

**July 2002** 

# FGH40N6S2D

# 600V, SMPS II Series N-Channel IGBT with Anti-Parallel Stealth™ Diode

# **General Description**

The FGH40N6S2D is a Low Gate Charge, Low Plateau Voltage SMPS II IGBT combining the fast switching speed of the SMPS IGBTs along with lower gate charge, plateau voltage and avalanche capability (UIS). These LGC devices shorten delay times, and reduce the power requirement of the gate drive. These devices are ideally suited for high voltage switched mode power supply applications where low conduction loss, fast switching times and UIS capability are essential. SMPS II LGC devices have been specially designed for:

- · Power Factor Correction (PFC) circuits
- · Full bridge topologies
- · Half bridge topologies
- · Push-Pull circuits
- Uninterruptible power supplies
- Zero voltage and zero current switching circuits

IGBT (co-pack) formerly Developmental Type TA49340 Diode formerly Developmental Type TA49391

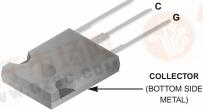
#### **Features**

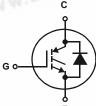
- 100kHz Operation at 390V, 24A
- · 200kHZ Operation at 390V, 18A
- 600V Switching SOA Capability
- Typical Fall Time. . . . . . . . . 85ns at TJ = 125°C
- Low Gate Charge ..... 35nC at V<sub>GF</sub> = 15V
- Low Plateau Voltage ..........6.5V Typical
- Low Conduction Loss

**Package** 

# **JEDEC STYLE TO-247**







# Device Maximum Ratings T<sub>C</sub>= 25°C unless otherwise noted

Symbol	Parameter	Ratings	Units
BV <sub>CES</sub>	Collector to Emitter Breakdown Voltage	600	V
I <sub>C25</sub>	Collector Current Continuous, T <sub>C</sub> = 25°C	75	Α
I <sub>C110</sub>	Collector Current Continuous, T <sub>C</sub> = 110°C	35	Α
I <sub>CM</sub>	Collector Current Pulsed (Note 1)	180	Α
V <sub>GES</sub>	Gate to Emitter Voltage Continuous	±20	V
$V_{GEM}$	Gate to Emitter Voltage Pulsed	±30	V
SSOA	Switching Safe Operating Area at T <sub>J</sub> = 150°C, Figure 2	100A at 600V	
E <sub>AS</sub>	Pulsed Avalanche Energy, I <sub>CE</sub> = 30A, L = 1mH, V <sub>DD</sub> = 50V	260	mJ
P <sub>D</sub>	Power Dissipation Total T <sub>C</sub> = 25°C	290	W
	Power Dissipation Derating T <sub>C</sub> > 25°C	2.33	W/°C
TJ	Operating Junction Temperature Range	-55 to 150	°C
T <sub>STG</sub>	Storage Junction Temperature Range	-55 to 150	°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTE:

Pulse width limited by maximum junction temperature.

Device Marking         Device           40N6S2D         FGH40N6S2D		Device	Package	Tape '	Width		Quantity	
				I/A		30		
Electri	cal Char	acteristics T <sub>J</sub> = 25°C	unless otherwi	se noted				
Symbol		Parameter	Test C	onditions	Min	Тур	Max	Units
Off Stat	e Characte	eristics						
BV <sub>CES</sub>	Collector to Emitter Breakdown Voltage		$I_C = 250 \mu A, V_{GE} = 0$		600	-	-	V
I <sub>CES</sub>	Collector to Emitter Leakage Current		V <sub>CE</sub> = 600V	T <sub>J</sub> = 25°C	-	-	250	μА
				$T_J = 125^{\circ}C$	-	-	2.0	mA
I <sub>GES</sub>	Gate to Emi	tter Leakage Current	$V_{GE} = \pm 20V$		-	-	±250	nA
On Stat	e Characte	eristics						
V <sub>CE(SAT)</sub>	Collector to	Emitter Saturation Voltage	I <sub>C</sub> = 20A,	T <sub>J</sub> = 25°C	-	1.9	2.7	V
*CE(SAI)		ŭ	V <sub>GE</sub> = 15V	T <sub>.I</sub> = 125°C	-	1.7	2.0	V
V <sub>EC</sub>	Diode Forwa	ard Voltage	I <sub>EC</sub> = 20A	1 0	-	2.2	2.6	V
	c Characte						1	
	Gate Charge		I <sub>C</sub> = 20A,	V <sub>GE</sub> = 15V		35	42	nC
$Q_{G(ON)}$	Cate Onarg		$V_{CE} = 300V$	$V_{GE} = 10V$		45	55	nC
V <sub>GE(TH)</sub>	Gate to Emi	tter Threshold Voltage	$I_C = 250 \mu A, V_C$	~-	3.5	4.3	5.0	V
V <sub>GEP</sub>	1	Gate to Emitter Plateau Voltage		$I_C = 20A$ , $V_{CE} = 300V$		6.5	8.0	V
SSOA	Switching S	OA	$T_J = 150$ °C, $V_{GE} = 15$ V, $R_G = 3\Omega$ L = 100 $\mu$ H, $V_{CE} = 600$ V		100	-	-	А
t <sub>d(ON)I</sub>	Current Turr	n-On Delay Time		IGBT and Diode at $T_J = 25^{\circ}$ C,		8.0	-	ns
t <sub>rl</sub>	Current Rise	Time	$I_{CE} = 20A$ ,	-	-	10	-	ns
t <sub>d(OFF)I</sub>	Current Turr	n-Off Delay Time	$V_{CE} = 390V,$		-	35	-	ns
t <sub>fl</sub>	Current Fall	Time	$V_{GE} = 15V,$ $R_{G} = 3\Omega$		-	55	-	ns
E <sub>ON1</sub>	Turn-On En	aray (Nota 2)	$L = 200 \mu H$			445		110
		ergy (Note 2)	L = 200μH		-	115	-	μJ
$E_{ON2}$	Turn-On En	ergy (Note 2)	Test Circuit - F	igure 26	-	200	-	
E <sub>ON2</sub>	1	· · · · · · · · · · · · · · · · · · ·	-	igure 26			- - 260	μJ
	Turn-Off En	ergy (Note 2)	Test Circuit - F	igure 26 de at T <sub>J</sub> = 125°C	-	200	- - 260 -	μJ μJ
E <sub>OFF</sub>	Turn-Off En	ergy (Note 2) ergy (Note 3) n-On Delay Time	Test Circuit - F  IGBT and Dioc  I <sub>CE</sub> = 20A,		-	200 195	- - 260 -	րվ իվ իվ
E <sub>OFF</sub>	Turn-Off End Current Turn Current Rise	ergy (Note 2) ergy (Note 3) n-On Delay Time	Test Circuit - F  IGBT and Dioc  I <sub>CE</sub> = 20A,  V <sub>CE</sub> = 390V,		-	200 195 14	- 260 - - 85	µJ µJ µJ ns
E <sub>OFF</sub> t <sub>d(ON)I</sub> t <sub>rl</sub>	Turn-Off End Current Turn Current Rise	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time	Test Circuit - F  IGBT and Dioc I <sub>CE</sub> = 20A, V <sub>CE</sub> = 390V, V <sub>GE</sub> = 15V,		- - -	200 195 14 18	-	μλ μλ μλ ns ns
$E_{OFF}$ $t_{d(ON)I}$ $t_{rI}$ $t_{d(OFF)I}$	Turn-Off End Current Turn Current Rise Current Turn Current Fall	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time	Test Circuit - F  IGBT and Dioc  I <sub>CE</sub> = 20A,  V <sub>CE</sub> = 390V,		- - - -	200 195 14 18 68	- - 85	μJ μJ μJ ns ns
$E_{OFF}$ $t_{d(ON)I}$ $t_{rI}$ $t_{d(OFF)I}$ $t_{fI}$	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_G = 3\Omega$	de at T <sub>J</sub> = 125°C	- - - -	200 195 14 18 68 85	- - 85	μ μ μ ns ns ns
$\begin{aligned} & & & & & & & & & & & & \\ & & & & & & $	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End Turn-On End	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time ergy (Note 2)	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_G = 3\Omega$ $L = 200\mu H$	de at T <sub>J</sub> = 125°C	- - - - -	200 195 14 18 68 85 115	- - 85 105	μ μ μ ns ns ns ns
$\begin{aligned} & E_{OFF} \\ & t_{d(ON)I} \\ & t_{rI} \\ & t_{d(OFF)I} \\ & t_{fI} \\ & E_{ON1} \\ & E_{ON2} \end{aligned}$	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End Turn-On End Turn-Off End	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time ergy (Note 2) ergy (Note 2)	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_{G} = 3\Omega$ $L = 200\mu$ H  Test Circuit - F	de at $T_J = 125$ °C igure 26 $dt = 200A/\mu s$	- - - - - -	200 195 14 18 68 85 115 380	- 85 105 - 450	μ μ μ ns ns ns ns ns
E <sub>OFF</sub> t <sub>d(ON)I</sub> t <sub>rI</sub> t <sub>d(OFF)I</sub> t <sub>fI</sub> E <sub>ON1</sub> E <sub>ON2</sub> E <sub>OFF</sub>	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End Turn-On End Turn-Off End	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time ergy (Note 2) ergy (Note 2) ergy (Note 3)	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_{G} = 3\Omega$ $L = 200\mu H$ Test Circuit - F	de at $T_J = 125$ °C igure 26 $dt = 200A/\mu s$	- - - - - -	200 195 14 18 68 85 115 380 375	- 85 105 - 450 600	м м ms ns ns ns ns ms
EOFF  td(ON)I  trI  td(OFF)I  tfI  EON1  EON2  EOFF  trr	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End Turn-On End Turn-Off End	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time ergy (Note 2) ergy (Note 2) ergy (Note 3) rse Recovery Time	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_{G} = 3\Omega$ $L = 200\mu$ H  Test Circuit - F	de at $T_J = 125$ °C igure 26 $dt = 200A/\mu s$		200 195 14 18 68 85 115 380 375 30	- 85 105 - 450 600 35	μ μ ns ns ns ns μ μ μ μ μ
E <sub>OFF</sub> t <sub>d(ON)I</sub> t <sub>rI</sub> t <sub>d(OFF)I</sub> t <sub>fI</sub> E <sub>ON1</sub> E <sub>ON2</sub> E <sub>OFF</sub> t <sub>rr</sub>	Turn-Off End Current Turn Current Rise Current Turn Current Fall Turn-On End Turn-Off End Diode Rever	ergy (Note 2) ergy (Note 3) n-On Delay Time e Time n-Off Delay Time Time ergy (Note 2) ergy (Note 2) ergy (Note 3) rse Recovery Time	Test Circuit - F  IGBT and Dioc $I_{CE} = 20A$ , $V_{CE} = 390V$ , $V_{GE} = 15V$ , $R_{G} = 3\Omega$ $L = 200\mu$ H  Test Circuit - F	de at $T_J = 125$ °C igure 26 $dt = 200A/\mu s$		200 195 14 18 68 85 115 380 375 30	- 85 105 - 450 600 35	LH LH INS INS INS INS LH LH LH INS

# NOTE:

<sup>2.</sup> Values for two Turn-On loss conditions are shown for the convenience of the circuit designer.  $E_{ON1}$  is the turn-on loss of the IGBT only.  $E_{ON2}$  is the turn-on loss when a typical diode is used in the test circuit and the diode is at the same  $T_J$  as the IGBT. The diode type is specified in figure 26.

<sup>3.</sup> Turn-Off Energy Loss ( $E_{OFF}$ ) is defined as the integral of the instantaneous power loss starting at the trailing edge of the input pulse and ending at the point where the collector current equals zero ( $I_{CF}$  = 0A). All devices were tested per JEDEC Standard No. 24-1 Method for Measurement of Power Device Turn-Off Switching Loss. This test method produces the true total Turn-Off Energy Loss.



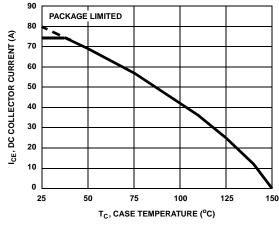


Figure 1. DC Collector Current vs Case

Temperature

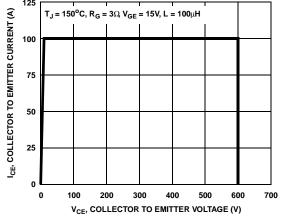


Figure 2. Minimum Switching Safe Operating Area

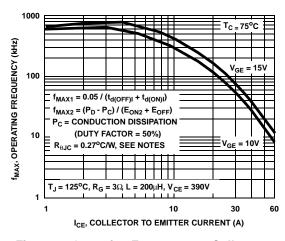


Figure 3. Operating Frequency vs Collector to Emitter Current

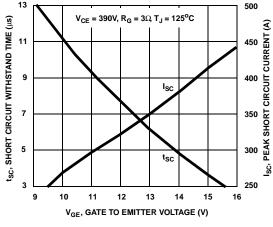


Figure 4. Short Circuit Withstand Time

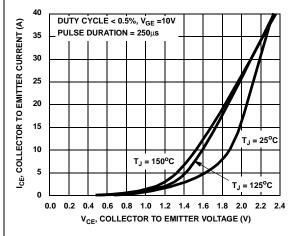


Figure 5. Collector to Emitter On-State Voltage

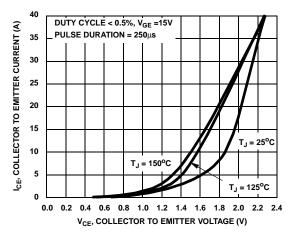


Figure 6. Collector to Emitter On-State Voltage

FGH40N6S2D RevA4

©2002 Fairchild Semiconductor Corporation



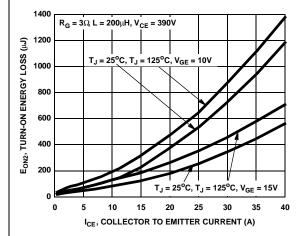


Figure 7. Turn-On Energy Loss vs Collector to Emitter Current

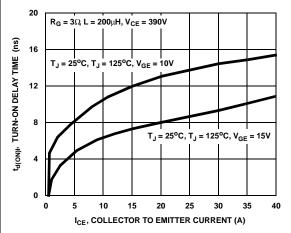


Figure 9. Turn-On Delay Time vs Collector to Emitter Current

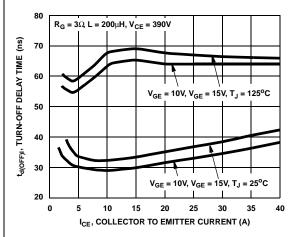


Figure 11. Turn-Off Delay Time vs Collector to Emitter Current

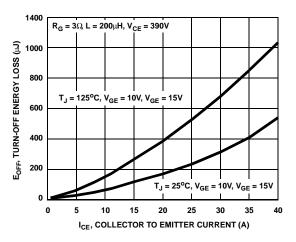


Figure 8. Turn-Off Energy Loss vs Collector to Emitter Current

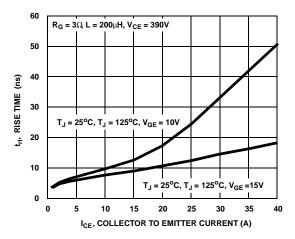


Figure 10. Turn-On Rise Time vs Collector to Emitter Current

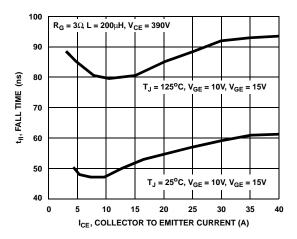
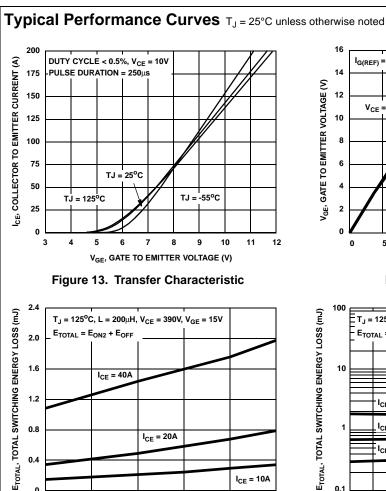


Figure 12. Fall Time vs Collector to Emitter
Current

©2002 Fairchild Semiconductor Corporation





I<sub>CE</sub> = 10A

0.4

0

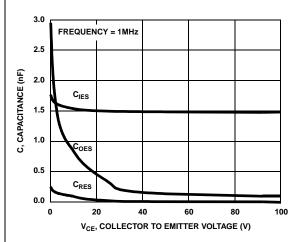


Figure 17. Capacitance vs Collector to Emitter Voltage

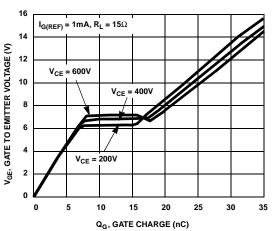


Figure 14. Gate Charge

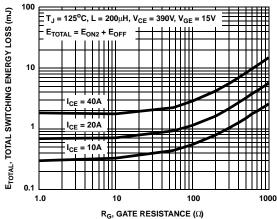


Figure 16. Total Switching Loss vs Gate Resistance

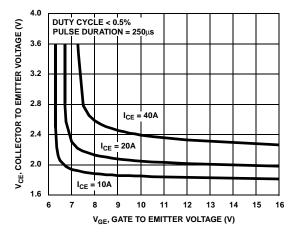


Figure 18. Collector to Emitter On-State Voltage vs **Gate to Emitter Voltage** 

©2002 Fairchild Semiconductor Corporation FGH40N6S2D RevA4



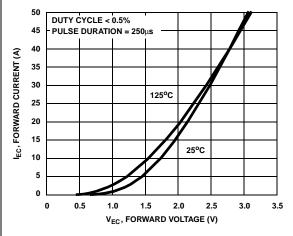


Figure 19. Diode Forward Current vs Forward Voltage Drop

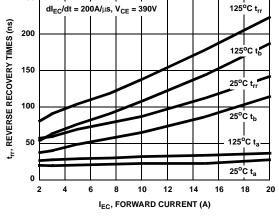


Figure 20. Recovery Times vs Forward Current

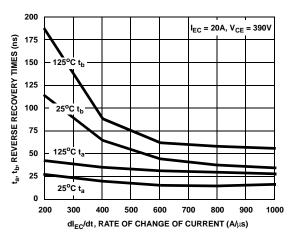


Figure 21. Recovery Times vs Rate of Change of Current

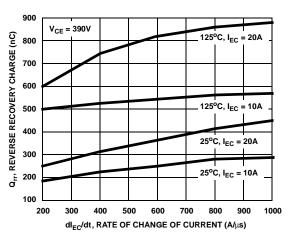


Figure 22. Stored Charge vs Rate of Change of Current

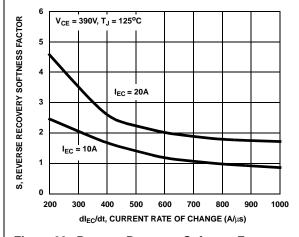


Figure 23. Reverse Recovery Softness Factor vs Rate of Change of Current

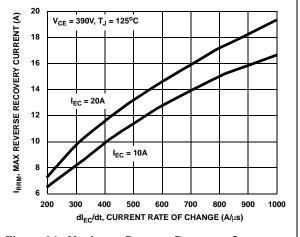


Figure 24. Maximum Reverse Recovery Current vs Rate of Change of Current

©2002 Fairchild Semiconductor Corporation FGH40N6S2D RevA4



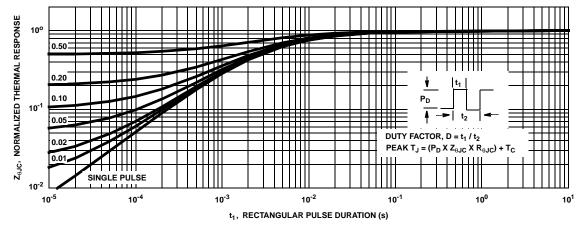


Figure 25. IGBT Normalized Transient Thermal Impedance, Junction to Case

# Test Circuit and Waveforms

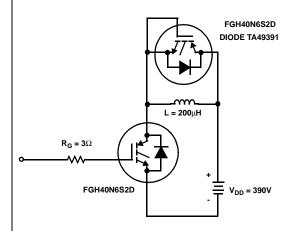


Figure 26. Inductive Switching Test Circuit

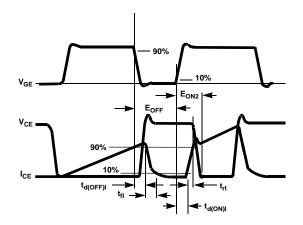


Figure 27. Switching Test Waveforms

# Handling Precautions for IGBTs

Insulated Gate Bipolar Transistors are susceptible to gate-insulation damage by the electrostatic discharge of energy through the devices. When handling these devices, care should be exercised to assure that the static charge built in the handler's body capacitance is not discharged through the device. With proper handling and application procedures, however, IGBTs are currently being extensively used in production by numerous equipment manufacturers in military, industrial and consumer applications, with virtually no damage problems due to electrostatic discharge. IGBTs can be handled safely if the following basic precautions are taken:

- Prior to assembly into a circuit, all leads should be kept shorted together either by the use of metal shorting springs or by the insertion into conductive material such as "ECCOSORBD™ LD26" or equivalent.
- When devices are removed by hand from their carriers, the hand being used should be grounded by any suitable means - for example, with a metallic wristband.
- 3. Tips of soldering irons should be grounded.
- 4. Devices should never be inserted into or removed from circuits with power on.
- Gate Voltage Rating Never exceed the gatevoltage rating of V<sub>GEM</sub>. Exceeding the rated V<sub>GE</sub> can result in permanent damage to the oxide layer in the gate region.
- 6. Gate Termination The gates of these devices are essentially capacitors. Circuits that leave the gate open-circuited or floating should be avoided. These conditions can result in turn-on of the device due to voltage buildup on the input capacitor due to leakage currents or pickup.
- Gate Protection These devices do not have an internal monolithic Zener diode from gate to emitter. If gate protection is required an external Zener is recommended.

# Operating Frequency Information

Operating frequency information for a typical device (Figure 3) is presented as a guide for estimating device performance for a specific application. Other typical frequency vs collector current ( $I_{CE}$ ) plots are possible using the information shown for a typical unit in Figures 5, 6, 7, 8, 9 and 11. The operating frequency plot (Figure 3) of a typical device shows  $f_{MAX1}$  or  $f_{MAX2}$ ; whichever is smaller at each point. The information is based on measurements of a typical device and is bounded by the maximum rated junction temperature.

 $f_{MAX1}$  is defined by  $f_{MAX1} = 0.05/(t_{d(OFF)l} + t_{d(ON)l}).$  Deadtime (the denominator) has been arbitrarily held to 10% of the on-state time for a 50% duty factor. Other definitions are possible.  $t_{d(OFF)l}$  and  $t_{d(ON)l}$  are defined in Figure 27. Device turn-off delay can establish an additional frequency limiting condition for an application other than  $T_{JM}$ .  $t_{d(OFF)l}$  is important when controlling output ripple under a lightly loaded condition

 $f_{MAX2}$  is defined by  $f_{MAX2} = (P_D - P_C)/(E_{OFF} + E_{ON2}).$  The allowable dissipation  $(P_D)$  is defined by  $P_D = (T_{JM} - T_C)/R_{\theta JC}.$  The sum of device switching and conduction losses must not exceed  $P_D.$  A 50% duty factor was used (Figure 3) and the conduction losses  $(P_C)$  are approximated by  $P_C = (V_{CE} \times I_{CE})/2.$ 

 $E_{ON2}$  and  $E_{OFF}$  are defined in the switching waveforms shown in Figure 27.  $E_{ON2}$  is the integral of the instantaneous power loss ( $I_{CE}$  x  $V_{CE}$ ) during turnon and  $E_{OFF}$  is the integral of the instantaneous power loss ( $I_{CE}$  x  $V_{CE}$ ) during turn-off. All tail losses are included in the calculation for  $E_{OFF}$ ; i.e., the collector current equals zero ( $I_{CE}$  = 0)

 ${\tt ECCOSORBD^{\sf TM}} \ is \ a \ Trademark \ of \ Emerson \ and \ Cumming, \ Inc.$ 

### **TRADEMARKS**

The following are registered and unregistered trademarks Fairchild Semiconductor owns or is authorized to use and is not intended to be an exhaustive list of all such trademarks.

ACEx™	FACT™	ImpliedDisconnect™	PACMAN™	SPM™
ActiveArray™	FACT Quiet Series™	ISOPLANAR™	POP™	Stealth™
Bottomless™	FAST®	LittleFET™	Power247™	SuperSOT™-3
CoolFET™	FASTr™	MicroFET™	PowerTrench®	SuperSOT™-6
CROSSVOLT™	FRFET™	MicroPak™	QFET™	SuperSOT™-8
DOME™	GlobalOptoisolator™	MICROWIRE™	QS™	SyncFET™
EcoSPARK™	GTO™	MSX™	QT Optoelectronics™	TinyLogic™
E <sup>2</sup> CMOS <sup>TM</sup>	HiSeC™	MSXPro™	Quiet Series™	TruTranslation™
EnSigna™	I <sup>2</sup> C <sup>TM</sup>	OCX™	RapidConfigure™	UHC™
Across the board	. Around the world.™	OCXPro™	RapidConnect™	UltraFET <sup>®</sup>
The Power Franchise™		OPTOLOGIC®	SILENT SWITCHER®	VCX™
Programmable Active Droop™		OPTOPLANAR™	SMART START™	

#### DISCLAIMER

FAIRCHILD SEMICONDUCTOR RESERVES THE RIGHT TO MAKE CHANGES WITHOUT FURTHER NOTICE TO ANY PRODUCTS HEREIN TO IMPROVE RELIABILITY, FUNCTION OR DESIGN. FAIRCHILD DOES NOT ASSUME ANY LIABILITY ARISING OUT OF THE APPLICATION OR USE OF ANY PRODUCT OR CIRCUIT DESCRIBED HEREIN; NEITHER DOES IT CONVEY ANY LICENSE UNDER ITS PATENT RIGHTS, NOR THE RIGHTS OF OTHERS.

#### LIFE SUPPORT POLICY

FAIRCHILD'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF FAIRCHILD SEMICONDUCTOR CORPORATION. As used herein:

- 1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, or (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in significant injury to the user
- A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.

### PRODUCT STATUS DEFINITIONS

### **Definition of Terms**

Datasheet Identification	Product Status	Definition
Advance Information	Formative or In Design	This datasheet contains the design specifications for product development. Specifications may change in any manner without notice.
Preliminary	First Production	This datasheet contains preliminary data, and supplementary data will be published at a later date. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
No Identification Needed	Full Production	This datasheet contains final specifications. Fairchild Semiconductor reserves the right to make changes at any time without notice in order to improve design.
Obsolete	Not In Production	This datasheet contains specifications on a product that has been discontinued by Fairchild semiconductor. The datasheet is printed for reference information only.