FAIRCHILD SEMICONDUCTOR®

April 2012

FSAR001
AC-DC Linear Regulator

Features

- High Output Voltage Accuracy: 2%
- Output Voltage: 5V
- Low Ground Current: < 2.0mA
- Ultra-Fast Line and Load Transient Response
- Hysteretic Thermal and Current-Limit Protections
- Over-Voltage and Under-Voltage Protections
- Ultra-Low Power Dissipation with No Load
- Universal Input Range: 80~265V_{RMS}
- No Inductor Required
- Low Components and Cost

Applications

- Non-Isolation AC/DC Converter
- Home Appliance

Description

FSAR001 is designed to replace capacitor-fed (“cap dropper”) non-isolated power supplies, offering better high-power conversion performance and high-energy efficiency than a cap dropper solution. The appliance needs no inductor, uses few components, and offers lower cost.

FSAR001 integrates a 600V high-power device, startup controller, voltage control circuit, synchronous circuit, low dropout regulator, over-temperature protector, over-voltage protector, under-voltage protector, and current-limit circuit onto a monolithic IC.

Ordering Information

Part Number	Operating Ambient Temperature Range	Output Voltage	Maximum Load	Package	Packing Method
FSAR001BNY	-40°C to +105°C	5V	35mA	DIP-8	Tube

Application Diagram

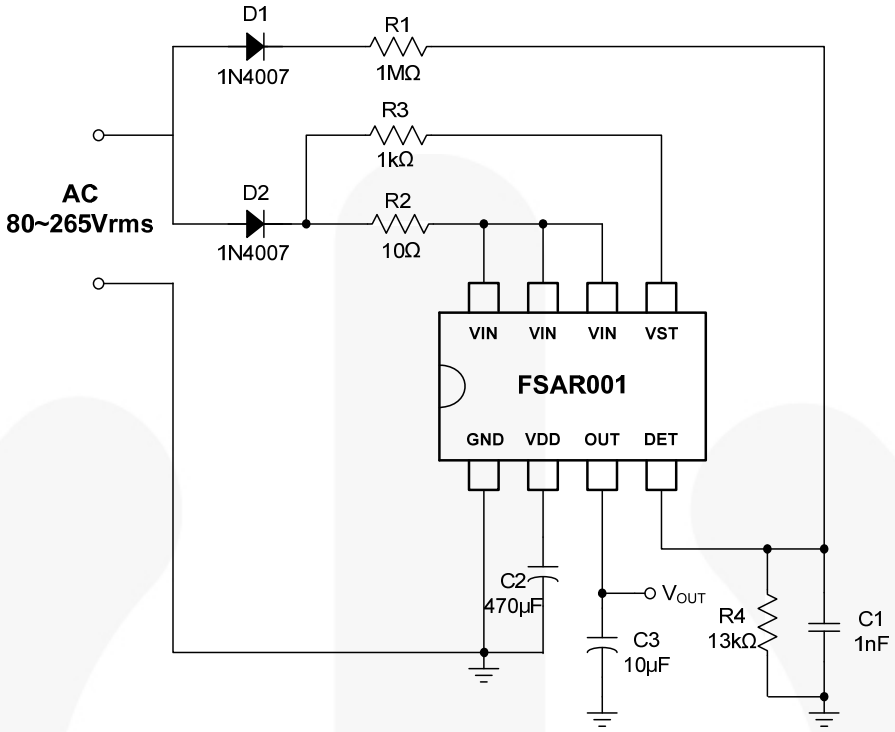


Figure 1. Typical Application

Internal Block Diagram

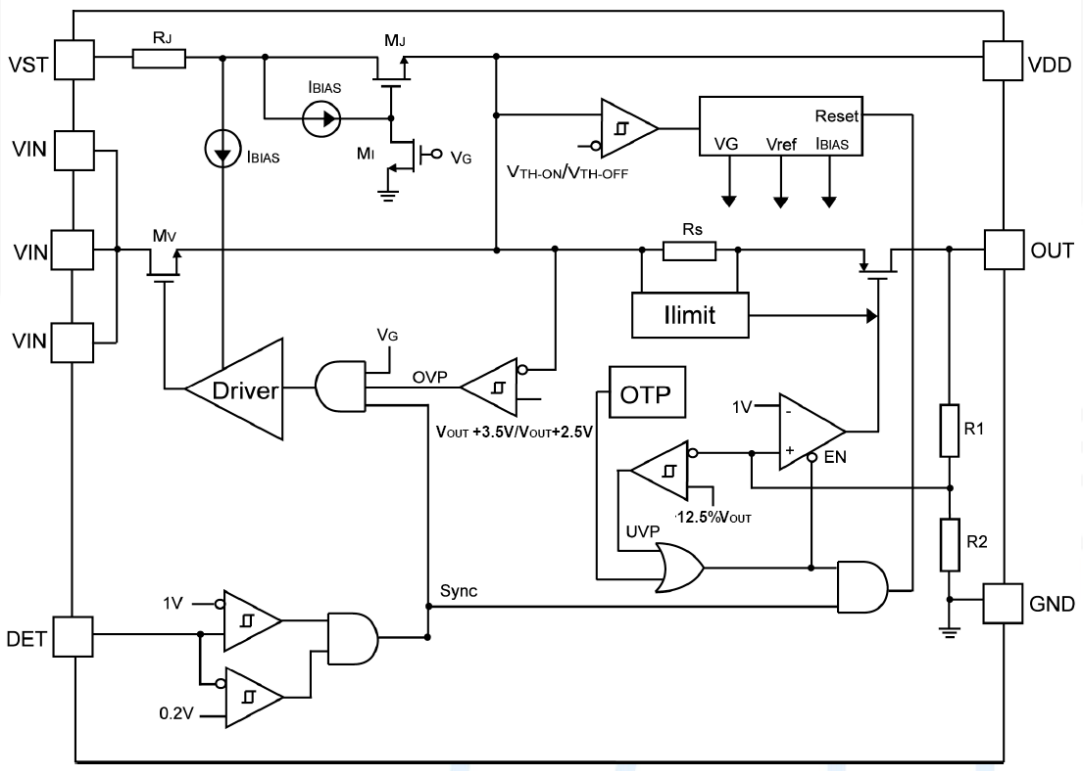
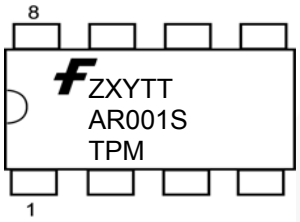


Figure 2. Functional Block Diagram

Marking Information



F - Fairchild Logo
Z - Plant Code
X - 1-Digit Year Code
Y - 1-Digit Week Code
TT - 2-Digit Die Run Code
S: B: 5V V_{OUT}
T: Package Type (N=DIP)
P - Y: Green Package
M - Manufacture Flow Code

Figure 3. Top Mark

Pin Configuration

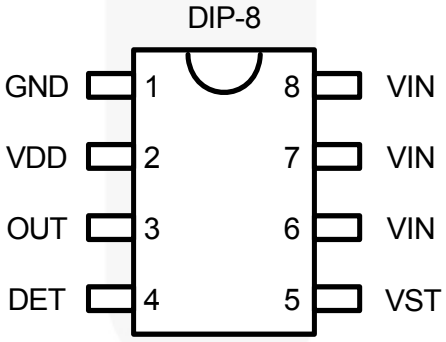


Figure 4. DIP-8 Pin Configuration

Pin Definitions

Name	Pin #	Type	Description
VDD	2	Power Supply	Connect a 470µF external capacitor to ground for generated V_{OUT}+2.5V ~ V_{OUT}+3.5V supply voltage.
GND	1	Ground	Ground
OUT	3	Output	Regulator output; fixed 5V output voltage
DET	4	Detect	Sin waveforms input connection. Connects to full-bridge output and provides synchronous signal.
VST	5	HV Start	500V power device startup connection.
VIN	6	600V Input	600V power device input connection
	7		
	8		

Absolute Maximum Ratings

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. The absolute maximum ratings are stress ratings only.

Symbol	Parameter		Min.	Max.	Unit
V_{IN}	Input Voltage of VIN Pin			600	V
V_{ST}	Input Voltage of VST Pin			500	V
V_{DET}	Input Voltage of DET Pin			7	V
V_{DD}	Input Voltage of VDD Pin			30	V
V_{OUT}	Input Voltage of OUT Pin			30	V
P_D	Power Dissipation ($T_A \leqq 50°C$)			1.15	W
Θ_{JA}	Thermal Resistance (Junction to Air)			95	°C/W
T_J	Operating Junction Temperature		-40	+125	°C
T_{STG}	Storage Temperature Range		-55	+150	°C
T_L	Lead Temperature (Wave Soldering or IR, 10 Seconds)			260	°C
ESD	Human Body Model, JEDEC:JESD22-A114	All Pins Except HV Pin(3)		6	KV
	Charged Device Model, JEDEC:JESD22-C101	All Pins Except HV Pin(3)		2	

Notes:
1. All voltage values, except differential voltages, are given with respect to the network ground terminal.
2. Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device.
3. ESD with HV pin CDM=1000V and HBM=500V.

Recommended Operating Conditions

Symbol	Parameter	Min.	Max.	Unit
V_{IN}	600V High-Voltage Input		600	V
V_{ST}	500V High-Voltage Startup		500	V
T_A	Operating Ambient Temperature	-40	+105	°C

Note:
4. For proper operation.

Electrical Characteristics

V_{IN}=open, V_{DD}=V_{OUT}+1 V, C_{VDD}=470 µF/ 25 V, C_{OUT}=10 µF/ 16 V, I_{OUT}=1 mA, T_A=25°C, unless otherwise noted.

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
VDD Section						
V_{TH-ON}	Turn-On Threshold Voltage (V_{OUT}=5V)	VDD Pin	9	10	11	V
V_{TH-OFF}	Turn-off Voltage (V_{OUT}=5V)	VDD Pin	3	4	5	V
I_{DD-ST}	Startup Current of VDD Pin	VDD Pin		10	30	µA
I_{DD-OP}	Operating Supply Current	I_{OUT}=1mA	1.0	1.5	2.0	mA
V_{DD-OVP}	Threshold of V_{DD} OVP		V_{OUT}+3.0	V_{OUT}+3.5	V_{OUT}+4.0	V
$V_{DD-OVPHYS}$	Threshold of V_{DD} OVP Hysteresis		0.8	1.0	1.2	V
tV_{DD-OVP}	Time Delay of V_{DD} OVP			1.5		µs
VIN Section						
V_{VIN}	Supply Voltage				600	V
VST Section						
I_{ST}	Supply Current from VST Pin	V_{AC}=90V (V_{DC}=120V), V_{DD}=10µF	2.50	3.75	5.00	mA
I_{ST-LC}	Supply Current After Startup	HV=500V, V_{DD}=V_{DD-OFF}+1V		1	20	µA
DET Section						
V_{DET_MAX}	Turn-Off Synchronous Voltage		0.90	0.95	1.00	V
V_{DET_MAXHYS}	Turn-Off Synchronous Voltage Hysteresis		0.08	0.10	0.12	V
V_{DET_MIN}	Turn-On Synchronous Voltage		0.08	0.14	0.20	V
V_{DET_MINHYS}	Turn-Off Synchronous Voltage Hysteresis		0.08	0.14	0.20	V
I_{DET}	DET Current			0.1		µA
VOUT Section						
UVP_{Vout}	Output Pin Under-Voltage Protection		-10.0	-12.5	-15.0	%
V_{ACC}	Output Voltage Accuracy		-2		2	%
LR	Load Regulation	I_{OUT}=1mA to Maximum	-2		2	%
$\Delta V_{OUT\ (VIN)}$	Line Regulation dV_{OUT}/dV_{IN}		-0.2		0.2	%/V
ILIM	Current Limit	V_{DD}=V_{OUT}+3V	110	140	170	mA
V_{Drop}	Dropout Voltage (V_{OUT}=5V)	I_{OUT}=35mA	0.3	0.4	0.5	V
I_G	Ground Pin Current[5]	Output Current = Maximum Load		1.5	2.0	mA
tD_{OUT-ST}	Output Voltage Rising Time (V_{OUT}=12V) V_{DD} to V_{OUT}	V_{OUT}=0%~90% C_{OUT}=1µF	40	50	60	µs
PSRR	Ripple Rejection[6]	f= 50Hz, C_{OUT}=10µF, I_{OUT} =35mA		60		dB
		f =100Hz, C_{OUT}=10µF, I_{OUT} =35mA				
T_{OTP}	Protection Junction Temperature[6]			150		°C
T_{HYS}	Restart Junction Temperature[6]			T_{OTP}-40		°C

Notes:

5. For V_{Drop}=1V of V_{OUT}=3.3V version, the test condition is modified to V_{DD}=V_{OUT}+1.5V.
6. Guaranteed by design.

Typical Performance Characteristics

V_{AC} = 264V/50Hz, V_{OUT} = 5V, I_{OUT}=35mA~40mA, C_{VDD} = 470μF, C_{OUT} = 10μF, T_A = 25℃, unless otherwise noted.

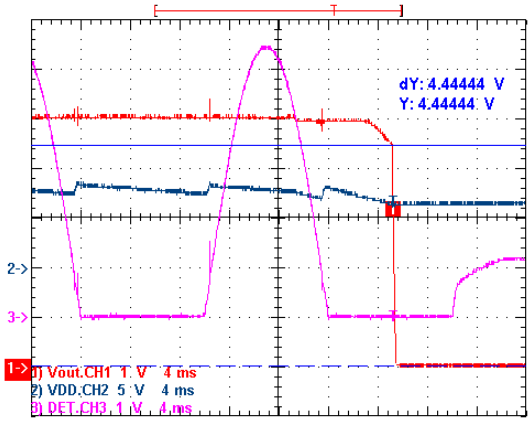


Figure 5. V_{OUT} Pin Under-Voltage Protection

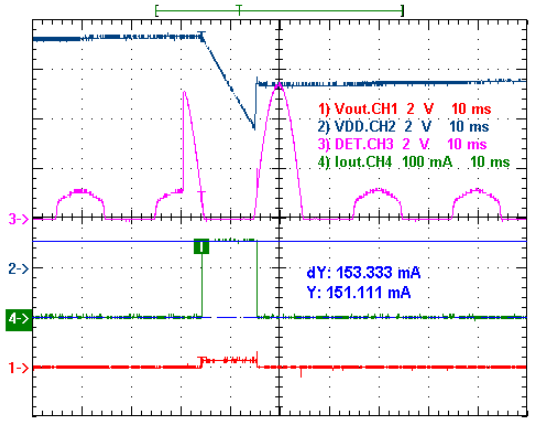


Figure 6. Current Limit

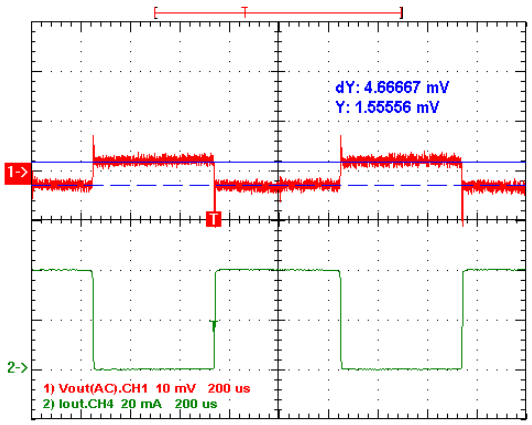


Figure 7. Load Transient

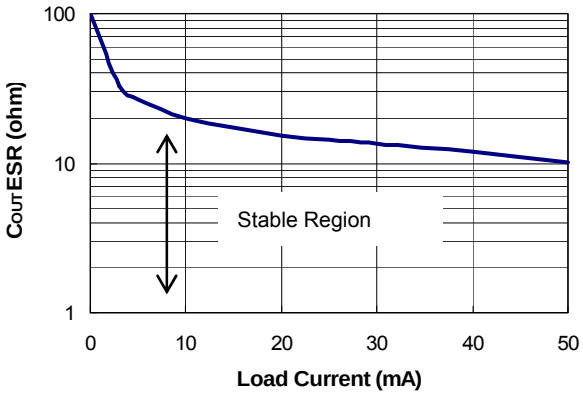


Figure 8. Region of Stable C_{OUT} ESR vs. Load Curre

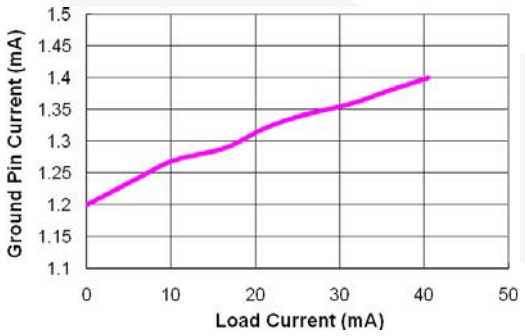


Figure 9. Ground Pin Current vs. Load Current

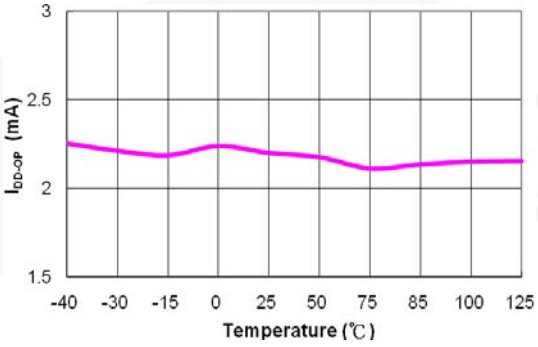


Figure 10. Operating Supply Current vs. Temperature

Typical Performance Characteristics (Continued)

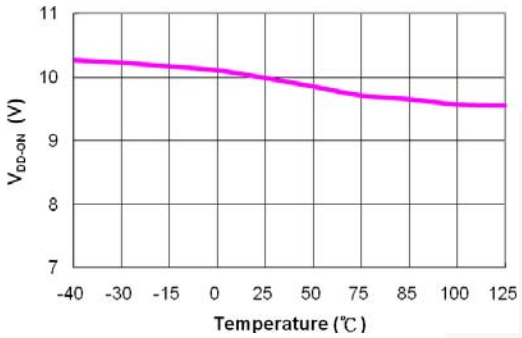


Figure 11. Turn-On Threshold Voltage vs. Temperature

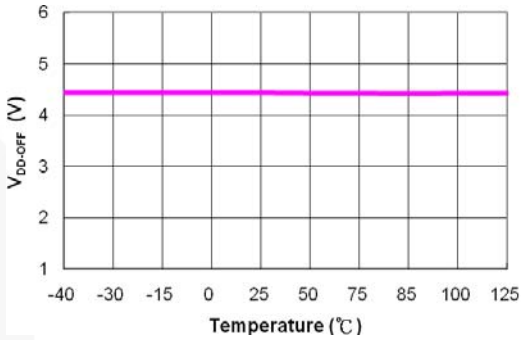


Figure 12. Turn-Off Threshold Voltage vs. Temperature

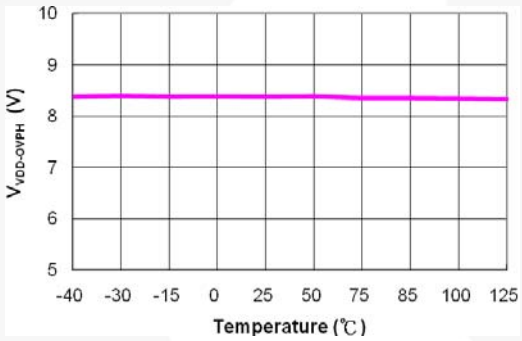


Figure 13. Threshold of V_{DD} OVP HIGH vs. Temperature

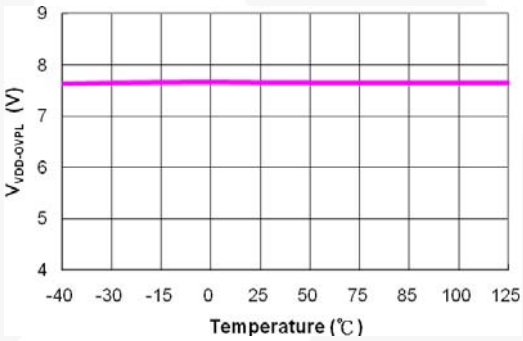


Figure 14. Threshold of V_{DD} OVP LOW vs. Temperature

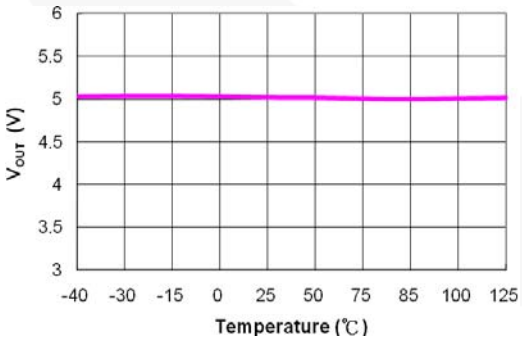


Figure 15. Output Voltage vs. Temperature

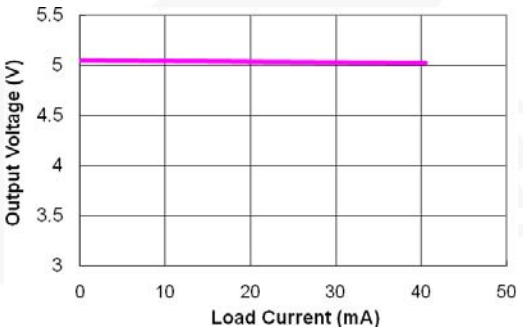


Figure 16. Output Voltage vs. Output Load

Functional Description

The FSAR001 is a compact, inductor-free, and highly monolithic AC/DC linear converter housed in 8-lead DIP packages and designed for non-isolated AC/DC converter and home appliances. The FSAR001 provides universal AC voltage input from $80V_{RMS}$ to $265V_{RMS}$ and fixed-DC output voltage with current limiter for the non-isolated AC/DC converter operating safety and stability. The FSAR001 integrates many protection functions, including output current limiter (I_{LIMIT}), output under-voltage protection (UVP), over-temperature protector (OTP), V_{DD} over-voltage protection (OVP), and AC synchronous signal detect function (V_{DET}).

As the FSAR001 operates in a typical application, the startup current flows through the startup pin (V_{ST}) and charges V_{DD} capacitor. When the voltage of V_{DD} is larger than V_{TH_ON}, the FSAR001 is turned on. After one AC synchronous signal, the LDO is turned on and creates output voltage (V_{OUT}). At steady state, the energy of V_{DD} capacitor decreases because of the chip operation and load power dissipation. The behavior is shown in Figure 17 and the energy is recharged during conduction angle interval (settled by R3 and R4) and under OVP function limitation ($V_{DD\text{-}OVPH}$). With a view to increasing LDO efficiency and system stability, FSAR001 sets the V_{DD} OVP voltage at 8.5V for 5V LDO regulator. The V_{DD} capacitor recovery angle controls below $50V_{RMS}$ settled by AC synchronous signal (DET sense voltage), detailed in the following sections.

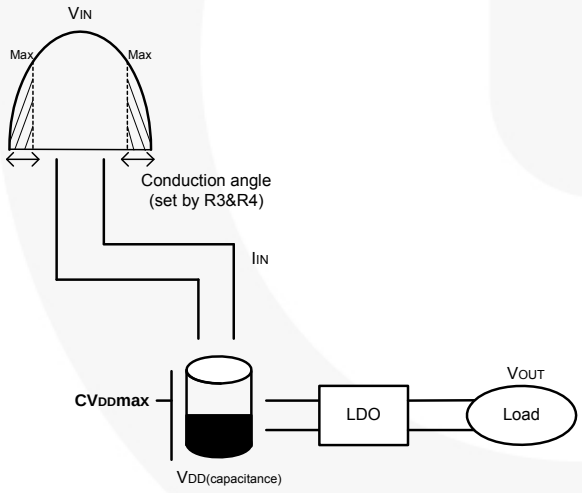


Figure 17. Operating Principle

Startup Current

During FSAR001 startup, the startup current through the rectifier and V_{ST} pin charges the V_{DD} capacitor with maximum start current of V_{ST} pin of 3.75mA and the synchronous current controlled by R3 (1MΩ) and R4 (13kΩ), shown in Figure 1. The FSAR001 remains off until the V_{DD} voltage is larger than $V_{TH\text{-}ON}$ and the output voltage is created at the same time. After the FSAR001 turns on, the V_{ST} function is disabled by the control loop. The major energy path changes from V_{ST} pin from the inner power MOSFET MV (V_{IN}).

OUT Pin Under-Voltage Protection

When the output power is larger than the maximum handling power of FSAR001, the condition causes the output voltage to drop. Until the output voltage is less than output nominal voltage -12% (5V – 0.625V = 4.375V), the UVP function disables the LDO stage and waits until the next AC synchronous signal to restart the FSAR001 automatically.

Current Limit

The FSAR001 includes a current limiter (ILIMIT) for safe LDO operation. The limiter monitors the loading current and directly controls the output delivery current of LDO. The typical limited current set is 140mA to avoid the output shorted to ground for an indefinite amount of time without damaging the part. At over-current operation, the I_{LIMIT} function limits the maximum output current and causes the unregulated output voltage to drop until the UVP function occurs.

Over-Temperature Protection

The FSAR001 operates in highly converting ratio. The thermal energy of FSAR001 is generated by the inner converting power of the MOSFET. When the junction temperature (T_J) exceeds 150°C, the OTP function disables LDO stage and waits for the next AC synchronous signal to restart. The over-temperature hysteresis range is 40°C. After startup, the OTP function monitors the junction temperature. When junction temperature decreases to the ($T_{OTP\text{-}THYS}$), the OTP function enables the signal and allows LDO turn on. If not, OTP function keeps the output function disabled and continuously monitors the junction temperature. The OTP function is designed to protect against abnormal conditions and over-power operation.

DET Pin Selection

The DET pin connects to the commutated AC bus. It sinks commutated AC voltage waveform used to provide the AC synchronous signal and to set the V_{DD} capacitor recovery conduction angle. For synchronous signal function, the AC synchronous signal used to enable output voltage of the LDO and to trigger the output stage protection with UVP and OTP. To limit the recovery-conduction angle of the V_{DD} capacitor, the DET pin sense voltage (V_{DET}) is set between 0.14V ~0.95V. During the sense-voltage range of the DET pin, the V_{DD} capacitor can be charged by the power MOSFET until the OVP function is operating in every synchronous cycle. As shown in Figure 18, the DET pin sense voltage limits the charge time of t0~t1 and t2~ts/2 settled by R3 and R4. The maximum commutated input voltage of FSAR001 can be determined by the following equation with the maximum DET sense voltage defined:

Functional Description (Continued)

$$V_{DET,max} = \frac{R4}{R3+R4} \times V_{ac}$$

$$V_{DET,min} = \frac{R4}{R3+R4} \times V_{ac} \quad \text{EQ 1}$$

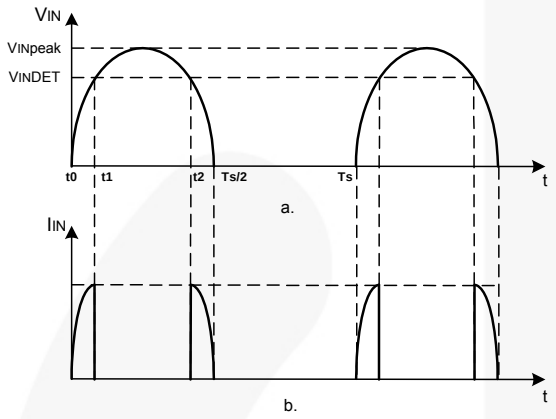


Figure 18. Typical Waveforms

VDD Pin Over-Voltage Protection

After startup, FSAR001 turns on the OVP function. During conduction angle interval, the V_{DD} voltage has two kinds of behavior. One is that if the V_{DD} capacitor recharges to OVP trigger point (8.5V for 5V version), the FSAR001 turns off the power MOSFET to limit the maximum V_{DD} voltage. The other is that if the voltage of V_{DD} cannot recharge to the OVP level during the conduction interval, the power MOSFET is turned off by AC synchronous signal and continuously recharges V_{DD} capacitor at next duration. Using this technique, energy is drawn from the AC mains only during the low-voltage portions of each positive half cycle, reducing the dissipation in the first stage. During the power MOSFET turn-on, the current provided by the commutated AC voltage is used to supply the loads and to charge the V_{DD} capacitor. In this way, when the power MOSFET switches off, the loads receive the required currents by the capacitor discharge. For this reason, it is important to properly set the conduction angle.

For the V_{DD} capacitor selection, during conduction angle interval; the energy is drawn from commutated AC bus, which not only provides the output requirement but also recharges the V_{DD} capacitor to OVP level. Outside of conduction angle, the V_{DD} capacitor supplies the whole system requirement. The V_{DD} capacitor can be reduced by maximum loading power. The capacitor is evaluated by Equation 2; the selection chart is shown in Figure 19.

$$C_{VDD} = \frac{I_{LOAD} \times 10m}{1}, (unit = F) \quad \text{EQ 2}$$

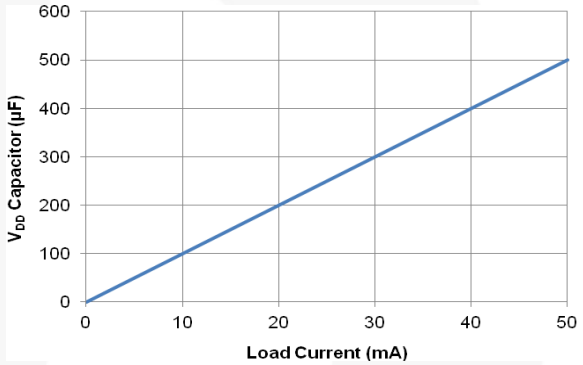


Figure 19. V_{DD} Capacitor vs. Output Current

Applications Information

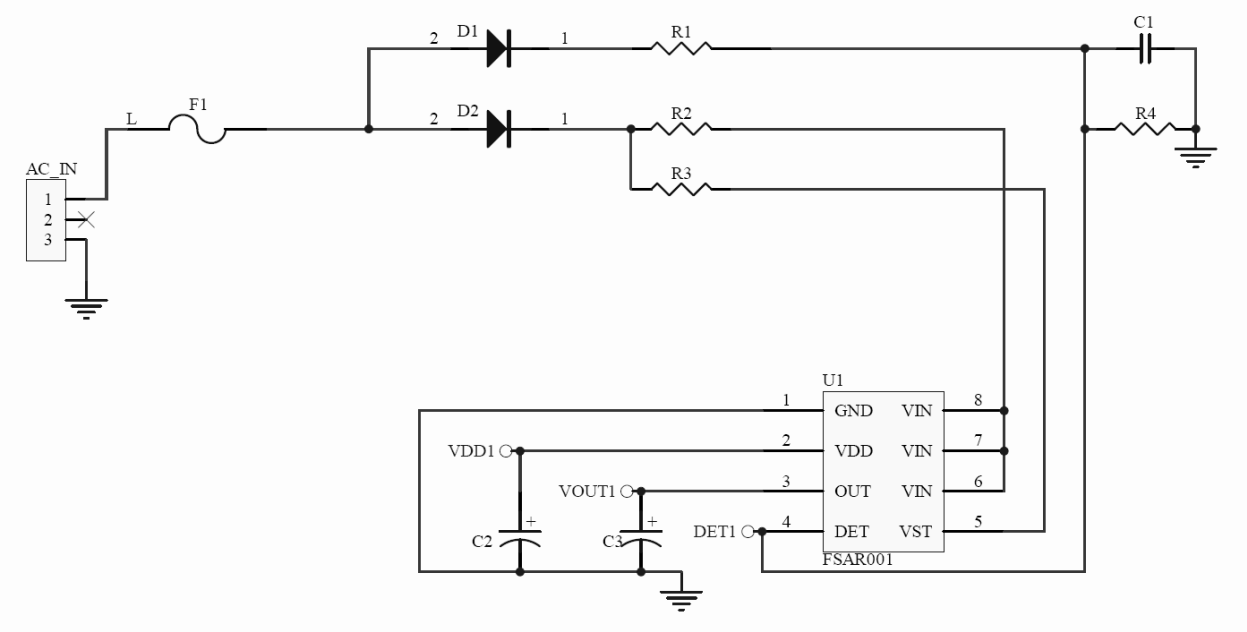


Figure 20. Application Circuit

Bill of Materials (BOM)

Designator	Part Type	Designator	Part Type
F1	FUSE 3A/250V	D2	1N4007
C1	1nF/50V	R1	1MΩ 1/4W
C2	470μF/25V	R2	10Ω 2W
C3	10μF/50V	R3	1KΩ 1/2W
D1	1N4007	R4	13KΩ 1/4W

Physical Dimensions

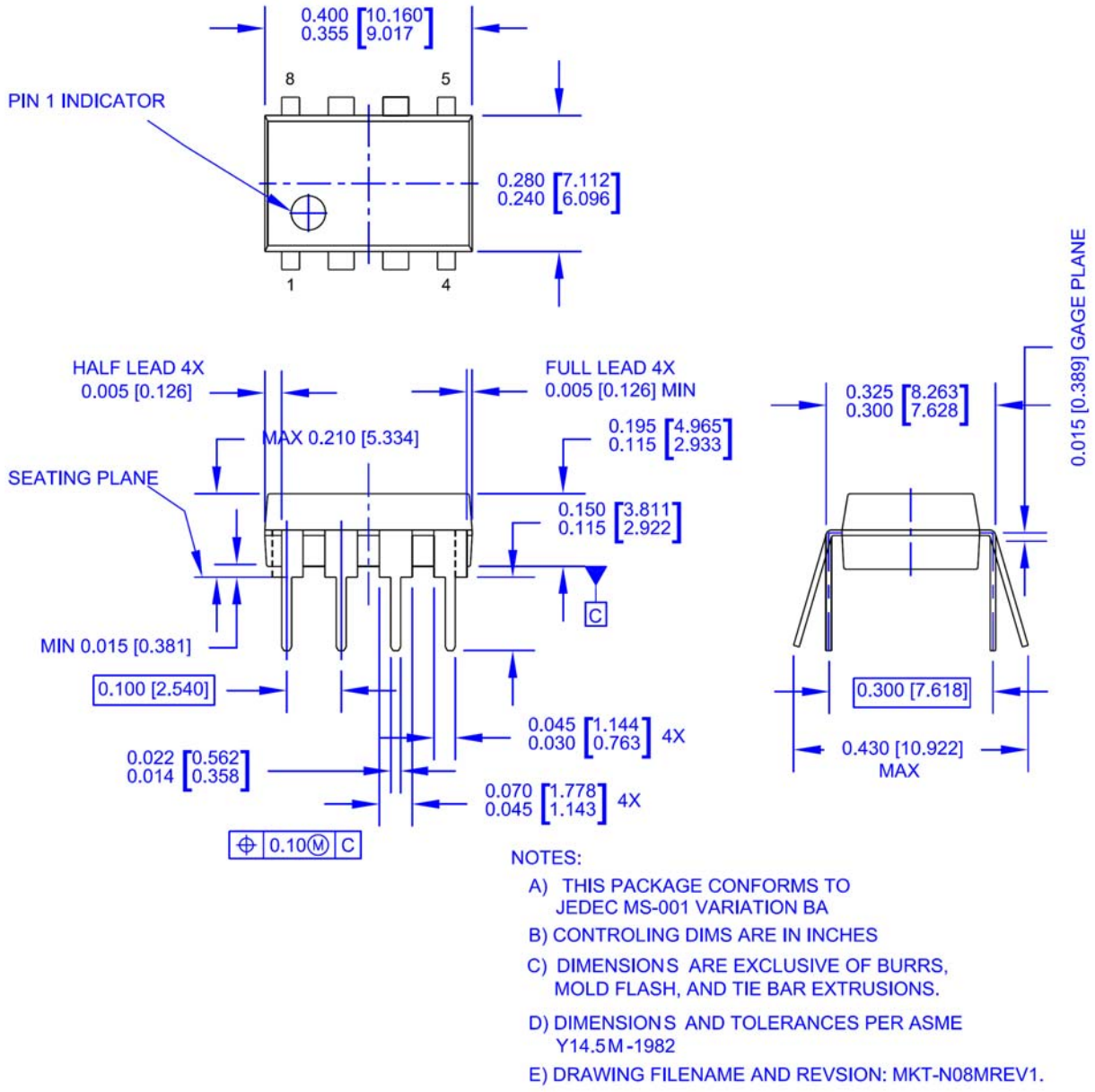


Figure 21. 8-Pin, DIP-8 Package

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FRFET®
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GreenBridge™
Green FPS™
Green FPS™ e-Series™
Gmax™
GTO™
IntelliMAX™
ISOPLANAR™
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MICROCOUPLER™
MicroFET™
MicroPak™
MicroPak2™
MillerDrive™
MotionMax™
Motion-SPM™
mWSaver™
OptoHiT™
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SuperFET®
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SuperSOT™-6
SuperSOT™-8
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Sync-Lock™
SYSTEM GENERAL®*
The Power Franchise®
the power franchise
TinyBoost™
TinyBuck™
TinyCalc™
TinyLogic®
TINYOPTO™
TinyPower™
TinyPWM™
TinyWire™
TranSiC™
TriFault Detect™
TRUECURRENT®*
μSerDes™
SerDes
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XS™

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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.

ANTI-COUNTERFEITING POLICY

Fairchild Semiconductor Corporation's Anti-Counterfeiting Policy. Fairchild's Anti-Counterfeiting Policy is also stated on our external website, www.fairchildsemi.com, under Sales Support.

Counterfeiting of semiconductor parts is a growing problem in the industry. All manufacturers of semiconductor products are experiencing counterfeiting of their parts. Customers who inadvertently purchase counterfeit parts experience many problems such as loss of brand reputation, substandard performance, failed applications, and increased cost of production and manufacturing delays. Fairchild is taking strong measures to protect ourselves and our customers from the proliferation of counterfeit parts. Fairchild strongly encourages customers to purchase Fairchild parts either directly from Fairchild or from Authorized Fairchild Distributors who are listed by country on our web page cited above. Products customers buy either from Fairchild directly or from Authorized Fairchild Distributors are genuine parts, have full traceability, meet Fairchild's quality standards for handling and storage and provide access to Fairchild's full range of up-to-date technical and product information. Fairchild and our Authorized Distributors will stand behind all warranties and will appropriately address any warranty issues that may arise. Fairchild will not provide any warranty coverage or other assistance for parts bought from Unauthorized Sources. Fairchild is committed to combat this global problem and encourage our customers to do their part in stopping this practice by buying direct or from authorized distributors.

PRODUCT STATUS DEFINITIONS

Definition of Terms

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

Rev. I61

Mouser Electronics

Authorized Distributor

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