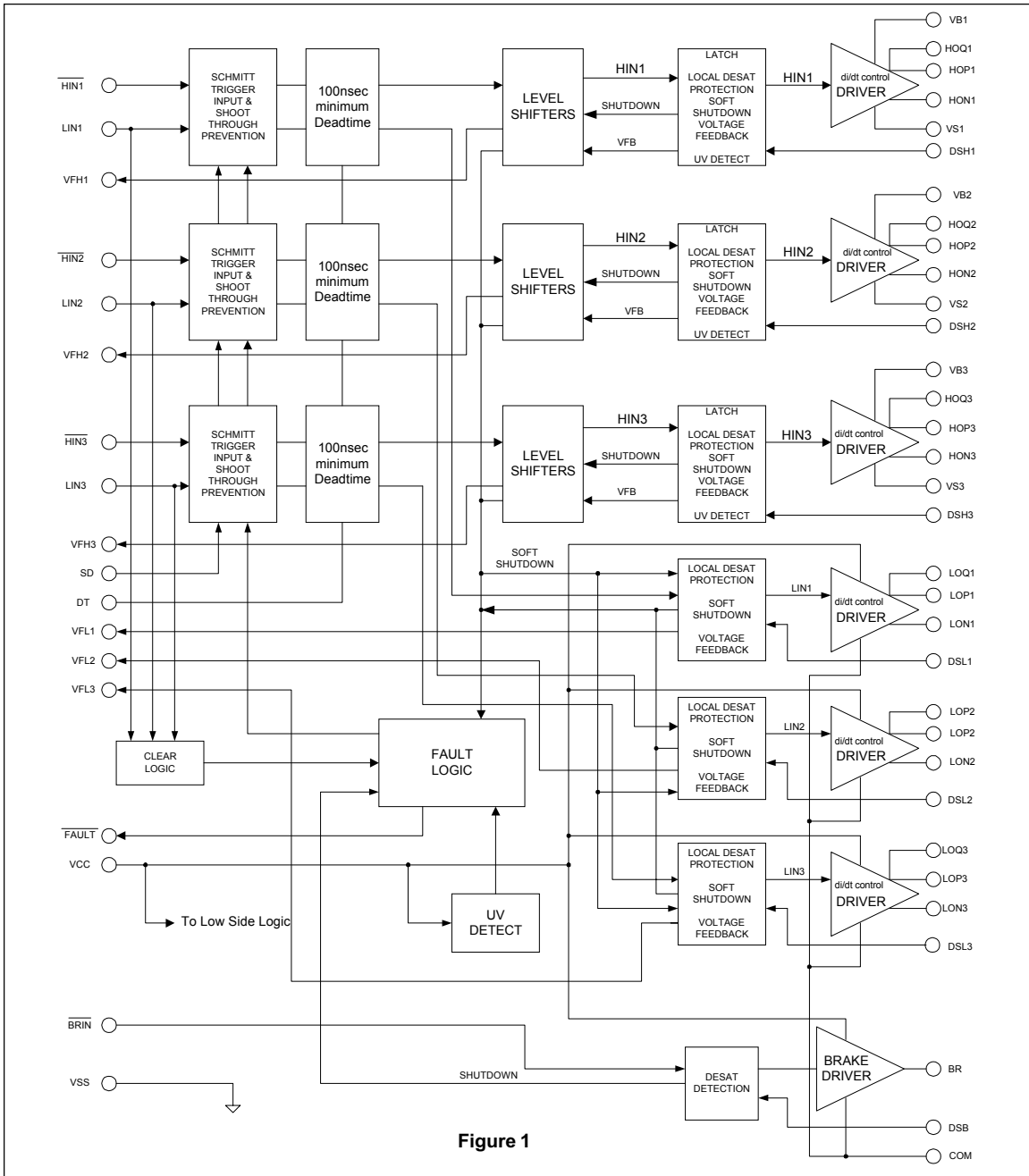


Figure 1



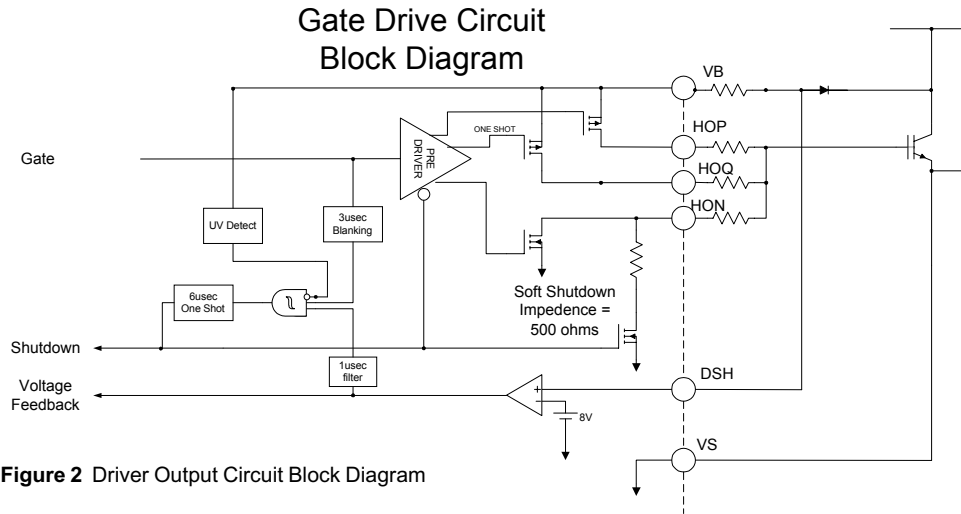


Figure 2 Driver Output Circuit Block Diagram

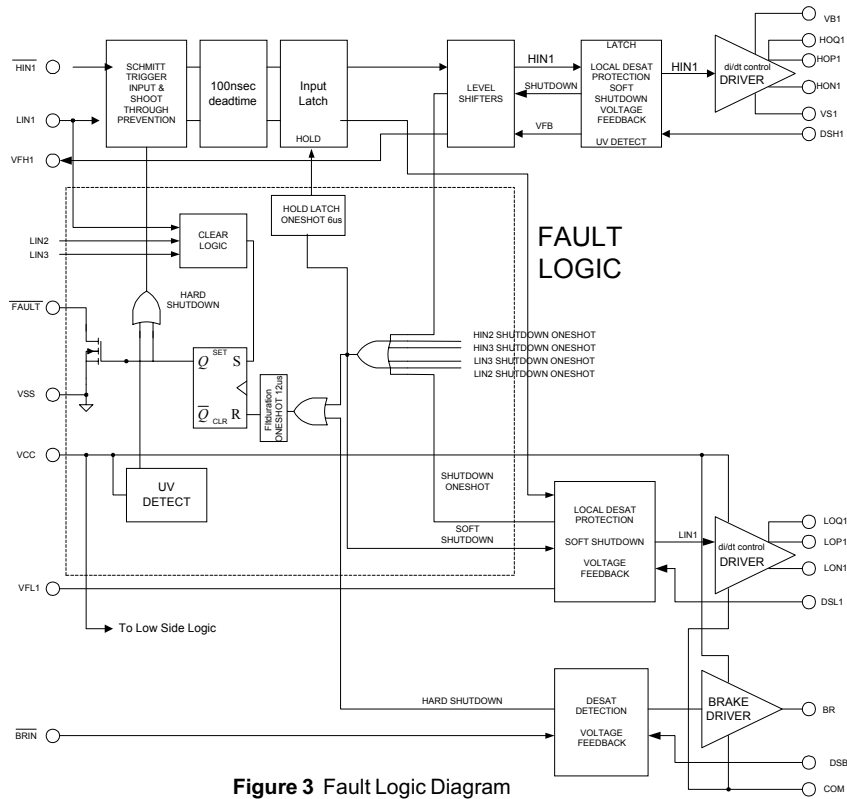
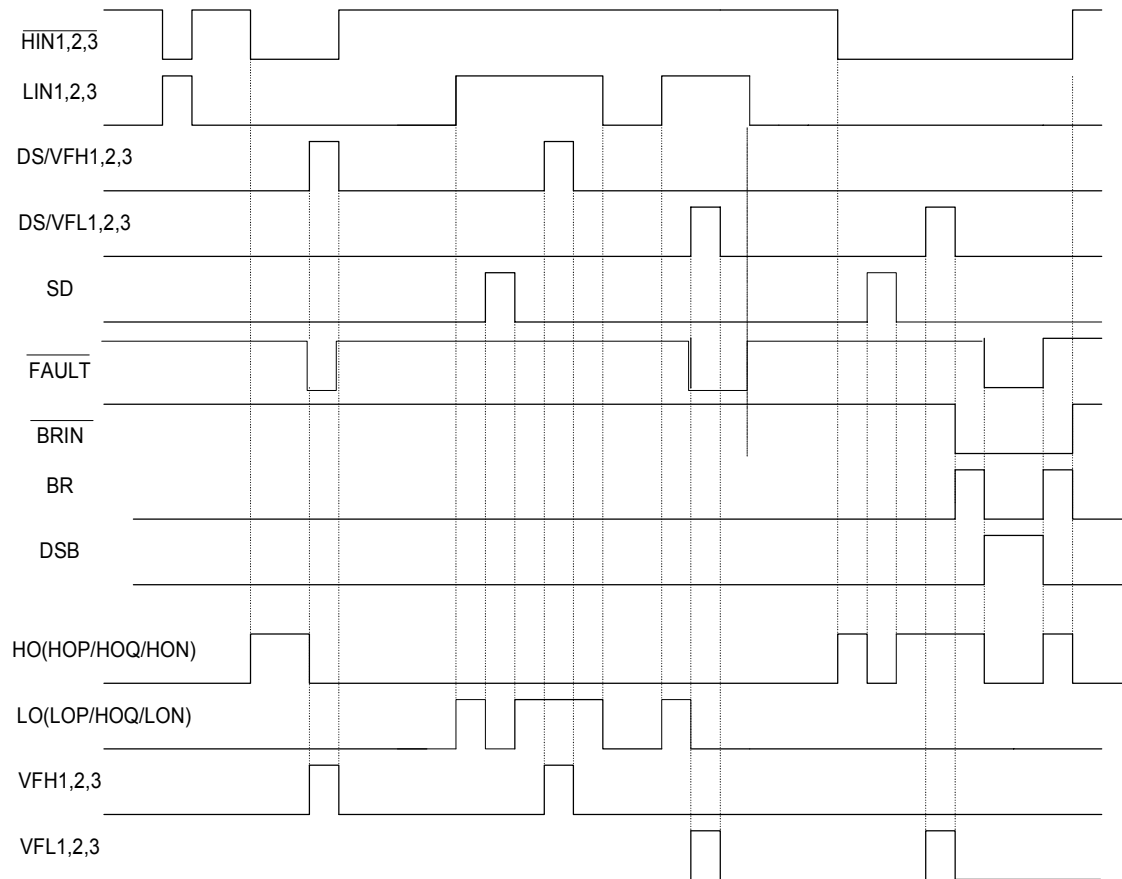
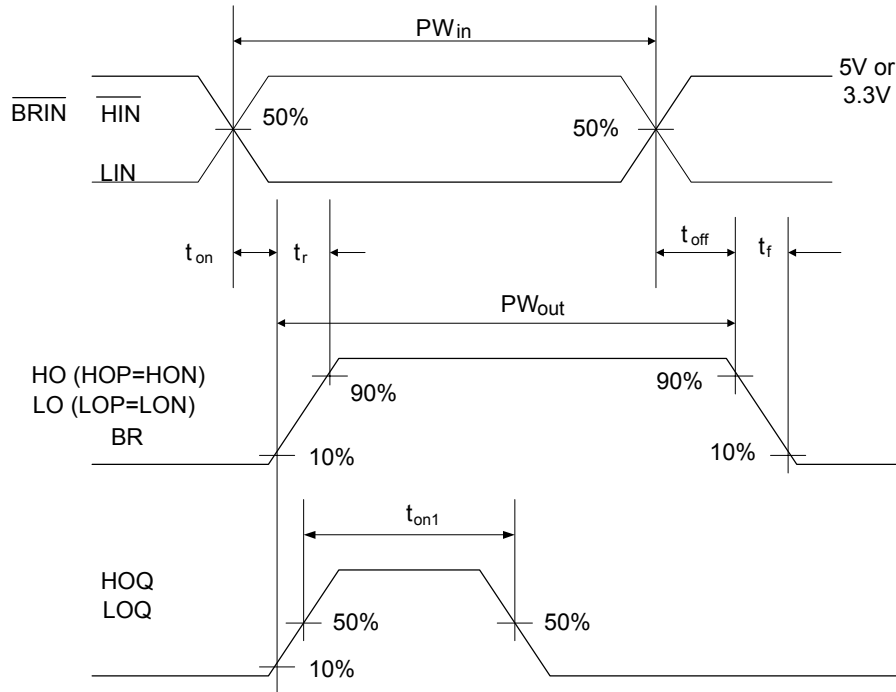


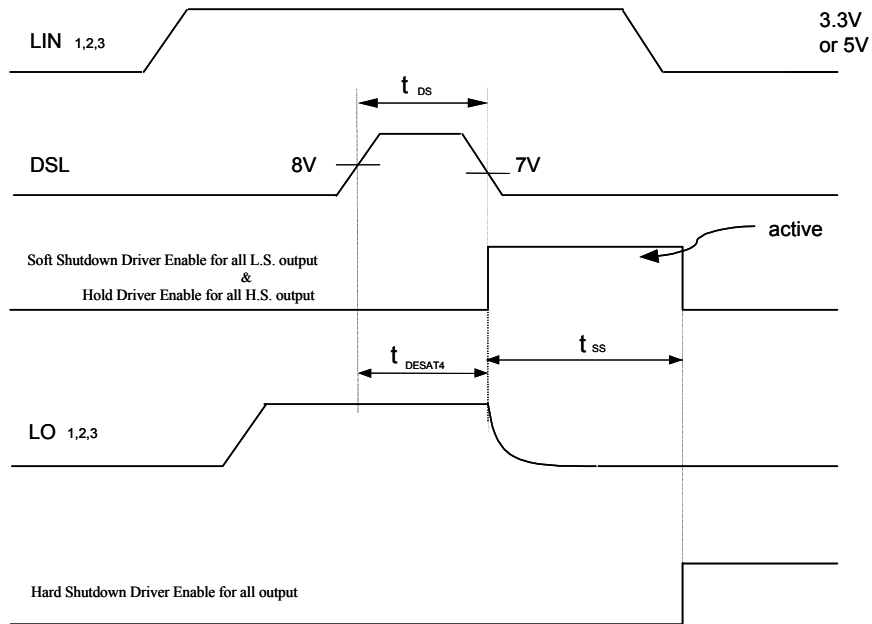
Figure 3 Fault Logic Diagram



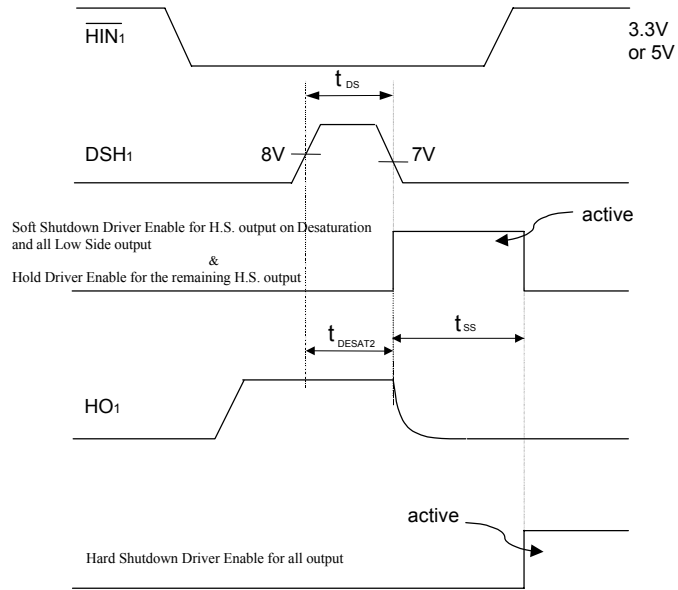
**Figure 4** Input/Output Timing Diagram



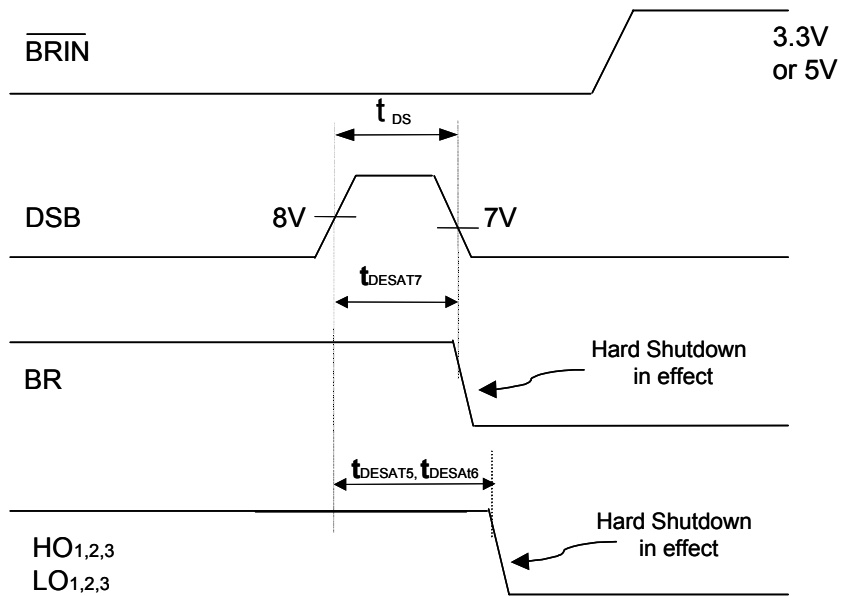
**Figure 5** Switching Time Waveforms



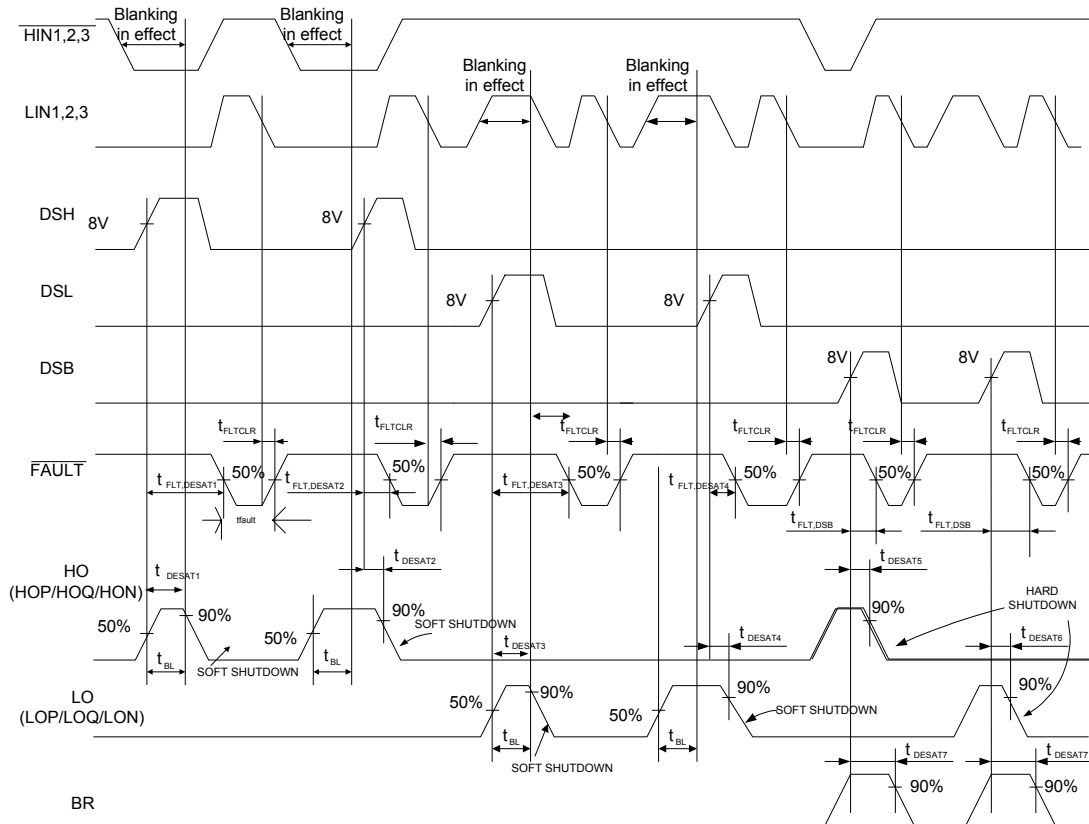
**Figure 6.1** Low Side Desat Soft Shutdown Timing Waveform



**Figure 6.2** High Side Desat Soft Shutdown Timing Waveform



**Figure 6.3** Brake Desat Timing Waveform



**Figure 7** Desat Timing Diagram

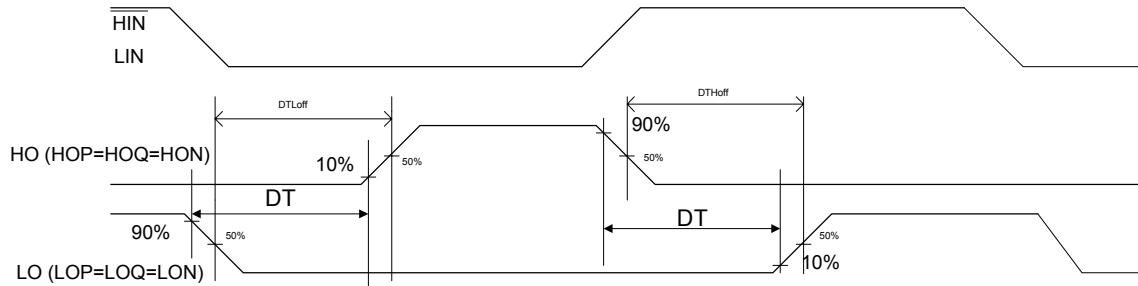


Figure 8 Internal Deadtime Timing

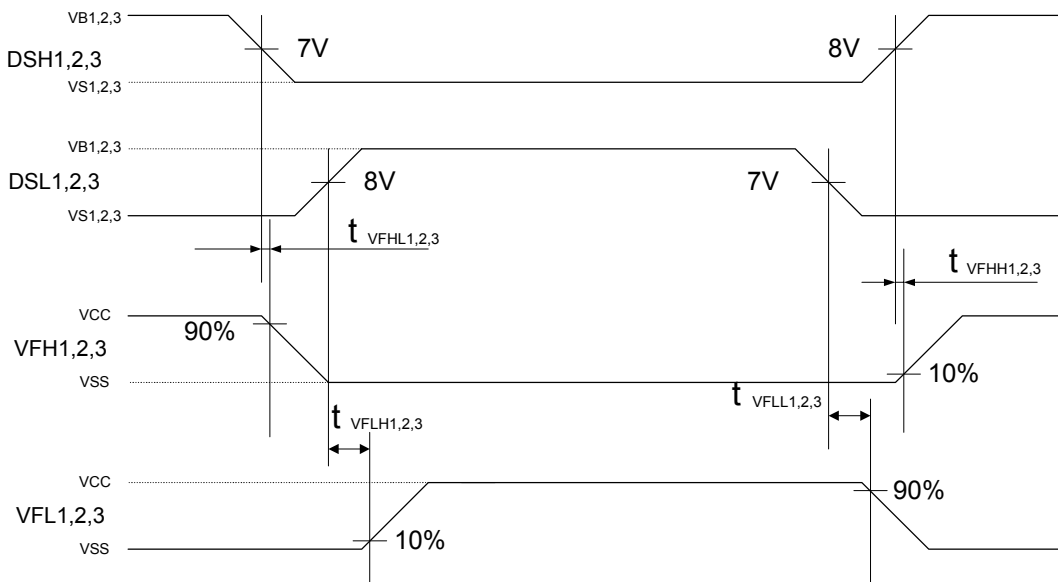


Figure 9 Voltage Feedback Timing

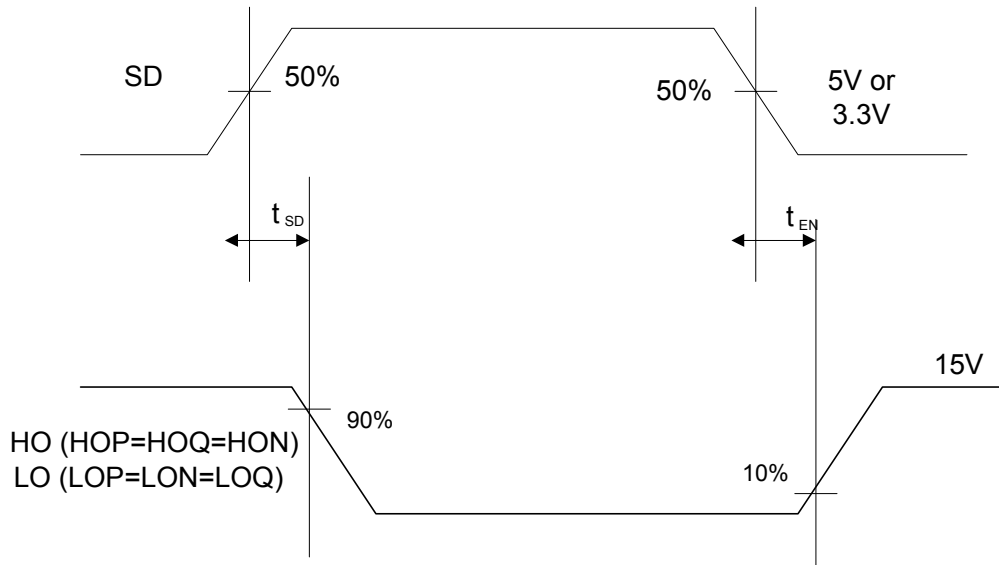


Figure 10 Shutdown Timing

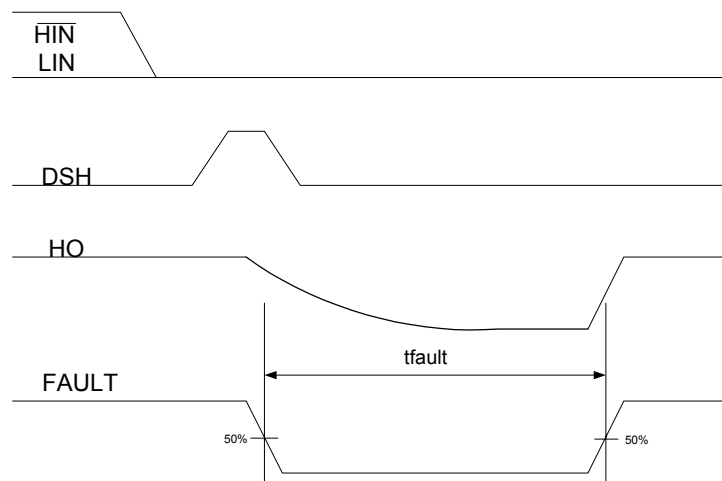


Figure 11 Fault Duration with Pending Faultclear Waveform  
 (refer to Note LD2 under the lead definition table)



## Lead Definitions

Symbol	Description
V <sub>CC</sub>	Low side supply voltage
V <sub>SS</sub>	Logic Ground
HIN <sub>1,2,3</sub>	Logic inputs for high side gate driver outputs (HOP <sub>1,2,3</sub> /HON <sub>1,2,3</sub> , out of phase)
LIN <sub>1,2,3</sub>	Logic inputs for low side gate driver outputs (LOP <sub>1,2,3</sub> /LON <sub>1,2,3</sub> , out of phase)
FAULT	Fault output (latched and open drain)
SD	Shutdown input
DT	Deadtime programmable resistor pin
DSB	Brake IGBT desaturation protection input and voltage feedback input
BRIN	Logic input for brake driver
BR	Brake driver output
COM	Low side drivers return
V <sub>B</sub> <sub>1,2,3</sub>	High side gate drive floating supply
HOP <sub>1,2,3</sub>	High side driver sourcing output
HOQ <sub>1,2,3</sub>	High side driver boost sourcing output
HON <sub>1,2,3</sub>	High side driver sinking output
DSH <sub>1,2,3</sub>	IGBT desaturation protection input and high side voltage feedback input
V <sub>S</sub> <sub>1,2,3</sub>	High voltage floating supply return
LOP <sub>1,2,3</sub>	Low side driver sourcing output
LON <sub>1,2,3</sub>	Low side driver sinking output
DSL <sub>1,2,3</sub>	IGBT desaturation protection input and low side voltage feedback input
VFH <sub>1,2,3</sub>	High side voltage feedback logic output
VFL <sub>1,2,3</sub>	Low side voltage feedback logic output

### NOTE:

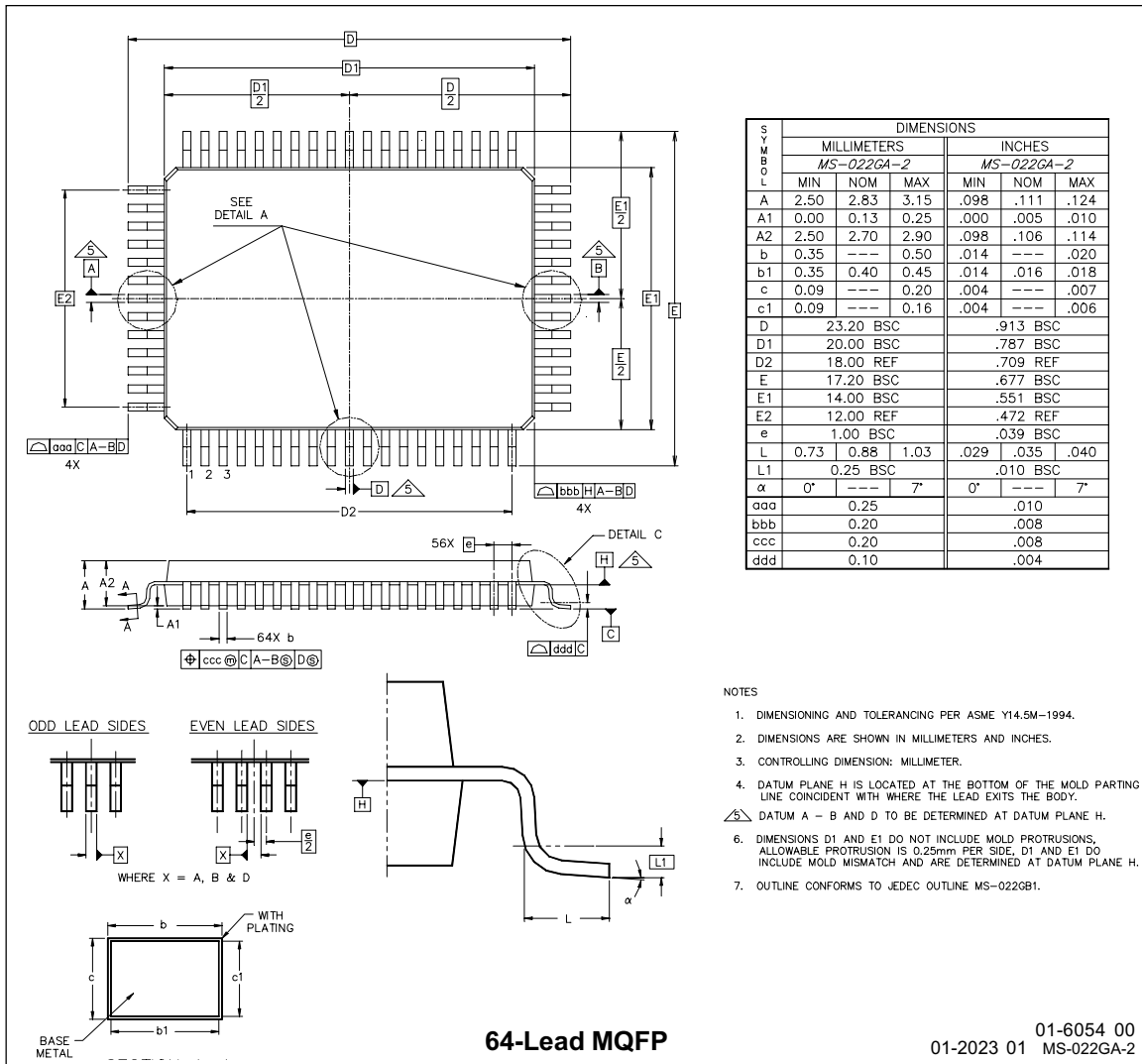
LD1- Low side soft shutdown is initiated locally in an event over current, which is sensed by the DSL pin. It is followed by the synchronized soft shutdown of the rest of the low side outputs; meanwhile it will hold all input information for a period of  $t_{ss}$  until the soft shutdown finishes. Then the hard shutdown will be initiated to complete the shut down cycle. (Figure 6.1)

High side soft shutdown is initiated locally in an event over current, which is sensed by the DSH pin. It is followed by the synchronized soft shutdown of all the low side outputs; meanwhile it will hold all input information for a period of  $t_{ss}$  until the soft shutdown finishes. Then the hard shutdown will be initiated to complete the shut down cycle. (Figure 6.2)

LD2- Soft shutdown is initiated in an event of overcurrent, which is followed by turn-off all six outputs. The fault condition will remain in a fixed period( $t_{fault}$ ) even though the faultclear condition is in effect (Fig11). In the case that faultclear is not in effect, fault duration =  $t_{fault} + t_{ftclr}$ .



Case outline



64-Lead MQFP

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