FAIRCHILD SEMICONDUCTOR™

www.fairchildsemi.com

RC5011

Step-up Regulator for Notebook Computers

Features

- Combines 5V precision linear regulator and boost-mode DC-DC converter
- High efficiency – 85% typical
- 6V to 22V input range (30V peak)
- Independent output enable control
- 10µA shutdown current
- Operates with companion RC5023 to form complete notebook computer power supply
- 8 pin SOIC package

Applications

- Complete notebook PC power supply when combined with RC5023 triple output DC-DC converter
- Sub-notebooks and PDAs
- PCMCIA and LCD panels

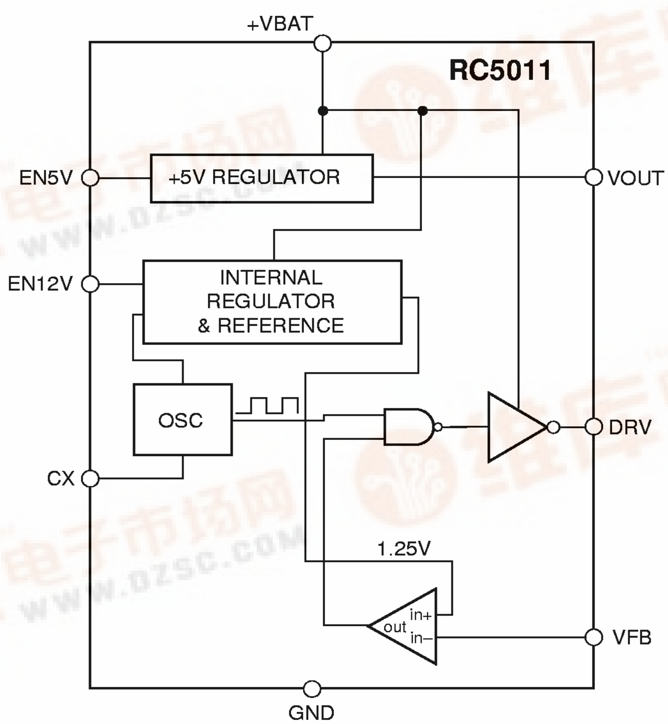
Description

The RC5011 is a combination 5V precision linear regulator and switch-mode boost converter suitable for use in notebook PC power supplies. The 5V regulator can drive loads in excess of 40mA, while the boost converter can be used to provide 12V for Flash BIOS or PCMCIA requirements.

Operating over a 6V to 22V (30V peak) input range, the RC5011 can be used as a standalone IC acheiving switch mode efficiencies of up to 85%. The RC5011 can also be used with the Fairchild Semiconductor RC5023 triple output DC-DC converter to generate the 5V, 3.3V, 12V and 2.xV required for typical Pentium® notebook computers. When used with the RC5023, the RC5011 acts as an input stage that provides 5V for the RC5023 Vcc as well as 12V for BIOS or PCMCIA. Using this scheme, system efficiencies of 88% can be realized for the entire 4-output solution.

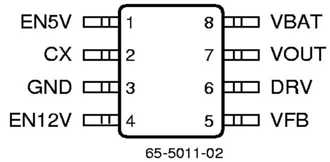
Advanced Information

Block Diagram



Rev. 0.5.1

Pin Assignments



Pin Descriptions

Pin Number	Pin Name	Pin Function Description
1	EN5V	**5V output enable**. TTL-compatible input disables 5V linear regulator when set to logic LOW. Serves as system global enable/disable when used with RC5023 companion IC.
2	CX	**Oscillator timing capacitor**. Connecting an external capacitor to this pin sets the internal oscillator frequency.
3	GND	**Ground**. Connect this pin to system ground so that ground loops are avoided.
4	EN12V	**12V output enable**. TTL-compatible input disables the switch-mode converter when set to logic LOW.
5	VFB	**Voltage feedback**. Input for the voltage feedback control loop.
6	DRV	**FET Driver output for switch-mode converter**. Connect this pin to the gate of an N-channel MOSFET. The trace from this pin to the MOSFET gate should be as short as possible (<0.5").
7	VOUT	**5V linear regulator output**. Connect this pin to loads up to 40mA or to VCCL pin of RC5023 when used in the notebook computer power supply system.
8	VBAT	**Battery Supply Voltage**. Connect to system battery or other 6V to 30V source.

Absolute Maximum Ratings[1]

Supply Voltage, VBAT	32V
Power Dissipation, $T_A < 50°C$[2]	300mW
Storage Temperature	-65 to 150°C
Junction Temperature	125°C
Lead Soldering Temperature, 10 seconds	300°C

Notes:
1. Functional operation under any of these conditions is not implied. Performance is guarenteed only if Operating Conditions are not exceeded.
2. For $T_A > 50°C$, derate at 4.2mW/°C.

Operating Conditions

Parameter	Min	Typ	Max	Units
Supply Voltage, VBAT	6		30	V
Input Logic HIGH	2			V
Input Logic LOW			0.8	V
Ambient Temp	0		70	°C

Advanced Information

Electrical Characteristics – Switch-mode Converter

V_{BAT} = 6V, Fosc = 50KHz, T_A = 0 to 70°C using circuit in Figure 1, unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Units
Output Voltage	Set by external resistors	12		30	V
Output Driver Voltage Swing		4.5			V
Line Regulation	V_{BAT} = 6V to 22V		0.2	0.4	%
Load Regulation	I_L = 0 to 200mA		0.1	0.2	%
Output Ripple/Noise	I_L = 200mA, BW = 20MHz		100	250	mV
Reference Voltage	Internal Reference	1.19	1.25	1.37	V
Efficiency		80	85		%
Operating Frequency Range		1.0		75	KHz
Oscillator Frequency Precision			±10		%
Capacitor Charging Current		4.0	8.0		µA
Capacitor Threshold Voltage +			1.4		V
Capacitor Threshold Voltage –			0.5		V
Feedback Input Current	VFB = 1.25V		0.1		µA

Electrical Characteristics - Linear Regulator

V_{BAT} = 6V, T_A = 0 to 70°C using circuit in Figure 1, unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Units
Output Setpoint Accuracy	No Load		±3		%
Line Regulation	V_{BAT} = 6V to 22V		+0.4	+0.8	%
Load Regulation	I_L = 0 to 40mA		-1.0	-2.5	%
Output Temperature Drift	I_L = 40mA		+100	+150	ppm/°C
Cumulative DC Accuracy[1]				±5	%
Output Drive Current				40	mA

Note:

1. Cumulative DC Accuracy includes Setpoint Accuracy, Line/Load Regulation and Temperature Drift.

Electrical Characteristics – Common

V_{BAT} = 6V, Fosc = 50KHz, T_A= 25°C using circuit in Figure 1, unless otherwise noted.

Parameter	Conditions	Min.	Typ.	Max.	Units
Supply Current	VBAT = 6 to 22V, No load VBAT = 6V, EN5V LOW VBAT = 6V, EN12V = LOW Vbat = 6V, EN5V = EN12V = LOW		1.5 0.8 0.5 0.5	2.5 1.5 1.5 1.5	mA mA mA µA

Advanced Information

Test Circuit

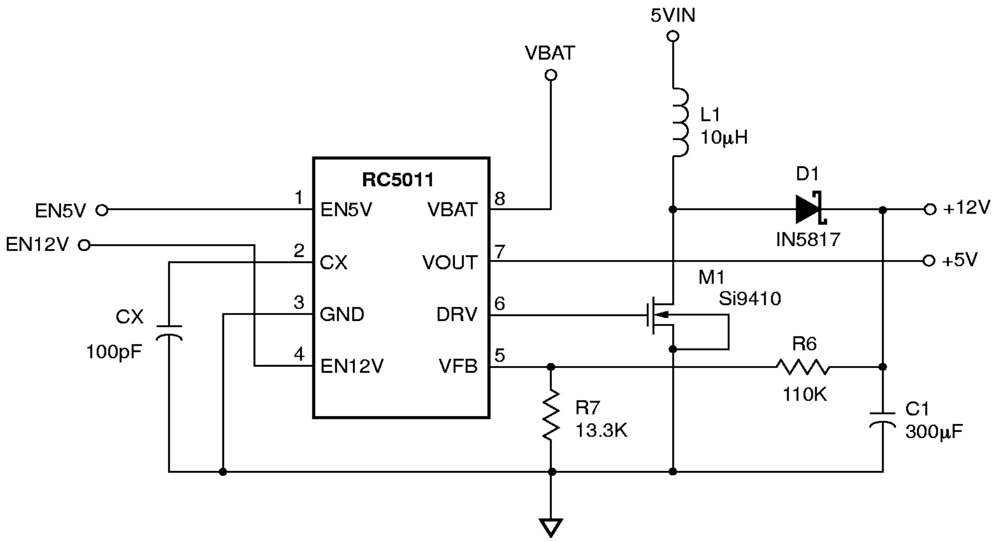


Figure 1. Standard Test Circuit Schematic

Application Information

Step-Up (Boost mode) Converter

A complete schematic of the minimum step-up converter application is shown in Figure 1. Upon application of power (V_{BAT}) and a logic high signal on the EN5V pin, the fixed 5V precision bandgap reference will become active and source up to 40mA of load current. If the 5V regulator is not needed, a logic low on the EN5V pin will disable the 5V regulator and reduce the supply current, thus minimizing power consumption. A 1µF capacitor connected from the 5V output to ground is recommended to reduce noise on the 5V output.

A logic high signal placed on the EN12V pin enables the switch mode regulator. Included in the switch-mode controller is a precision bandgap regulator that generates both a 1.25V reference and a 4V reference internally. The 4V reference is effectively "filtered " from the V_{BAT} supply to increase the power supply rejection of the IC, thus making it less susceptable to changes in the battery voltage and noise. The 1.25V reference is used for comparison against the divided down output voltage occuring at the voltage feedback (VFB) input.

A voltage supply connected to one side of the inductor as shown will cause the filter capacitor to instantaneously charge to V_{BAT} -V_F, where V_F is the forward voltage of the blocking diode. The voltage on the output capacitor C1 is also applied to resistor voltage divider R6 and R7, where the ratio of these resistors determines the final output voltage. The VFB node is connected to one side (-input) of a voltage comparator and the other side (+input) is connected to the 1.25V reference. If the voltage across C1 is less than the programmed value set by the ratio of R6 and R7, the output of the comparator will be at logic high.

One input of a NAND logic gate is connected to the comparator output, while the other NAND input is connected to the oscillator output. A logic high will allow the NAND output to respond to the oscillator input, thus allowing the totem-pole inverter to pulse the gate of the external N-channel MOSFET. The totem-pole inverter is referenced to V_{BAT} since this higher voltage will allow a higher gate drive and reduce the $R_{DS,ON}$ value of the MOSFET. When the FET is turned on, the inductor conducts current to ground through the FET. When the FET is turned off, diode D1 charges the output capacitor C1.

The VFB node will continuously monitor the output voltage and allow the oscillator to drive the MOSFET until the voltage at VFB surpasses the internal 1.25V reference voltage. At this time the output of the comparator switches to a logic low state, which forces the NAND output high. The totem-pole inverter will then transition low and turn off the MOSFET. Because the output voltage is now higher than V_{BAT}, the blocking diode prevents any further current flow into the output capcitor or the load. This condition will remain until the output voltage drops enough to lower the VFB node below 1.25V, at which time the process starts again. Using this system, the feedback network will vary the MOSFET duty cycle in response to changes in load current or battery voltage.

The inductor value and oscillator frequency must be carefully tailored to the battery voltage, output current, and ripple requirements of the application. If either the inductor value or the oscillator frequency is too high, the inductor current will never reach a value high enough to meet the load current drain and the output voltage will collapse. If the inductor value or the oscillator frequency is too low, the inductor current will become excessive, causing higher output voltage ripple, inductor core saturation, or MOSFET destruction due to over-stress.

Design Equations

The inductor (L1) and timing capacitor (CX) values must be tailored to the input voltage range, output voltage, and load current requirements of the application. The key to the problem is to select the correct inductor value for a given oscillator frequency such that the inductor current rises to a peak value (Imax) sufficient to meet the average load current drain. The worst-case conditions for calculating its ability to supply load current are found at the minimum supply voltage. Therefore, $V_{BAT,MIN}$ is used to calculate the inductor value. Conversely, the worst-case condition for output voltage ripple will occur at $V_{BAT,MAX}$.

The value of the timing capacitor is set according to the following equation:

$$F_O(Hz) = (5 \times 10^{-6})/C_X$$

The output of the oscillator is measured at pin 2 (CX) and the voltage at the CX pin will be a triangle waveform. By pulling the VFB pin above 1.25V, the oscillator square wave output can be measured directly at pin 6 (DRV). Capacitor selection will depend on the specific application; higher operating frequencies will reduce the output voltage ripple and will allow the use of an inductor with a physically smaller inductor core, but excessively high frequencies will reduce load driving capability and efficiency.

Maximum on time of the MOSFET is calculated as follows:

$$T_{on} = 1/2F_O + 0.5\mu S$$

The 0.5µS term is added to represent the MOSFET gate-discharge time, although it is an approximation only and should be checked for the specific MOSFET used.

The peak inductor current is:

$$I_{MAX} = \left(\frac{V_{OUT} + V_F - V_{BAT}}{(F_O)T_{on}[V_{BAT} - V_{DS,ON}]}\right)2I_{DC}$$

where:

V_{BAT} = supply voltage
V_F = diode forward voltage
I_{DC} = dc load current
$V_{DS,ON}$ = drain-source on voltage of MOSFET

Inductor value:

$$LX(Henries) = \left(\frac{V_{BAT} - V_{DS,ON}}{I_{MAX}}\right)T_{ON}$$

Output filter capacitor:

$$C1(\mu F) = \frac{T_{ON}\left(\frac{V_{BAT}I_{MAX}}{V_{OUT}} + I_{DC}\right)}{V_{RIPPLE}}$$

where V_{RIPPLE} = Peak output voltage ripple

To reduce system power consumption when the switch-mode section is not in use, the circuit shown in Figure 2 is recommended. This circuit prevents any load connected to V_{OUT} from drawing current out of V_{BAT}.

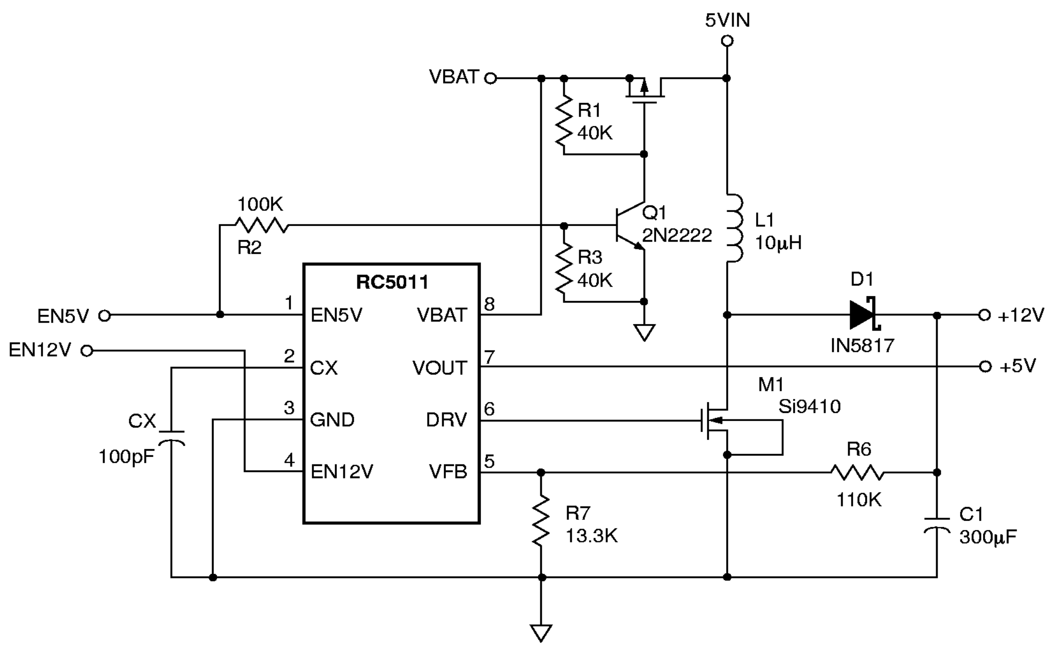


Figure 2. Standard Test Schematic with 12V Shutdown Circuit added

Notebook Power Supply Application

RC5011/RC5023 System

The RC5011/RC5023 Portable Power Supply System is designed to cost-effectively address the notebook computer power supply requirements. The RC5011 generates the +12V power supply while also providing the startup 5V supply current for the RC5023. The RC5011 is designed on a high voltage technology which can support battery voltages as high as 32V. The 5V linear regulator from the RC5011 rejects the large potential battery voltage changes and provides a well-regulated +5V to power the RC5023. To optimize efficiency, the RC5023 utilizes an internal 5V switch to remove the +5V supply coming from the RC5011 and to then utilize the efficient +5V switcher output to supply the power for the digital logic, analog control circuitry, and output drivers of the RC5023.

The RC5023 has an internal comparator which senses the difference between the regulator 5V from the RC5011 and the output of the 5V switch-mode regulator. When the switch-mode regulator output exceeds 4.5V, the comparator commands the analog switch within the RC5023 to convert the +5V supply source from the RC5011 to the +5V switch-mode output. Thus, power is now drawn from the 88% efficient switch-mode regulator rather than the less efficient 5V linear regulator in the RC5011. The 5V linear regulator in the RC5011 remains connected to the RC5023 and continues to power both the bandgap reference as well as the 5Vswitch comparator; however the current consumption of these blocks is small and will not have a significant effect on the overall efficiency of the power supply system.

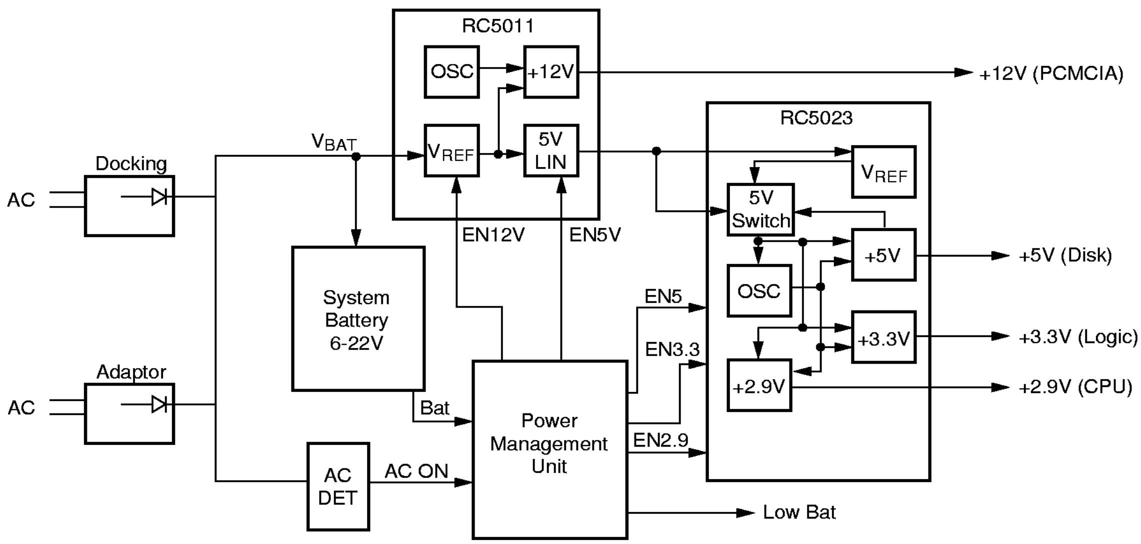


Figure 3. Notebook Computer Power Supply System using the RC5011 and RC5023

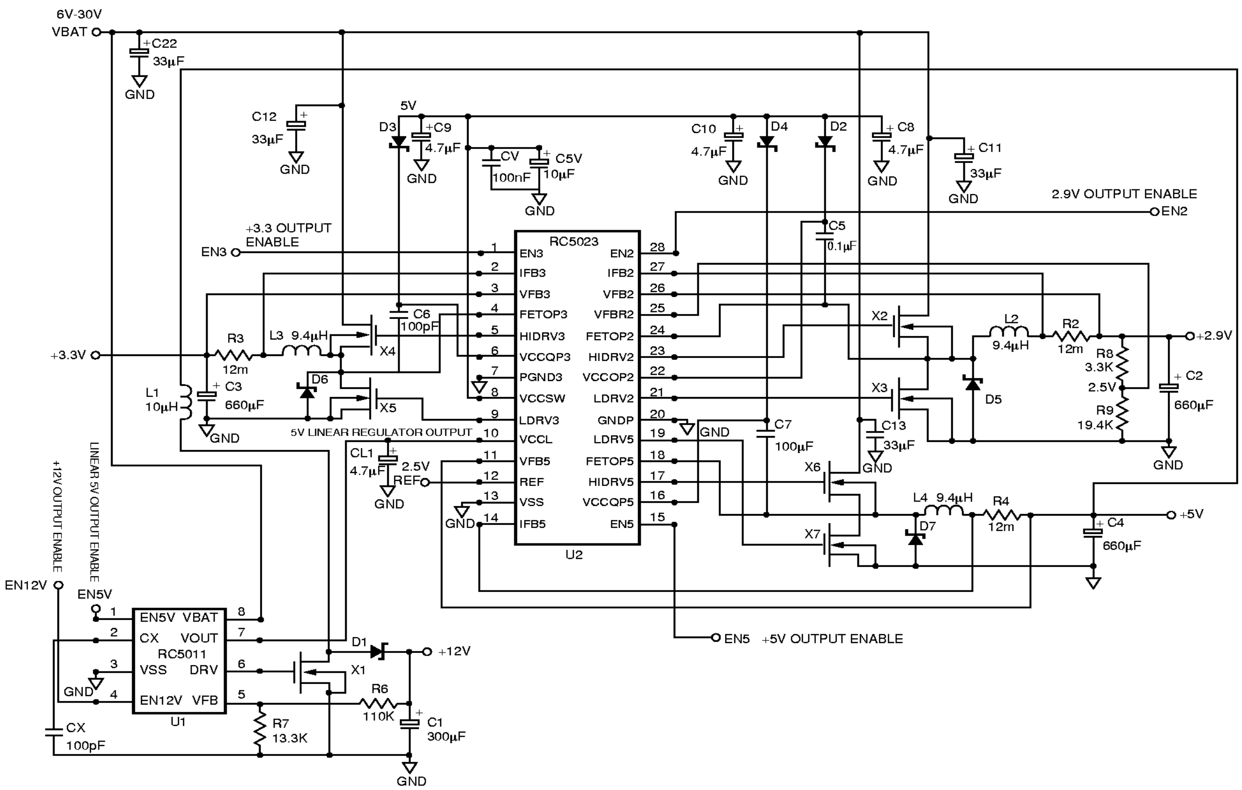


Figure 4.

RC5023/RC5011 Power Supply System Bill of Materials

Reference	Qty	Specification	Part No.	Manufacturer
L2-L4	3	9.4µH, 2.8A Inductors	PE-53631	Pulse Engineering
X2-X7, X1	7	N-channel MOSFETs	Si4410DY	Siliconix
D5-D7	3	3.3A, 20V SMT diodes	NSQ03A02L	Nihon
D2-D4, D1	4	1.1A, 20V SMT diodes	EC10QS02L	Nihon
R2-R4	3	1 watt 12m ohm, 1% resistors	LRC-2512	IRC
C2-C4	6	330µF, 10V tantalum capacitors	595D337X0010R2T	Sprague
C5-C7, CV	4	0.1µF, 16V ceramic capacitors	GRM40X7R104K025BL	Murata
C8-C10, CLI	4	4.7µF, 10V tantalum capacitors	NR Series	NEC
C11-C13, C22	4	33µF, 35V tantalum capacitors	595D336X0035R2T	Sprague
C5V	1	10µF, 10V tantalum capacitors	NR Series	NEC
R8	1	3.3K ohm, 0.1% resistor		Panasonic
R9	1	19.4K ohm, 0.1% resistor		Panasonic
RC5023	1	Triple-Output DC-DC Converter		Fairchild Semiconductor
L1	1	10µH, 2.65A inductor	CDRH125	Sumida
C1	2	100µF, 20V tantalum capacitor	595D107X0020R2T	Sprague
CX	1	100pF, 16V ceramic capacitor	GRM40C0G101J050BD	Murata
R6	1	110K ohm, 1% resistor		Panasonic
R7	1	133K ohm, 1% resistor		Panasonic
RC5011	1	12V Complement of RC5023		Fairchild Semiconductor

Advanced Information

Ordering Information

RC5011M	8 pin SOIC

Advanced Information

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 THE PRESIDENT 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, and (c) whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonable expected to result in a significant injury of the user.
2. A critical component in 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.

Fairchild Semiconductor Corporation
Americas
Customer Response Center
Tel:1-888-522-5372

Fairchild Semiconductor Europe
Fax: +49 (0) 1 80-530 85 86
Email: europe.support@nsc.com
Deutsch Tel: +49 (0) 8 141-35-0
English Tel: +44 (0) 1 793-85-68-56
Italy Tel: +39 (0) 2 57 5631

Fairchild Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Center, 5 Canto Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel:+852 2737-7200
Fax:+852 2314-0061

National Semiconductor Japan Ltd.
Tel:81-3-5620-6175
Fax:81-3-5620-6179

www.fairchildsemi.com

2/98 0.0m
Stock#DS30005011