FAIRCHILD SEMICONDUCTOR®

AC/DC Switch Mode Power Supply Design Guide

www.fairchildsemi.com

the power franchise™

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Global Power Resources™

Total Solutions

Fairchild is the only semiconductor supplier that provides a complete portfolio for AC/DC switch mode power supplies. Whether your design is 1W or 1200W, Fairchild's solutions help achieve increased efficiency, reduce stand-by power, and support the industry's 1W initiatives. These solutions include: SuperFET™ technology that achieves world-class $R_{DS(ON)}$ and provides higher power density, reducing heat sink size, Green Fairchild Power Switch (FPS) that offers state-of-the-art stand-by power supporting the industry's initiatives targeting less than 1W, and Power Factor Correction ICs that decrease cost and increase system efficiency.

SMPS IGBTs

- Increase output power
- Reduce system cost
- Stealth™ Diode Co-Pack enhances recovery time

High Voltage MOSFETs

- 25% lower A * $R_{DS(ON)}$ minimizes system size
- 100% Avalanche tested
- Voltage ranges from 60V to 1000V
- SuperFET offers best in class FOM

Power Factor Correction (PFC) Controllers

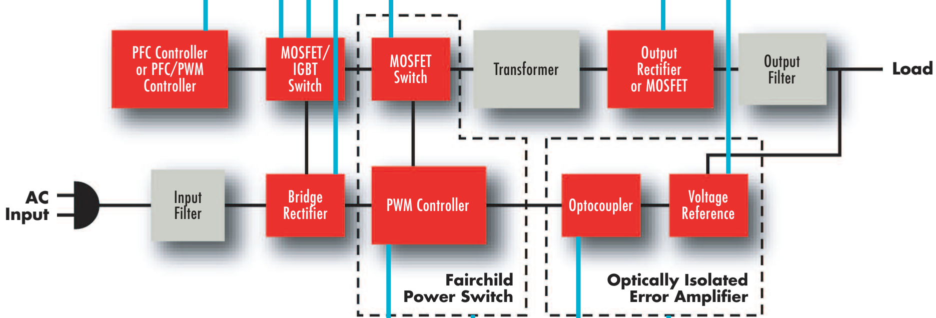
- Increase efficiency
- Increase usable PFC bandwidth and simplifiy compensation
- Reduce ripple voltage and output capacitor size
- Reduce EMI and system noise

Additional Discrete Components

- Low-Voltage MOSFETs
- MOSFET and Schottky Combos
- Diodes and Rectifiers
- Bipolar Transistors and JFETs

Voltage References/Shunt Regulators

- Programmable output voltages
- Temperature compensated
- Low output noise
- Fast turn-on time



PWM Controller

- Green current mode reduces power consumption with burst mode operation
- Internal start-up switch
- Programmable soft start
- Over Voltage Protection (OVP)

Optically Isolated Error Amplifier

- Single component solution vs. 2 components
- High isolation, 5,000V RMS
- Low tolerance results in easier design, fewer components
- Save board space

Fairchild Power Switch (FPS)

- Green FPS reduces power consumption with burst mode operation
- Avalanche rated SenseFET™
- Frequency modulation reduces EMI
- Built in soft start

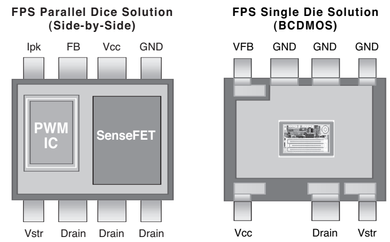
Optocoupler

- MICROCOUPLER™ offers stable CTR up to 125°C
- Narrow Current Transfer Ratio (CTR)
- Multiple package types for ease of use

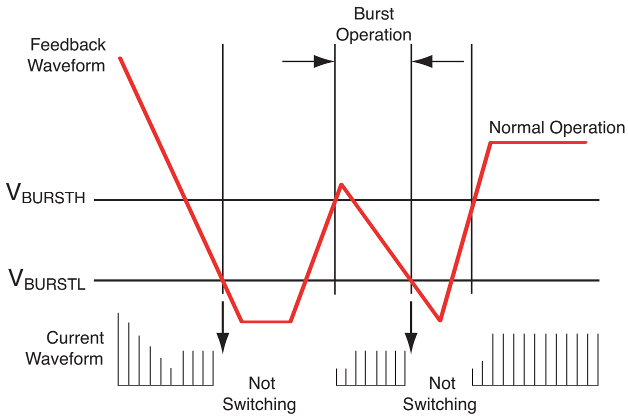
Fairchild Power Switch (FPS)

Fairchild's FPS products are highly integrated off-line power switches with a fully avalanche rated SenseFET and a current mode PWM IC (see Burst Mode Operation figure below). The Green FPS products help reduce the system's stand-by power to below 1Watt with the burst mode operation.

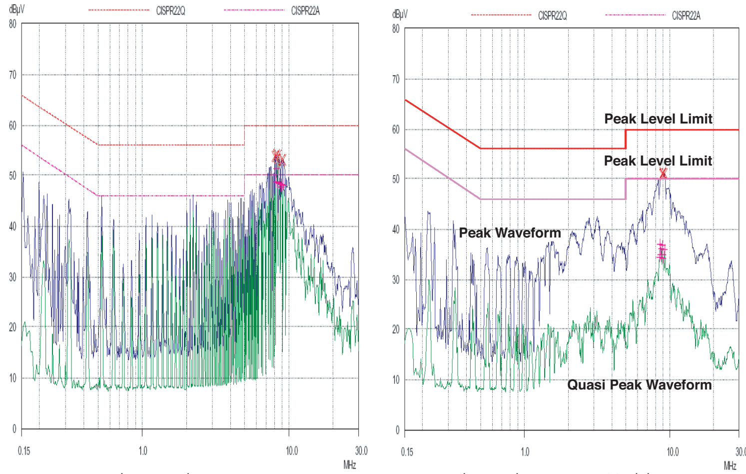
- Advanced burst mode operation supports 1W standby power regulations
- Integrated frequency modulation reduces EMI emissions
- Various protection and control functions reduce Bill-of-Material costs



Burst Mode Operation Reduces Stand-By Power to Less than 1W



Frequency Modulation Reduces Overall Electromagnetic Interference (EMI)



100kHz Fixed Frequency
FSDH0165

134kHz with Frequency Modulation
FSD210

EMI reduction can be accomplished by modulating the switching frequency of a SMPS.
Frequency modulation can reduce EMI by spreading the energy over a wider frequency range.

Fairchild Power Switch (FPS)

Green FPS

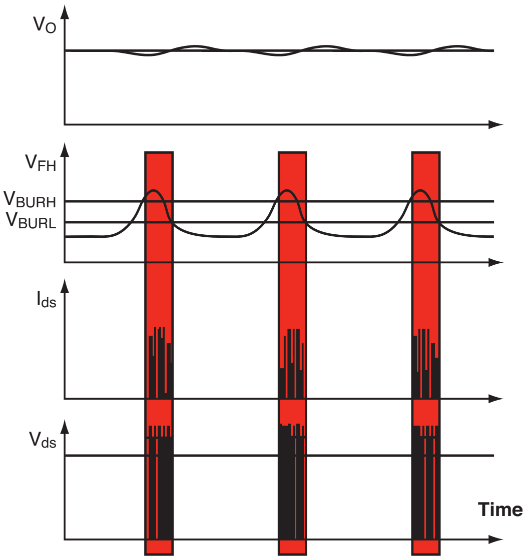
Part Number	Application	$P_{O(max)}$ (W) 85-265VAC	$P_{O(max)}$ (W) 230VAC ±15%	Peak Current Limit (A)	HV-FET Rating (V)	$R_{DS(ON)}$ max (Ω)	Switching Frequency (V)	Frequency Mod. (kHz)	Package
FSCM0565RC	STB, LCD Monitor	70	85	2.5	650	2.2	66	Yes	TO220-5L
FSCM0565RD	STB, LCD Monitor	50	65	2.5	650	2.2	66	Yes	D2PAK-5L
FSCM0765RC	STB, LCD Monitor	85	95	3	650	1.6	66	Yes	TO220-5L
FSCM0765RD	STB, LCD Monitor	60	70	3	650	1.6	66	Yes	D2PAK-5L
FSCQ0765RT	CTV, DVD, Audio Electronics	85	100	5	650	1.6	QRC	No	TO220F-5L
FSCQ1265RT	CTV, DVD, Audio Electronics	140	170	7	650	0.9	QRC	No	TO220F-5L
FSCQ1565RP	CTV, DVD, Audio Electronics	210	250	11.5	650	0.65	QRC	No	TO3PF-7L
FSCQ1565RT	CTV, DVD, Audio Electronics	170	210	8	650	0.65	QRC	No	TO220F-5L
FSD1000	PC Main + Aux , LCD	12	13.6	Adjustable	700	9	70	No	DIPH-12
FSD200B	Charger, Aux Power	5	7	0.3	700	32	134	Yes	LSOP-7
FSD200BM	Charger, Aux Power	5	7	0.3	700	32	134	Yes	DIP-7
FSD210B	Charger, Aux Power	5	7	0.3	700	32	134	Yes	DIP-7
FSD210BM	Charger, Aux Power	5	7	0.3	700	32	134	Yes	LSOP-7
FSDH0265RL	DVDP, STB, Fax, Printer, Scanner, Adapters	20	27	1.5	650	6	100	Yes	LSOP-8
FSDH0265RN	DVDP, STB, Fax, Printer, Scanner, Adapters	20	27	1.5	650	6	100	Yes	DIP-8
FSDH321	PC Aux, STB, DVD, Adapters	12	17	0.7	650	19	100	Yes	DIP-8
FSDH321L	PC Aux, STB, DVD, Adapters	12	17	0.7	650	19	100	Yes	LSOP-8
FSDL0165RL	DVDP, STB, Printer, Fax, Scanner, Adapters	12	23	1.2	650	10	50	Yes	LSOP-8
FSDL0165RN	DVDP, STB, Printer, Fax, Scanner, Adapters	12	23	1.2	650	10	50	Yes	DIP-8
FSDL0365RL	DVDP, STB, Printer, Fax, Scanner, Adapters	24	30	2.15	650	4.5	50	Yes	LSOP-8
FSDL0365RNB	DVDP, STB, Printer, Fax, Scanner, Adapters	24	30	2.15	650	4.5	50	Yes	DIP-8
FSDL321	PC Aux, STB, DVD, Adapters	12	17	0.7	650	19	50	Yes	DIP-8
FSDL321L	PC Aux, STB, DVD, Adapters	12	17	0.7	650	19	50	Yes	LSOP-8
FSDM0265RNB	DVDP, STB, Fax, Printer, Scanner, Adapters	20	27	1.5	650	6	67	Yes	DIP-8
FSDM0365RL	DVDP, STB, Fax, Printer, Scanner, Adapters	24	30	2.15	650	4.5	67	Yes	LSOP-8
FSDM0365RNB	DVDP, STB, Fax, Printer, Scanner, Adapters	24	30	2.15	650	4.5	67	Yes	DIP-8
FSDM0565RB	LCD ,STB, Adapters	48	56	2.3	650	2.2	66	No	TO220F-6L
FSDM07652RB	LCD ,STB, Adapters	56	64	2.5	650	1.6	66	No	TO220F-6L
FSDM311	Aux Power, Adapters	12	20	0.55	650	19	70	No	DIP-8
FSDM311L	Aux Power, Adapters	12	20	0.55	650	19	70	No	LSOP-8

Pulse Width Modulator (PWM) Controllers

Similarly to Green FPS, the FAN7601, FAN7602, and 7610 are green PWM controllers, offering burst mode operation during stand-by mode allowing the design to meet the International Energy Agency's (IEA) "1-Watt Initiative".

- Burst mode operation
- Operating frequency of up to 300kHz
- Operating current 4mA (max)
- Programmable soft start 20mS

Burst Mode Operation Diagram



Burst mode operation: In order to minimize the power dissipation in standby mode, the Green PWMs implement burst mode functionality. As the load decreases, the feedback voltage decreases. As shown in the figure, the device automatically enters burst mode when the feedback voltage drops below V_{BURL}. At this point switching stops and the output voltages start to drop at a rate dependent on standby current load. This causes the feedback voltage to rise. Once it passes V_{BURH} switching starts again. The feedback voltage falls and the process repeats. Burst mode operation alternately enables and disables switching of the power MOSFET thereby reducing switching loss in standby mode.

PWM Controllers

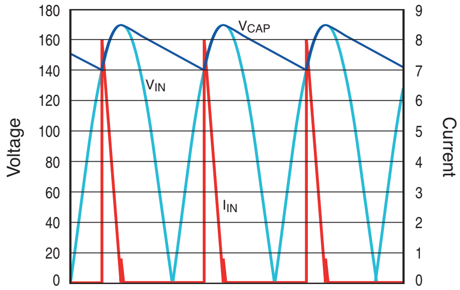
Part Number	Number of Outputs	Control Mode	Switching Frequency (kHz)	Supply Voltage Max (V)	Output Current Max (A)	Duty Ratio (%)	Startup Current (μA)	Package
FAN7554	1	Current	500	30	1	98	200	SO-8
FAN7601*	1	Current	300	20	0.25	98	Internal Switch	DIP-8, SO-8, SSOP-10
FAN7602*	1	Current	65	20	0.25	75	Internal Switch	DIP-8, SO-8, SSOP-10
FAN7610*	1	Current	QRC	20	0.5	–	Internal Switch	DIP-14, SO-14
KA3524	–	Voltage	350	40	0.1	–	8000	DIP-16
KA3525A	2	Voltage	-	40	0.5	–	8000	DIP-16
KA3842A	1	Current	500	30	1	100	200	DIP-8, SO-14
KA3842B	1	Current	500	30	1	100	450	DIP-8, SO-14
KA3843A	1	Current	500	30	1	100	200	DIP-8, SO-14
KA3843B	1	Current	500	30	1	100	450	DIP-8, SO-14
KA3844B	1	Current	500	30	1	50	450	DIP-8, SO-14
KA3845	1	Current	500	30	1	50	450	DIP-16
KA3846	2	Current	500	40	0.5	100	200	DIP-16
KA3882E	1	Current	500	30	1	100	200	SO-8
KA7500C	2	Voltage	300	42	0.25	–	1000	DIP-16, SO-16
KA7552A	1	Voltage	600	30	1.5	74	150	DIP-8
KA7553A	1	Voltage	600	30	1.5	49	150	DIP-8
KA7577	1	Voltage	208	31	0.5	53	150	DIP-16
ML4823	1	Voltage	1000	30	–	80	1100	DIP-16, SO-16

NOTE: FAN7602 and FAN7610 under development
*Burst Mode Operation reduces system standby power to 1W or less

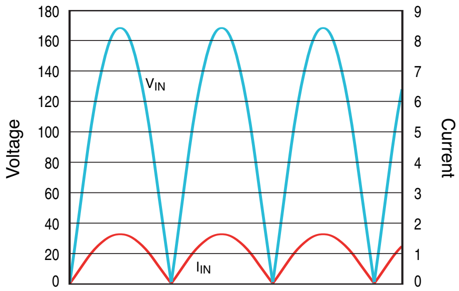
Power Factor Correction (PFC) Standalone and PFC/PWM Combo Controllers

Fairchild's full line of both stand alone PFC controllers and PFC/PWM combo controllers offer crucial cost-and energy-saving solutions that address the demanding requirements of a diverse range of medium-and high-power Switch Mode Power Supply (SMPS) designs.

- Offerings include both continuous/discontinuous devices
- Current fed gain modulator for improved noise immunity
- Synchronized clock output to reduce system noise and to synchronize to downstream converter
- Patented one-pin voltage error amplifier with advanced input

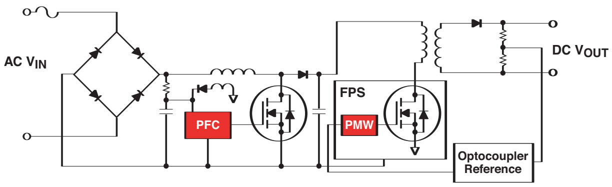


Before Power Factor Corrected

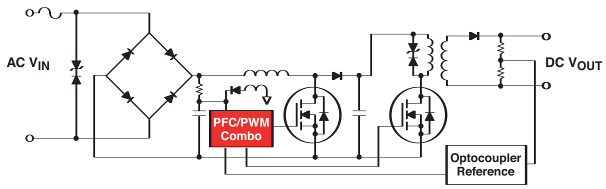


After Power Factor Corrected

Simplified Application Circuits



Stand-Alone PFC Controllers



PFC/PWM Combo Controllers

Power Factor Correction Stand-Alone Controllers

Part Number	PFC Control	Operating Current (mA)	Startup Current (µA)	Package
FAN7527B	Discontinuous Mode	3	60	DIP-8, SOP-8
FAN7528	Discontinuous Mode	2.5	40	DIP-8, SOP-8
KA7524B	Discontinuous Mode	6	250	DIP-8, SOP-8
KA7525B	Discontinuous Mode	4	200	DIP-8, SOP-8
KA7526	Discontinuous Mode	4	300	DIP-8, SOP-8
ML4821	Average Current Mode	26	600	DIP-18, SOIC-20
FAN4810	Average Current Mode	5.5	200	DIP-16, SOIC-16
FAN4822	Average Current Mode	22	700	DIP-14, SOIC-16

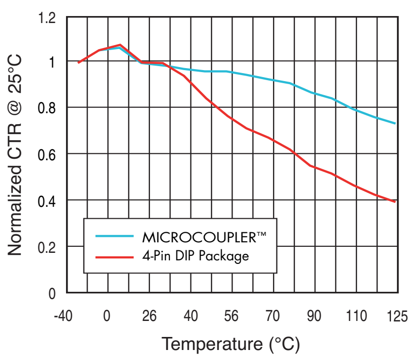
Power Factor Correction Combo Controllers

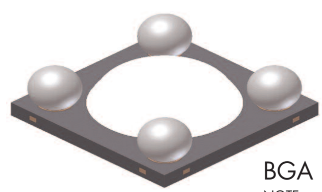
Part Number	PFC Control	Fpwm Over Fpfc	Operating Current (mA)	PWM Duty Cycle Max (%)	Startup Current (µA)	Package
FAN4800	Average Current Mode	1	5.5	49	200	DIP-16, SOIC-16
FAN4803-1	Input Current Shaping Mode	1	2.5	50	200	DIP-8, SOIC-8
FAN4803-2	Input Current Shaping Mode	2	2.5	50	200	DIP-8, SOIC-8
ML4824-1	Average Current Mode	1	16	50	700	DIP-16, SOIC-16
ML4824-2	Average Current Mode	2	16	45	700	DIP-16, SOIC-16
ML4826	Average Current Mode	2	22	50	700	DIP-20

Optocoupler Solutions

The MICROCOUPLER™ package platform of optocouplers reduces board space and offers stable CTR up to 125°C, while offering high input to output isolation voltages.

- High Current Transfer Ratio, CTR at low I_F
- Operating Temperature Range, Topr: -40°C to +125°C
- Ultra small packaging – low profile 1.2mm
- Applicable to Pb-free IR reflow soldering profile: 260°C peak



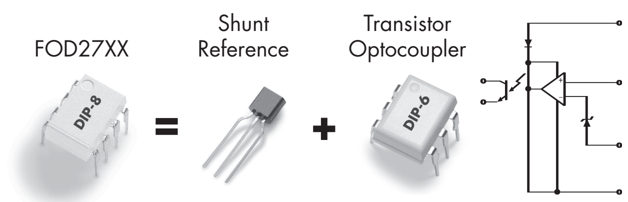


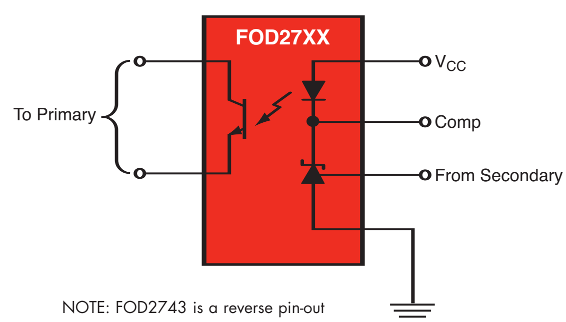
BGA Package
NOTE: under devlopement

For a complete listing of Fairchild’s Optocouplers please visit:
www.fairchildsemi.com/products/opto

Optically Isolated Error Amplifiers

Fairchild's FOD27XX series optically isolated error amplifiers offer designers a comprehensive selection of reference voltages, tolerances, isolation voltages and package sizes to optimize their specific power design.





NOTE: FOD2743 is a reverse pin-out

Optical Amplifiers

Part Number	V_{REF} (V)	Tolerance (%)	Isolation (kV)	Package	Operating Temperature (°C)	CTR* (%)	Bandwidth (kHz)
FOD2711	1.24	1	5.0	DIP-8	-40 to +85	100 – 200	30
FOD2741	2.5	0.5 – 2.0	5.0	DIP-8	-25 to +85	100 – 200	30
FOD2743	2.5	0.5 – 2.0	5.0	DIP-8	-25 to +85	50 – 100	50

* CTR is specified at I_{LED} = 1mA

Voltage References and Shunt Regulators

Fairchild's suite of voltage references/shunt regulators offer flexible output voltages, space saving packages, and multiple voltage tolerances to meet the challenges of a SMPS design.

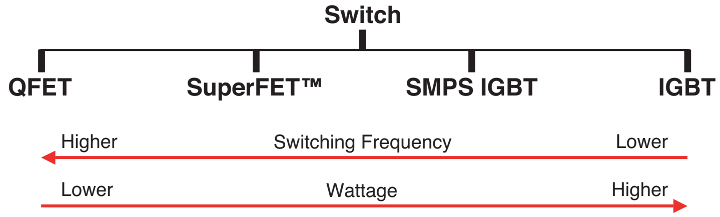
- Programmable output voltages
- Temperature compensated
- Low output noise
- Fast turn-on time

Regulators

Part Number	Preset Output Voltage (V)	Adj. Output Voltage (Min) (V)	Adj. Output Voltage (Max) (V)	Tolerance (V)	Max Current (mA)	Package
FAN4041CI	Adjustable	1.22	12	0.5	30	SOT-23
FAN4041DI	Adjustable	1.22	12	1	30	SOT-23
FAN431	2.5 Adjustable	2.5	3	2	100	TO-92
KA431S	2.5 Adjustable	2.5	37	2	100	SOT-23F
LM336Bx5	5 Adjustable	4	6	2	15	TO-92
LM336x25	2.5	2.5	37	2	15	TO-92
LM336x5	5 Adjustable	4	6	4	15	TO-92
LM431A	2.5 Adjustable	2.5	37	2	100	SOIC-8, TO-92
LM431B	2.5 Adjustable	2.5	37	1	100	SOIC-8, TO-92
LM431C	2.5 Adjustable	2.5	37	0.5	100	SOIC-8, TO-92
LM431SA	2.5 Adjustable	2.5	37	2	100	SOT-23F, SOT-89
LM431SB	2.5 Adjustable	2.5	37	1	100	SOT-23F, SOT-89
LM431SC	2.5 Adjustable	2.5	37	0.5	100	SOT-23F, SOT-89
RC431A	Adjustable	1.24	12	1.5	20	SOT-23, TO-92
TL431A	2.5 Adjustable	2.5	37	1	100	SOIC-8, TO-92
TL431CP	2.5 Adjustable	2.5	37	2	100	DIP-8

High Voltage Switching Technologies

Fairchild offers an array of switching solutions for each application



Switch Mode Power Supply IGBTs

Fairchild's SMPS IGBTs are optimized for switch mode power supply designs offering better V_{SAT}/E_{OFF}. Additionally, this control smooths the switching waveforms for less EMI. SMPS IGBTs are manufactured using stepper based technology which offers better control and repeatability of the top side structure, thereby providing tighter specifications.

SMPS IGBTs vs. MOSFETs

- Reduce conduction losses due to low saturation voltage
- Reduce current tail, reduces switching losses
- Improve transistor and system reliability
- IGBT advantage in current density facilitates higher output power

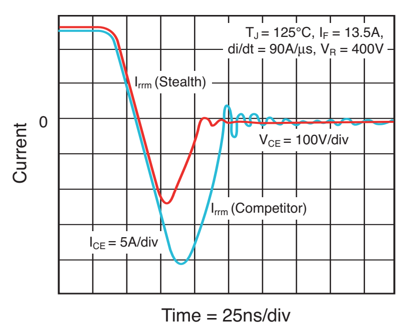
Reduce System Cost

- Smaller die size for higher voltages reduces overall costs
- May often eliminate components
- Increase operating frequency and reduce transformer/filter cost
- Fastest switching IGBTs in the market today

Stealth™ Diode Co-Pack

- Avalanche energy rated
- Offers soft recovery switching (S = tb/ta>1) at rated current, high switching di/dt, and hot junction temperature (125°C)
- Maximize IGBTs efficiency with the improved lower reverse recovery charge (Q_{RR}) and reduced I_{rrm}
- Reduces switching transistor turn-on losses in hard switched applications
- Reduces EMI
- Offers reverse recovery times (t_{rr}) as low as 25ns – superior to fast recovery diode MOSFETs
- Elimination of snubber circuit becomes possible
- Improved device efficiency with the improved lower reverse recovery charge (Q_{RR}) and reduced I_{rrm}
- Reduces switching transistor turn-on losses in hard switched applications

Diode Recovery Comparative Data

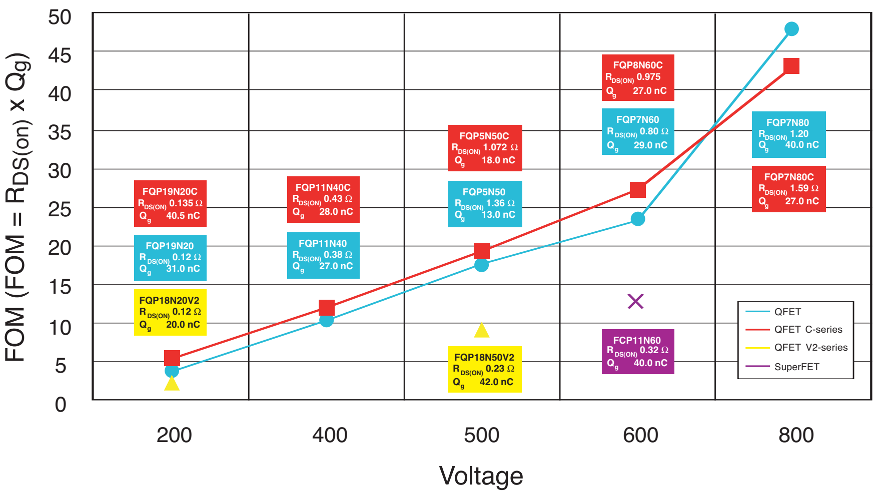


High-Voltage MOSFETs

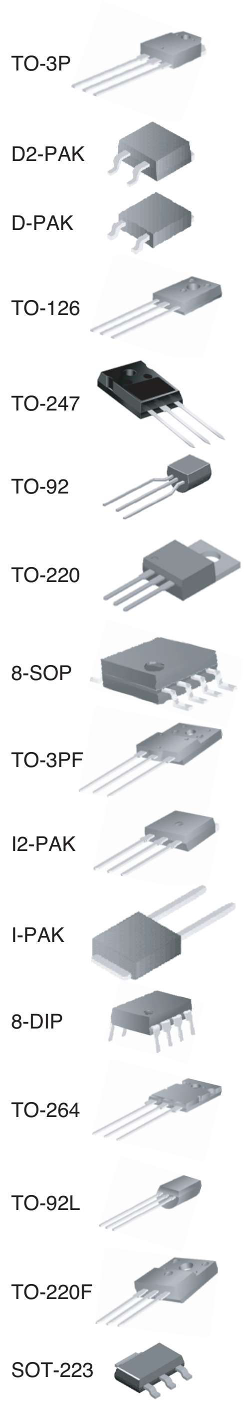
SuperFET and QFET technologies are high voltage MOSFETs from Fairchild with outstanding low on-resistance and low gate charge performance, a result of proprietary technology utilizing advanced charge balance mechanisms.

- Ultra-low $R_{DS(ON)}$ (0.32Ω), typical
- Best-in-class di/dt (1430A/µs, max)
- Low output capacitance (Coss = 35pF, typical)

Fairchild MOSFET Technology Comparison



Packages



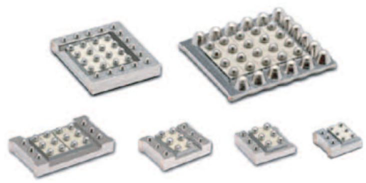
MOSFET Selection Table

V_{DSS} Specification	QFET™	C-Series	V2-Series	SuperFET™
200V	**FQP19N20**	**FQP19N20C**	**FQP18N20V2**	
$R_{DS(ON)}$, typ (Ω)	0.12	0.135	0.12	–
$R_{DS(ON)}$, max (Ω)	0.15	0.017	0.14	–
Q_g, typ (nC)	31.00	40.50	20.00	–
Q_{gd}, typ (nC)	13.50	22.50	10.00	–
400V	**FQP11N20**	**FQP11N40C**	**–**	
$R_{DS(ON)}$, typ (Ω)	0.38	0.43	–	–
$R_{DS(ON)}$, max (Ω)	0.48	0.53	–	–
Q_g, typ (nC)	27.00	28.00	–	–
Q_{gd}, typ (nC)	12.30	15.00	–	–
500V	**FQP5N50**	**FQP5N50C**	**FQP18N50V2**	
$R_{DS(ON)}$, typ (Ω)	1.36	1.072	0.23	–
$R_{DS(ON)}$, max (Ω)	1.80	1.40	0.265	–
Q_g, typ (nC)	13.00	18.00	42.00	–
Q_{gd}, typ (nC)	6.40	9.70	14.00	–
600V	**FQP7N60**	**FQP8N60C**	**–**	**FCP11N60**
$R_{DS(ON)}$, typ (Ω)	0.8	0.975	–	0.32
$R_{DS(ON)}$, max (Ω)	1.00Ω	1.2Ω	–	0.38
Q_g, typ (nC)	29.00	28.00	–	40.00
Q_{gd}, typ (nC)	14.50	12.00	–	21.00
800V	**FQP7N80**	**FQP7N80C**	**–**	**–**
$R_{DS(ON)}$, typ (Ω)	1.2	1.59	–	–
$R_{DS(ON)}$, max (Ω)	1.5	1.9	–	–
Q_g, typ (nC)	40.00	27.00	–	–
Q_{gd}, typ (nC)	20.00	10.60	–	–

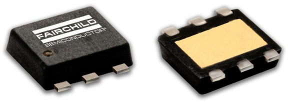
Additional Discrete Components

Fairchild is a leading supplier of discrete components providing a broad portfolio in an array of packages and functions to meet each design need, including:

- Low-voltage MOSFETs
- Low-voltage MOSFET and Schottky combos
- Diodes and rectifiers
  - Schottky
  - Bridge
  - Small signal
  - Zener
- Bipolar transistors and JFETs



Discrete BGA Packaging



Discrete FLMP Packaging

Low-voltage MOSFET BGAs combine small footprint, low profile, low $R_{DS(ON)}$, and low thermal resistance to effectively address the needs of space-sensitive, performance-oriented load management and power conversion applications. For additional information on Fairchild's BGA packaging and product selection, visit *www.fairchildsemi/products/discrete/power_bga.html*

Fairchild's patented FLMP packaging eliminates conventional wire-bonds and also provides an extremely low thermal resistance path between the PCB and the MOSFET die (drain connection). This can greatly improve performance compared to many other MOSFET packages by reducing both the electrical and the thermal constraints. For additional information on Fairchild's FLMP packaging and product selection, visit *www.fairchildsemi/products/discrete/flmp.html*

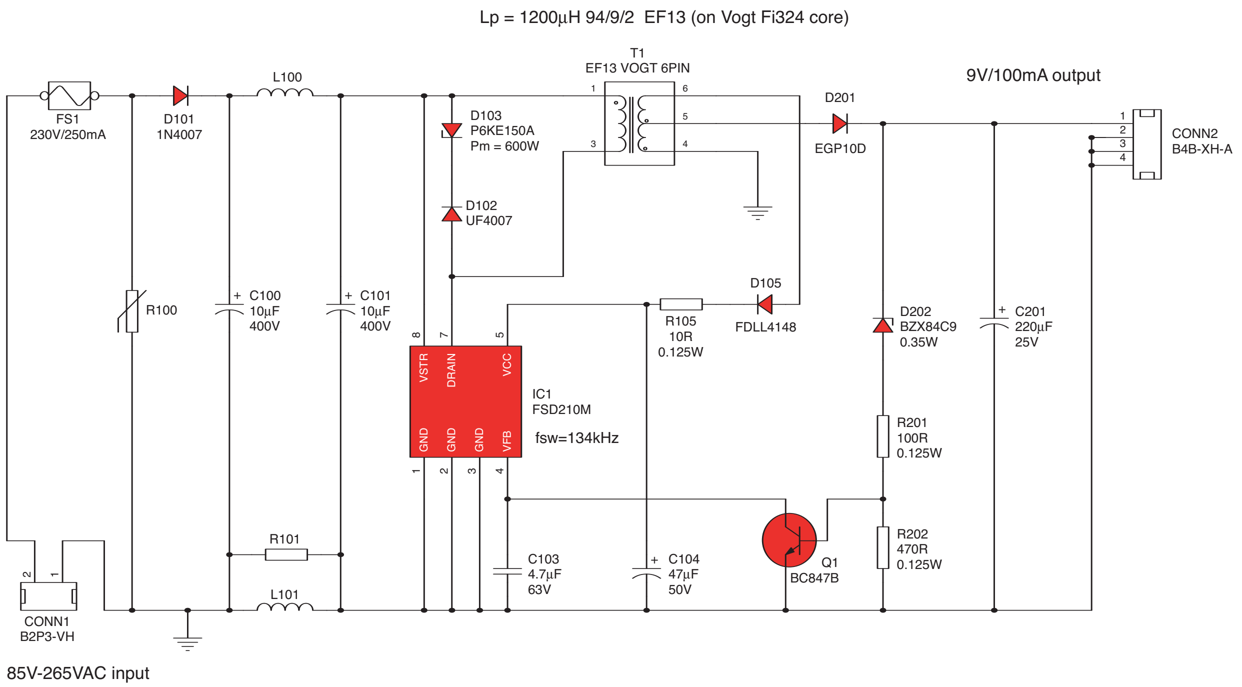
Package Impedance Comparisons

Package Description	L_{dd} (nH)	L_{ss} (nH)	L_{gg} (nH)	R_d (mΩ)	R_s (mΩ)	R_g (mΩ)
2 x 2.5mm BGA	0.056	0.011	0.032	0.05	0.16	0.79
4 x 3.5mm BGA	0.064	0.006	0.034	0.02	0.06	0.95
5 x 5.5mm BGA	0.048	0.006	0.041	0.01	0.04	0.78
FLMP (Large 3s)	0.000	0.744	0.943	0.002	0.245	2.046
FLMP (Large 7s)	0.000	0.194	0.921	0.002	0.137	2.038
SO-8	0.457	0.901	1.849	0.12	2.04	20.15
SO-8 Wireless	0.601	0.709	0.932	0.16	0.23	1.77
IPAK (TO-251)	2.920	3.490	4.630	0.25	0.74	8.18
DPAK (TO-252)	0.026	3.730	4.870	0.00	0.77	8.21
D2PAK (TO-263)	0.000	7.760	9.840	0.00	0.96	12.59

Examples of Typical Application Circuits

1W Power Supply with less than 100mW Standby Power using FSD210

Typical Application – Small home or factory automation appliances



This compact non-isolated flyback solution draws less than 100mW standby power over the whole input voltage range. This example shows a 9V output system. Here the FSD210 is powered from an auxiliary winding rather than directly from the high voltage bus. For output voltages of 12V and over, the device may be powered directly from the output winding. A low cost Zener diode circuit provides the regulation reference.

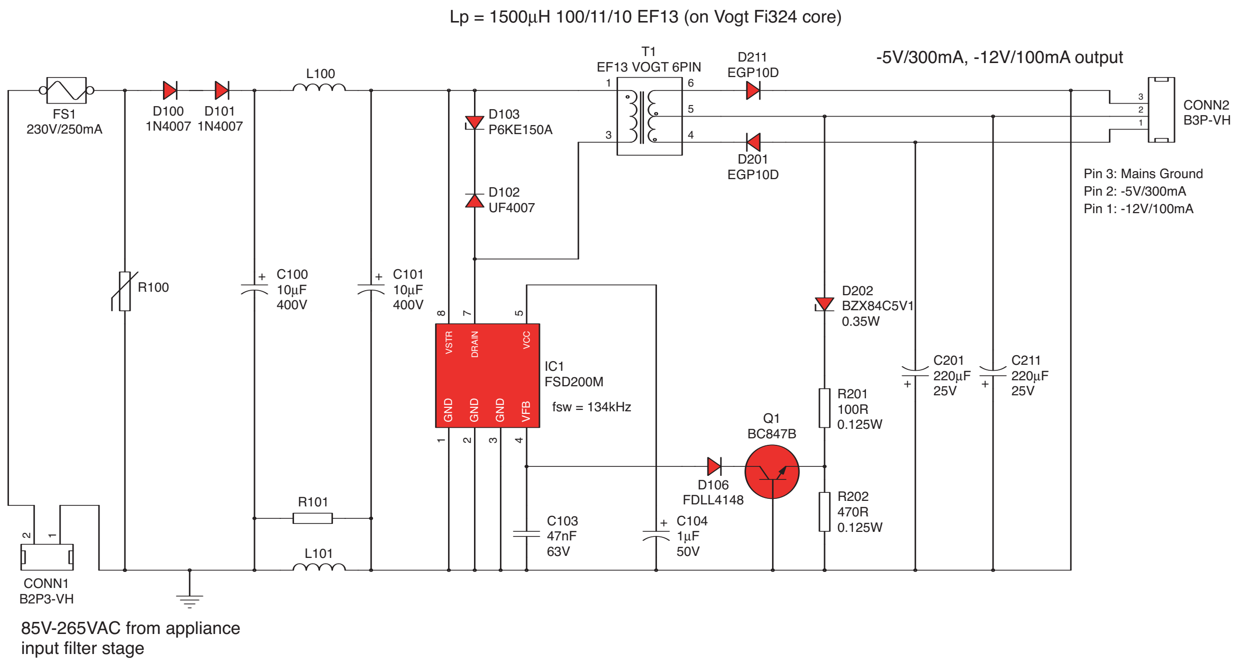
- Less than 100mW standby power
  - Ideal for applications permanently connected to an AC supply
- Overload protection circuit distinguishes between temporary and permanent overload
  - Device does not shut down during load surge conditions
  - Inherent short circuit protection
- Frequency modulation reduces EMI reduction circuitry
  - Low cost, compact solution possible

Fairchild Devices	Description
FSD210M	Fairchild Power Switch (0.3A/134kHz)
P6KE150A	Transient Voltage Suppressor (600W/150V)
EGP10D	Fast Recovery Diode (1A/200V)
BZX84C9	Zener Diode (9V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4007	General Purpose Diode (1A/1000V)
FDLL4148	General Purpose Diode (10mA/100V)
BC847B	General Purpose Transistor

Examples of Typical Application Circuits

Dual Negative Output Non-Isolated Flyback using FSD200

Typical Application – Home appliance control board power supply



A dual non-isolated flyback is used to generate voltages which are negative with respect to the neutral power line. This is used in applications where triacs are driven, such as in household appliances. A Zener diode, a bipolar transistor and a diode allow the negative voltage to be regulated by the FPS. The dual input diode helps to protect against line transients.

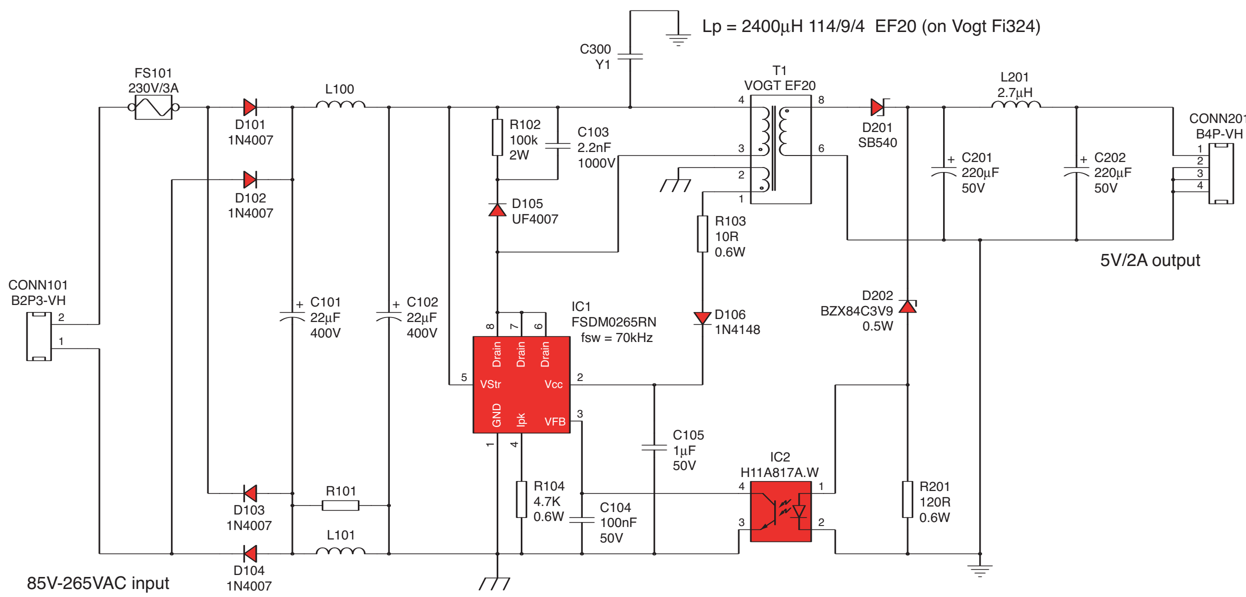
- Generation of two negative outputs referred to the input line
  - Useful for applications using triacs
- High switching frequency reduces the required inductance
  - More compact, lower cost core
- Frequency modulation reduces EMI reduction circuitry
  - Split 400V input capacitor and input inductor sufficient in most cases

Fairchild Devices	Description
FSD200M	Fairchild Power Switch (0.3A/134kHz)
P6KE150A	Transient Voltage Suppressor (600W/150V)
EGP10D	Fast Recovery Diode (1A/200V)
BZX84C5V1	Zener Diode (5.1V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4007	General Purpose Diode (1A/1000V)
FDLL4148	General Purpose Diode (10mA/100V)
BC847B	General Purpose Transistor

Examples of Typical Application Circuits

10W Single Output Isolated Flyback using FSDM0265RN and Zener Diode

Typical Application – Power bricks and single-phase frequency inverters



The FSDM0265RN contains a PWM controller and a MOSFET on two different chips. The 650V MOSFET is fully avalanche rated and tested which leads to increased system reliability. This application shows a cost reduced feedback circuit using a Zener diode. R104 is used to reduce the current limit. Higher power parts in the green FPS family have a higher current limit and a lower $R_{DS(ON)}$ than the lower power parts. Using a lower $R_{DS(ON)}$ part increases the efficiency, particularly at low input voltages. So replacing a low power part with a high power part increases the efficiency but also the current limit. If it were not possible to reduce the current limit, the flyback transformer would have to be rated at the higher current limit, making it more expensive.

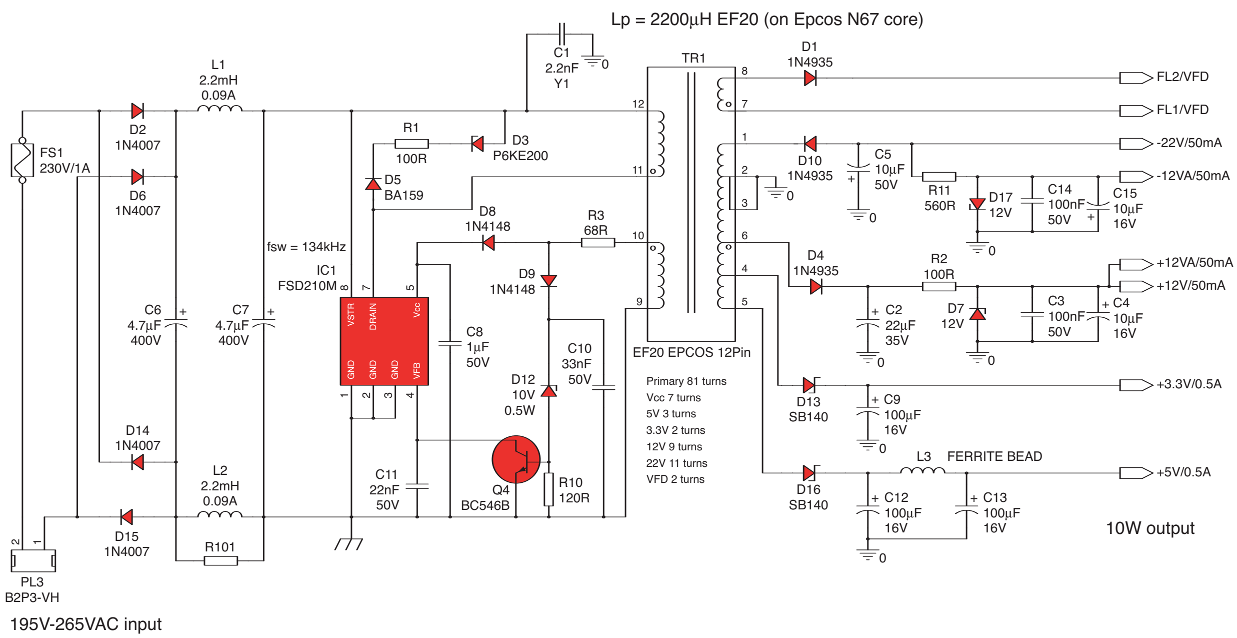
- FSDM0265RN has a fully avalanche rated MOSFET
  - Robust performance under transient conditions
- Overload protection circuit distinguishes between temporary and permanent overload
  - Device does not shut down during load surge conditions
  - Inherent short circuit protection
- Current limit may be lowered using an external resistor
  - Increased flexibility in choice of range of FPS parts

Fairchild Devices	Description
FSDM0265RN	Fairchild Power Switch (1.5A/70kHz)
BZX84C3V9	Zener Diode (3.9V)
H11A817A	Transistor Optocoupler
SB540	Schottky Diode (5A/40V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4007	General Purpose Diode (1A/1000V)
1N4148	General Purpose Diode (10mA/100V)

Examples of Typical Application Circuits

10W Multiple Output Isolated Flyback using FSD210 with Primary Side Regulation

Typical Application – Set top boxes, decoders and small DVD players



Multiple output flyback converters are used in applications where power is supplied to diverse sub-systems such as drives, tuners, audio stages and complex processor and logic circuits. Primary side regulation is used in this circuit to reduce the total cost. For this power level and above it is more cost effective to use four diodes in a full bridge configuration than a single diode with a larger capacitor. For high current outputs it is recommended to use a Schottky diode on the secondary side.

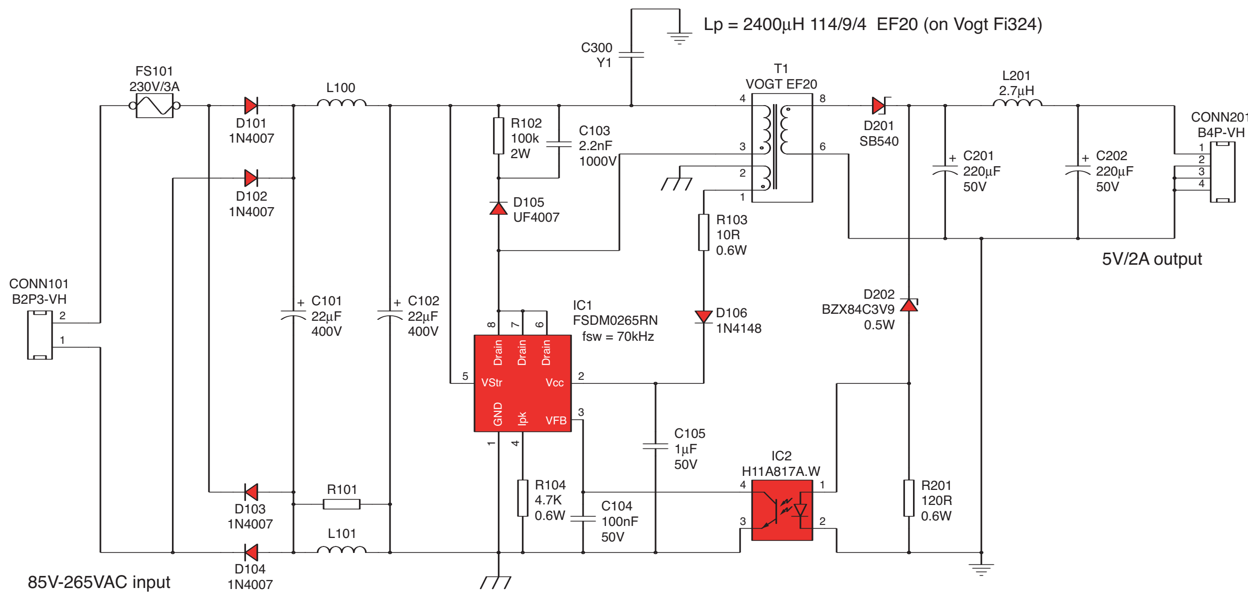
- Primary side regulation reduces system cost
  - Cross regulation is good, total regulation worse than with an optocoupler solution
- Frequency modulation approach minimizes EMI circuitry
  - Common-mode choke can be replaced by a simple dual capacitor, dual low cost inductor circuit
- Overload protection circuit distinguishes between temporary and permanent overload
  - Device does not shut down during load surge conditions from drive unit
  - Inherent short circuit protection

Fairchild Devices	Description
FSD210M	Fairchild Power Switch (0.3A/134kHz)
BZX84Cxx	Zener Diodes (10V, 12V)
P6KE200	Transient Voltage Suppressor (600W/200V)
SB140	Schottky Diode (1A/40V)
1N4935	Fast Recovery Diode (1A/200V)
1N4937	Fast Recovery Diode (1A/600V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4007	General Purpose Diode (1A/1000V)
1N4148	General Purpose Diode (10mA/100V)
BC546B	General Purpose Transistor

Examples of Typical Application Circuits

2.5W Single Output Isolated Flyback using FSD200 with KA431 Reference

Typical Application – Isolated main or standby power supplies for household appliances



In this converter, isolation is provided by the transformer and the H11A817A optocoupler. Output accuracy is improved using the KA431 voltage reference. The values R201, R203, C206, R204 and C104 set the closed loop control parameters and performance. Using a Schottky diode is a cost-effective method of improving efficiency where needed.

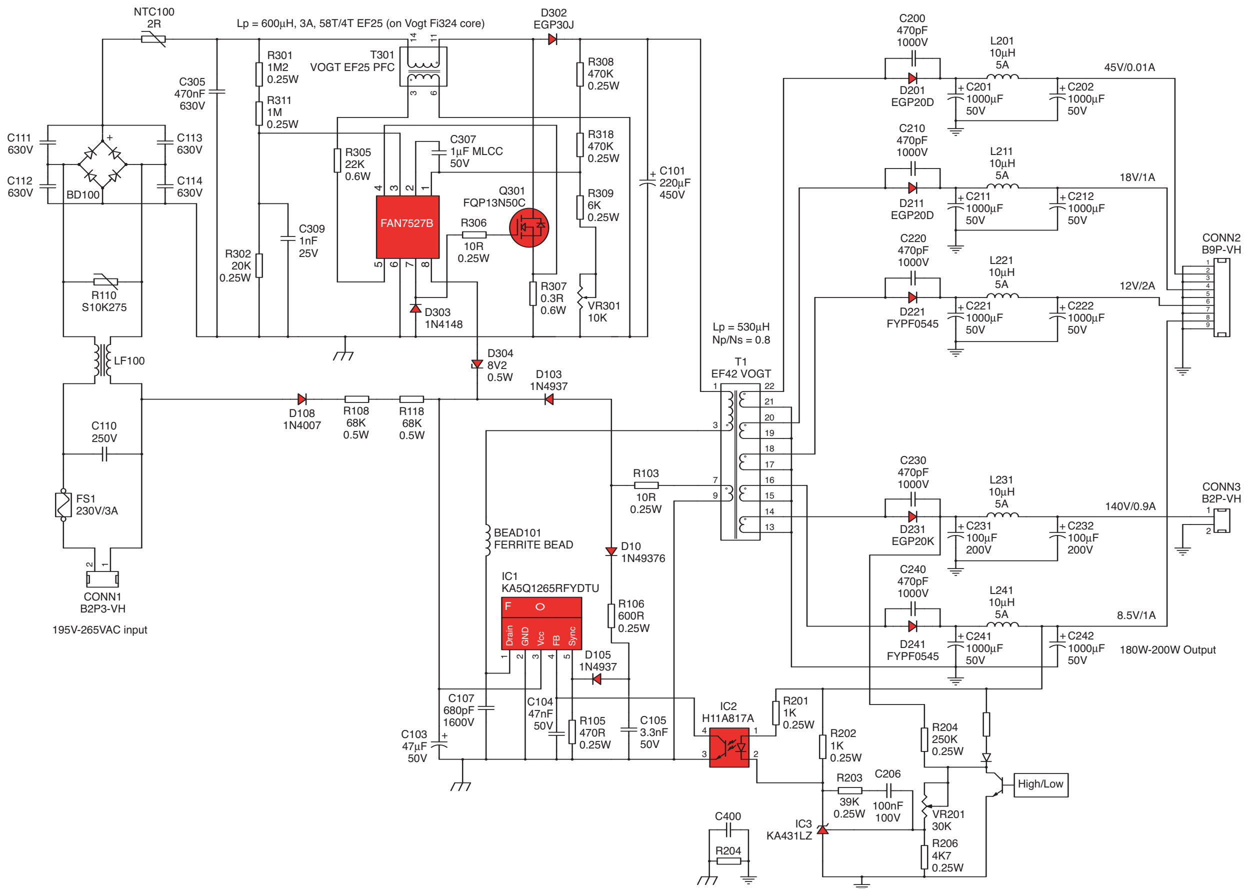
- Feedback circuit using KA431 reference and H11A817A optocoupler
  - More accurate regulation over line, load and temperature than with a Zener diode
- Schottky diode used in output stage
  - Cost-effective means of improving efficiency
- Integrated soft start function
  - Prevents power surges during switch-on time

Fairchild Devices	Description
FSD200M	Fairchild Power Switch (0.3A/134kHz)
KA431	2.5V Reference (2.5V)
H11A817A	Transistor Optocoupler
SB180	Schottky Diode (1A/80V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4007	General Purpose Diode (1A/1000V)

Examples of Typical Application Circuits

180W-200W Quasi-Resonant Flyback with Input Power Factor Correction using KA5Q1265RF, FAN7527B, and FQP13N50C

Typical Application – Color Televisions



Examples of Typical Application Circuits

180W-200W Quasi-Resonant Flyback with Input Power Factor Correction using KA5Q1265RF, FAN7527B, and FQP13N50C *(Continued)*

Typical Application – Color Televisions

The circuit shown consists of a PFC stage built around the FAN7527B/FQP13N50C/EGP30J circuit and the quasi-resonant PWM stage built around the KA5Q1265RF/T1 circuit. This circuit is suited for input voltages in the range from around 195V to 265V.

The transition mode PFC stage generates a DC bus voltage of around 400V. The purpose of the stage is to reduce the harmonic content of the input current drawn from the AC supply as required by the EN61000-3-2 standard. An additional benefit is that the input power factor is very high.

The KA5Q1265RF circuit generates the required output voltages using a multiple output flyback configuration. The device operates in discontinuous mode and detects the point where the secondary current has dropped to zero. The device then switches on after a delay set by the circuit around C105. As the delay is chosen to be at the first minimum of the primary side voltage ring as it changes from $V_{in} + nV_o$ to $V_{in} - nV_o$ the device is switched on at a low voltage, which reduces the switching loss. The switching frequency is therefore asynchronous and varies with the load. This reduces the visible effect of switching noise on the television screen. Fixed frequency switching noise would be seen as diagonal lines on the screen. The turns ratio is chosen to be unusually low for a standard flyback because the output voltage on the main winding is exceptionally high. This keeps the reflected voltage nV_o low.

If the load on a quasi-resonant flyback circuit is reduced, the switching frequency increases which causes a reduction in efficiency.

The KA5Q series has a burst mode of operation. In normal operation the High/Low signal is High. When this signal which is typically supplied by a microcontroller is Low, the current increases through the optocoupler, the feedback voltage goes to ground and the device enters burst mode. In this case the output voltages drop until the voltage supplied to the chip through the auxiliary winding drops to around 12V. The device remains in hysteretic burst mode until the feedback voltage increases. In this low power mode, the PFC chip is deactivated via D304. In normal operation, the auxiliary winding voltage is around 24V, so there is sufficient voltage to power up the PFC chip. In burst mode, the FPS voltage is between 11V and 12V, so the FAN7527B chip is deactivated, as its supply voltage is around 8V lower than this.

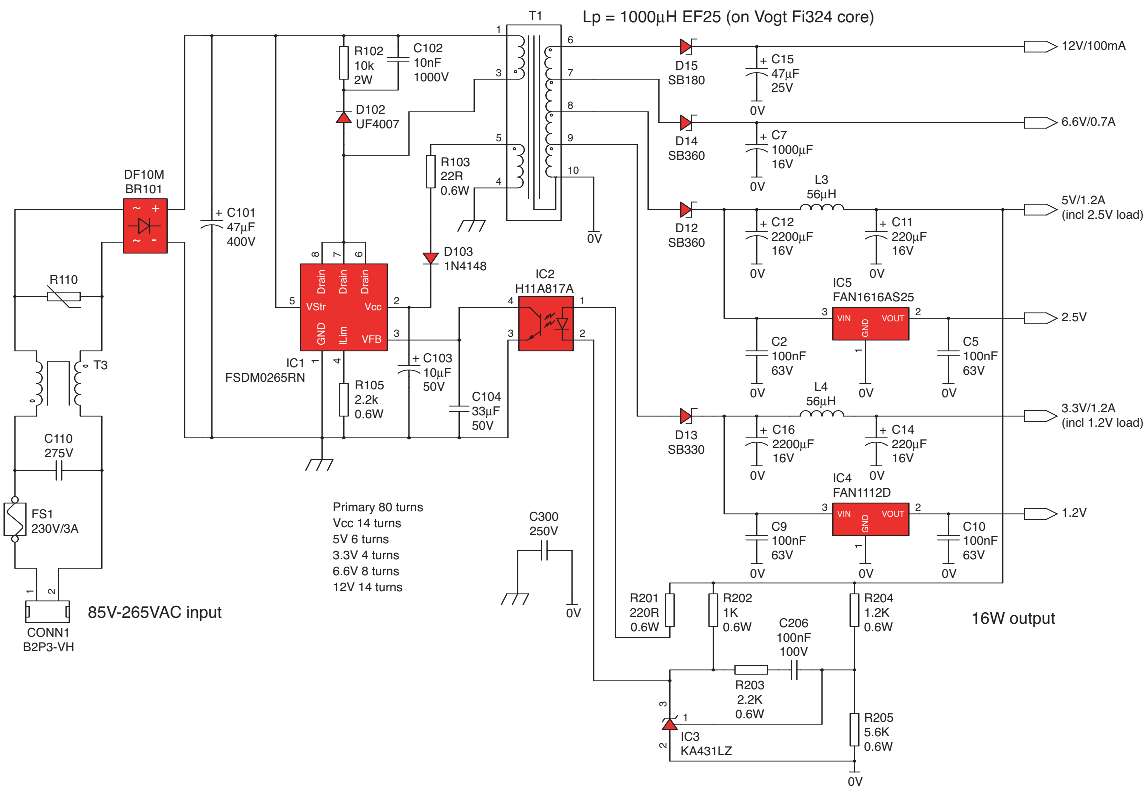
- Complete PFC and PWM solution for a color television power supply
  - High efficiency (typically 90% at full load)
  - High power factor and low input current harmonics
- Quasi-resonant mode ideal for TV applications
  - High efficiency due to lower voltage switching
  - Asynchronous switching is not at constant frequency
  - Slower dV/dt causes lower internal radiated interference
- Supports low power standby
  - Hysteretic burst mode for KA5Q1265RF device
  - FAN7527B PFC controller deactivated at low power

Fairchild Devices	Description	Fairchild Devices	Description
KA5Q1265RF	Fairchild Power Switch (8A/quasi resonant)	KA431	2.5V Reference (2.5V)
FAN7527B	Transition mode PFC controller	H11A817A	Transistor Optocoupler
FQP13N50C	High Voltage MOSFET (13A/500V)	EGP20D	Fast Recovery Diode (1A/200V)
EGP30J	Fast Recovery Diode (3A/600V)	EGP20K	Fast Recovery Diode (1A/600V)
1N4937	Fast Recovery Diode (1A/600V)	FYPF0545	Fast Recovery Diode (5A/45V)
GBU4M	Bridge Rectifier (4A/1000V)	1N4007	Fast Recovery Diode (1A/1000V)
BZX85C8V2	Zener Diode (8.2V)	1N4148	General Purpose Diode (10mA/100V)

Examples of Typical Application Circuits

16W Multiple Output Isolated Flyback Converter using FSDM0265RN

Typical Application – Set top boxes, decoders, and small DVD players
Industrial and communications applications using FPGAs and complex logic chips



The isolated, multiple output application shown is suited to applications requiring all of the common logic supply voltages: 5V, 3.3V, 2.5V and 1.2V. The flyback architecture is easily expandable: two additional outputs at 12V and 6.6V are shown in this application. The design is scalable to higher power levels by changing the size of the FPS device and the transformer. The FSDM0265RN uses current mode control which provides excellent response to line and load transient conditions. The flexible overload protection can distinguish between a temporary current surge and a longer term overload condition. The over current latch is a current limit which is active even during the blanking time. This provides additional system robustness against a secondary diode short circuit condition.

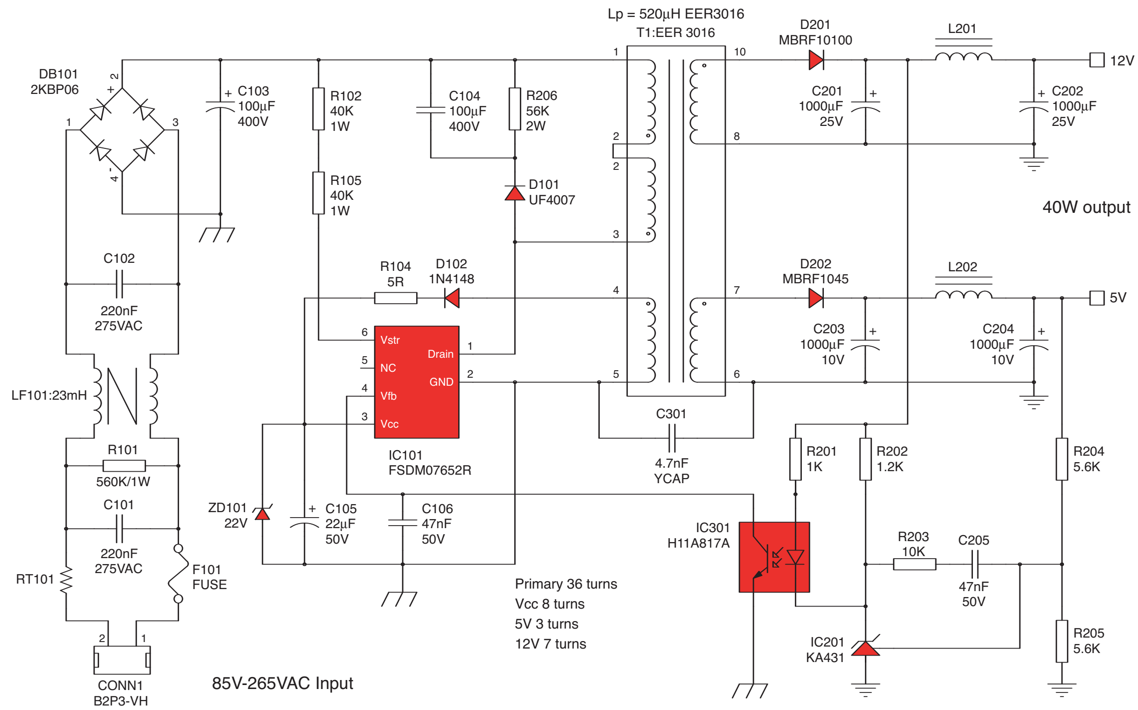
- FSDM0265RN has a fully avalanche rated MOSFET with overcurrent latch
  - Robust performance under transient conditions
  - Device switches off if there is a secondary diode short
- Overload protection circuit distinguishes between temporary and permanent overload
  - Device does not shut down during load surge conditions
  - Inherent short circuit protection
- Current limit may be lowered using an external resistor
  - Increased flexibility in choice of range of FPS parts

Fairchild Devices	Description	Fairchild Devices	Description
FSDM0265RN	Fairchild Power Switch (1.5A/70kHz)	SB180	Schottky Diode (1A/80V)
FAN1112D	Voltage Regulator (1.2V/1A)	SB330	Schottky Diode (3A/30V)
FAN1616AS25	Voltage Regulator (2.5A/0.5A)	SB360	Schottky Diode (3A/60V)
H11A817A	Transistor Optocoupler	UF4007	Fast Recovery Diode (1A/1000V)
KA431	2.5V Reference (2.5V)	1N4148	General Purpose Diode (10mA/100V)
DF10M	Bridge Rectifier		

Examples of Typical Application Circuits

40W Isolated Flyback Power Supply using FSDM07652R

Typical Application – AC Input Industrial Control, LCD Monitor



This shows a higher power isolated flyback application, sharing the same features as many of the lower power applications. A lower inductance value is used to ensure that the associated leakage inductance is also kept low in this application, remembering that snubber losses are proportional to the leakage inductance and to the square of the current.

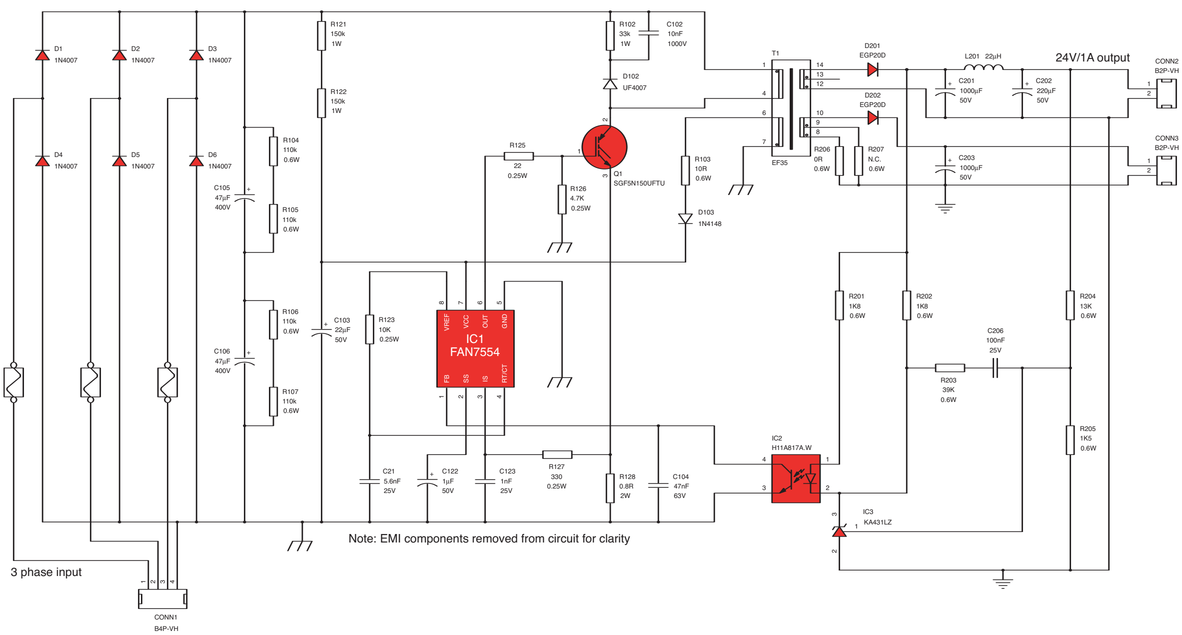
- FPS containing PWM IC with co-packaged MOSFET solution is very robust and improves system reliability
  - Fully avalanche rated switch
  - Over current protection for secondary diode short circuit
  - Over voltage protection
- Current mode control gives excellent line and load regulation
  - Better regulation
- Overload protection distinguishes between temporary and permanent overload
- Internal soft start reduces inrush current and output overshoot on turn on

Fairchild Devices	Description
FSDM07652R	Fairchild Power Switch (2.5A/70kHz)
H11A817A	Optocoupler
KA431	2.5V Reference (2.5V)
1N4007	General Purpose Diode (1A/1000V)
1N4148	General Purpose Diode (10mA/100V)
KBP06M	Bridge Rectifier Diode (1.5A/600V)

Examples of Typical Application Circuits

24W Flyback Converter using 1500V IGBT and FAN7554

Typical Application – Motor Drives, Uninterruptible Power Supplies, 3-Phase Input Systems



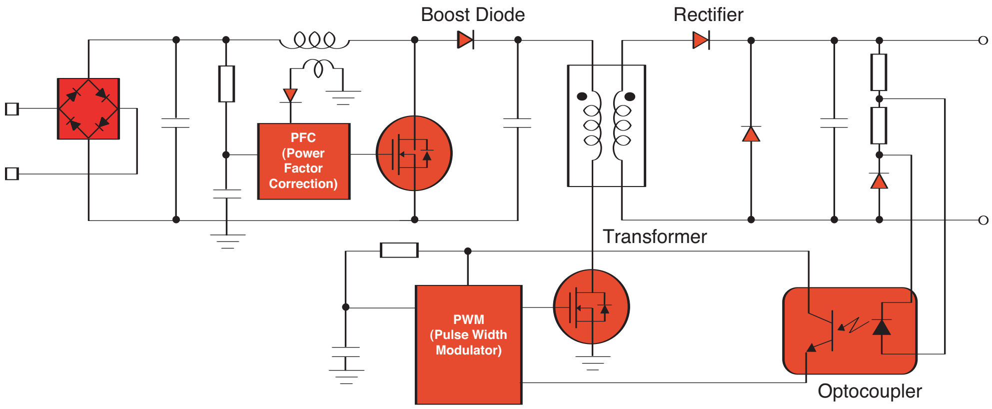
This inventive flyback solution uses a cost-effective 1500V IGBT as the main switching element, offering a more robust design. The alternative option for the switch would be a MOSFET with a rated voltage exceeding 1000V, which is a more expensive solution. The FAN7554 PWM controller provides the PWM regulation. Frequency compensation comes from the standard KA431 reference circuit.

- Flyback converter with cost-effective 1500V IGBT
  - Ensures high robustness against external voltage transients at a reasonable cost
- Complete, tested sub-system solution from Fairchild's Global Power Resource with test circuit data
  - Fairchild Semiconductor offers all semiconductor components in the circuit
  - Efficiency exceeds 78% for 24W output, 600V input, 20kHz switching frequency
  - Efficiency exceeds 74% for 24W output, 600V input 40kHz switching frequency
  - IGBT temperature rises less than 40°C in test circuit

Fairchild Devices	Description
SGF5N150UFTU	1500V, 5A IGBT
FAN7554	PWM Controller
EGP20D	Fast Recovery Diode (1A/200V)
H11A817A.W	Transistor Optocoupler
KA431LZ	2.5V Reference (2.5V)
1N4007	Diode (1A/1000V)
UF4007	Fast Recovery Diode (1A/1000V)
1N4148	General Purpose Diode (10mA/100V

Design Ideas

250W to 450W Desktop PC Forward Switch Mode Power Supply

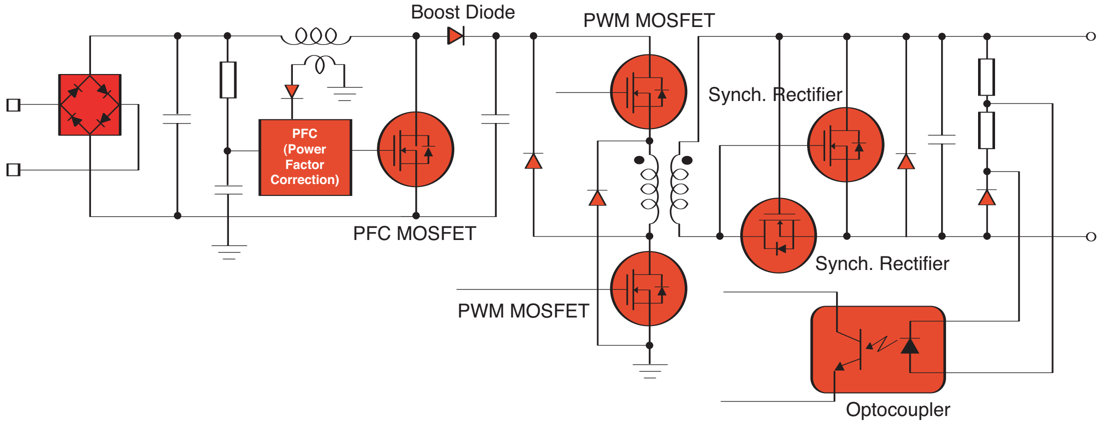


Suggested Products

Bridge Rectifier	PFC IC	PFC MOSFET	Boost Diode	PWM IC	PWM MOSFET	Rectifier	Optocoupler
2KBP10M	ML4821	FCP20N60	FFP05U60DN	KA384X	FQP8N80C	12V FPF06U20DN	H11A817
GBU4M	FAN4810	FQP18N50V2	RHRP860	KA3525	FQP9N90C	12V FFPF10U20DN	MOC819
GBU6M	FAN4822	FDH27N50	FFP10U60DN		FQA10N80C	12V FFAF10U20DN	
KBL10		FCP11N60	IRL9R860		FQA11N90	5V FYAF3004DN	
						3.3V FYP1504DN	
						3.3V FYP2004DN	
						3.3V FYAF3004DN	

Design Ideas

500W Telecom/Server Double Switch Forward Switch Mode Power Supply

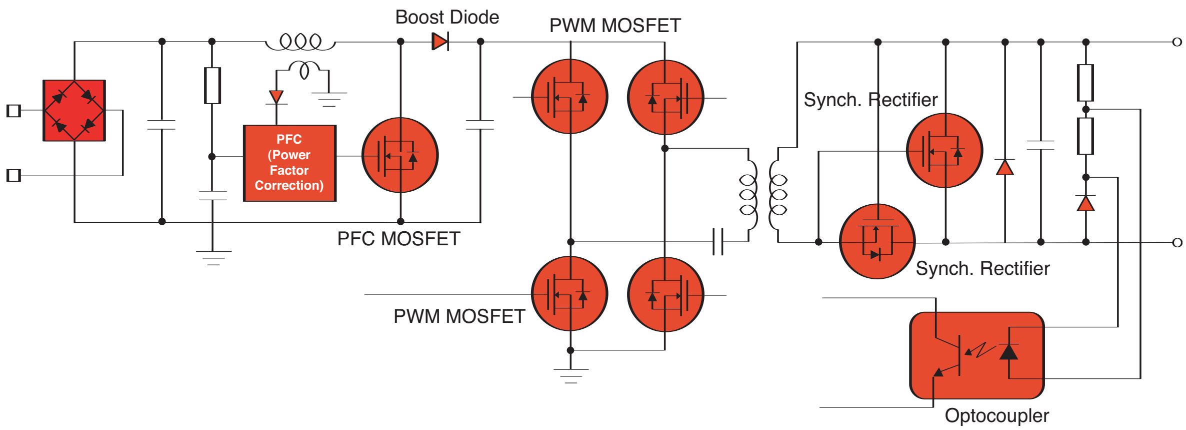


Suggested Products

Bridge Rectifier	PFC IC	PFC MOSFET	Boost Diode	PWM MOSFET	Synch. Rectifier	Optocoupler
2KBP10M	ML4821	FQA24N50	ISL9R860	FQH18NH50V2	FDP060AN08A0	H11A817
GBU4M	FAN4810	FCP11N60	IRL9R1560	FQA24N50	FDP047AN08A0	MOC819
GBU6M	FAN4822	FDH44N50	RHRP860	FQH27N50	FDP3652	
KBL10			RHRP1560	FQH44N50	FDP3632	
				FCP11N60	FQP90N10V2	
				FCP20N60		

Design Ideas

500W Telecom/Server ZVS Phase-Shift Full Bridge Switch Mode Power Supply



Suggested Products

Bridge Rectifier	PFC IC	PFC MOSFET	Boost Diode	PWM MOSFET	Synch. Rectifier	Optocoupler
2KBP10M	ML4821	FQA24N50	ISL9R860	FQH18N50V2	FDP060AN08A0	H11A817
GBU4M	FAN4810	FCP11N60	IRL9R1560	FQA24N50	FDP047AN08A0	MOC819
GBU6M	FAN4822	FCP20N60	RHRP860	FDH27N50	FDP3652	
KBL10		FDH44N50	RHRP1560	FDH44N50	FDP3632	
				FCP11N60	FQP90N10V2	
				FCP20N60		

Application Note Highlight

Design Guidelines for Off-Line Flyback Converters using Fairchild Power Switch (FPS™) (AN-4137)

Introduction

Designing a switched mode power supply (SMPS) is a complex process with many variables and considerations. While most power supply design engineers have developed their own methods, here is an overview describing the design of a flyback converter using Fairchild FPS devices. For a more detailed explanation of this procedure, refer to Application Note AN-4137, *Design Guidelines for Off-line Flyback Converters Using Fairchild Power Switch on* **www.fairchildsemi.com/an/AN/AN-4137.pdf**

System Specifications

Once the initial parameters of the power supply are known, the design can begin. These parameters include the min and max input voltage, input frequency, maximum output power, and estimated efficiency. From this, the initial system specifications can be calculated. The maximum input power can be determined by $P_{IN} = P_O/E_{ff}$.

The bulk capacitor can be estimated as 2-3µF per watt of input power for universal input range (85-265V_{RMS}) and 1µF per watt of input power from European input range (195V-265V_{RMS}).

Next, the maximum duty cycle can be determined. The duty cycle should be as large as possible providing there is enough margin in the MOSFET voltage rating.

Transformer and FPS Device

Worst case conditions should be used when calculating the inductance for the primary side of the transformer (L_M). For both continuous and discontinuous modes of operation, the worst case condition is at full load and minimum input voltage. Once L_M is calculated, the maximum peak current (I_{ds}^{peak}) and RMS current (I_{ds}^{rms}) of the MOSFET in normal operation can be established.

When choosing the FPS device for the design, it is important to make sure that the pulse-by-pulse current limit level (I_{over}) is greater than the maximum peak current of the MOSFET.

Once the proper FPS device is chosen, the transformer can be designed. The first step is to choose the proper core depending on the input voltage range, number of outputs and switching frequency of the FPS device. The initial core selection will be somewhat rough due to the many variables involved, but the manufacturer's core selection guide should be referred to when making this initial choice. With the selected core, calculate the minimum number of primary turns (N_P^{min}) by using the cross sectional area of the core (A_e) and the saturation flux density (B_{sat}) which can be extracted from the B-H curves on the manufacturer's datasheet. The turns ratio and resultant number of secondary turns for the transformer can then be found. Once the number of turn on the primary side is determined, the gap length of the core is calculated followed by the calculation of the wire diameter for each winding to make the transformer design is complete.

Output

In its most basic form, the output structure of a flyback converter typically consists of a series rectifier diode and output capacitor placed in parallel with the output. There may be additional LC networks following this configuration for filtering purposes in the event that the ripple current specifications of the output capacitor cannot be met.

To determine the output rectifier diode, the maximum reverse recovery voltage (V_{RRM}) and the RMS current of the diode must be calculated. With that, a diode can be chosen from Fairchild's diode selection guide.

When choosing the output capacitor, ensure that the calculated ripple current is smaller than the ripple current given on the capacitor's datasheet. If a post filter is necessary, set the corner frequency from 1/10th to 1/5th of the FPS switching frequency.

Snubber

An RCD snubber network is needed when there is a high voltage spike on the drain of the FPS MOSFET when it is in the OFF state. This spike can lead to failure of the FPS device. The snubber network will clamp the voltage and protect the circuit. The first step is to determine the snubber capacitor voltage at the minimum input voltage and maximum load (V_{sn}). The power dissipated in the snubber network can then be calculated.

The snubber resistor should be chosen with the proper wattage rating according to the power loss of the circuit. The capacitor voltage for the snubber is then calculated under maximum input and full load conditions.

After choosing the snubber resistor and capacitor, the snubber diode can then be chosen. The maximum voltage stress on the MOSFET drain (V_{ds}^{max}) should be calculated and should be below 90% of the rated voltage of the MOSFET (BV_{dss}). The voltage rating of the snubber diode should be higher than the MOSFET BV_{dss}.

Application Note Highlight

Design Guidelines for Off-Line Flyback Converters using Fairchild Power Switch (FPS™) *(Continued)* (AN-4137)

Feedback loop

Most FPS devices employ current mode control, therefore the feedback loop can be typically implemented with a one pole and one zero compensation circuit. Calculating the control-to-output transfer function origin is different depending on whether the circuit is operating in continuous or discontinuous mode. When a continuous mode converter design has multiple outputs, the low frequency control-to-output transfer function is proportional to the parallel combination of all of the load resistances, adjusted by the square of the turns ratio.

Design of the feedback loop consists of the following steps.

a) Determine the crossover frequency (f_c). For CCM mode flyback, set f_c below 1/3 of right half plane (RHP) zero to minimize the effect of the RHP zero. For DCM mode fc can be placed at a higher frequency, since there is no RHP zero.

b) When an additional LC filter is employed, the crossover frequency should be placed below 1/3 of the corner frequency of the LC filter, since it introduces a -180 degrees phase drop. Never place the crossover frequency beyond the corner frequency of the LC filter. If the crossover frequency is too close to the corner frequency, the controller should be designed to have a phase margin greater than 90 degrees when ignoring the effect of the post filter.

c) Determine the DC gain of the compensator (w_i/w_{zc}) to cancel the control-to-output gain at f_c.

d) Place a compensator zero (f_{zc}) around $f_c/3$.

e) Place a compensator pole (f_{pc}) above $3f_c$.

For the complete Application Note, please visit us at *www.fairchildsemi.com/an/AN/AN-4137.pdf*

Application Note Highlight

Power Factor Correction (PFC) Basics (AN-42047)

What is Power Factor?

Power Factor (PF) is defined as the ratio of the real power (P) to apparent power (S), or the cosine (for pure sine wave for both current and voltage) that represents the phase angle between the current and voltage waveforms (see Figure 1). The power factor can vary between 0 and 1, and can be either inductive (lagging, pointing up) or capacitive (leading, pointing down). In order to reduce an inductive lag, capacitors are added until PF equals 1. When the current and voltage waveforms are in phase, the power factor is 1 (cos (0°) = 1). The whole purpose of making the power factor equal to one is to make the circuit look purely resistive (apparent power equal to real power).

Real power (watts) produces real work; this is the energy transfer component (example electricity-to-motor rpm). Reactive power is the power required to produce the magnetic fields (lost power) to enable the real work to be done, where apparent power is considered the total power that the power company supplies, as shown in Figure 1. This total power is the power supplied through the power mains to produce the required amount of real power.

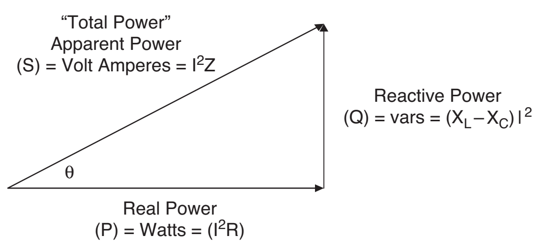


Figure 1. Power Factor Triangle (Lagging)

The previously-stated definition of power factor related to phase angle is valid when considering ideal sinusoidal waveforms for both current and voltage; however, most power supplies draw a non-sinusoidal current. When the current is not sinusoidal and the voltage is sinusoidal, the power factor consists of two factors: 1) the displacement factor related to phase angle and 2) the distortion factor related to wave shape. Equation 1 represents the relationship of the displacement and distortion factor as it pertains to power factor.

$$PF = \frac{Irms(1)}{Irms} \cos\theta = Kd \cdot K\theta$$

Irms(1) is the current's fundamental component and *Irms* is the current's RMS value. Therefore, the purpose of the power factor correction circuit is to minimize the input current distortion and make the current in phase with the voltage.

When the power factor is not equal to 1, the current waveform does not follow the voltage waveform. This results not only in power losses, but may also cause harmonics that travel down the neutral line and disrupt other devices connected to the line. The closer the power factor is to 1, the closer the current harmonics will be to zero since all the power is contained in the fundamental frequency.

Understanding Recent Regulations

In 2001, the European Union put EN61000-3-2, into effect to establish limits on the harmonics of the ac input current up to the 40^{th} harmonic. Before EN61000-3-2 came into effect, there was an amendment to it passed in October 2000 that stated the only devices required to pass the rigorous Class D (Figure 2) emission limits are personal computers, personal computer monitors, and television receivers. Other devices were only required to pass the relaxed Class A (Figure 3) emission limits.

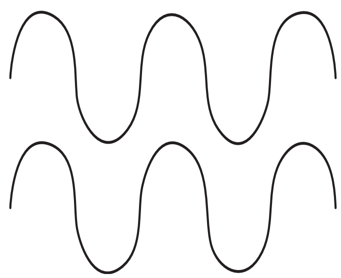


Figure 2. Both Current and Voltage Waveforms are in Phase with a PF =1 (Class D)

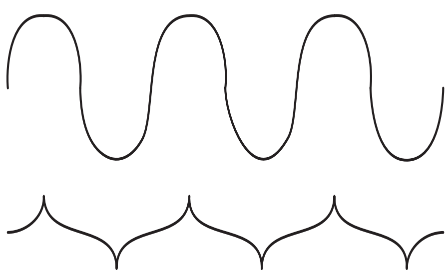


Figure 3: This is What is Called Quasi-PFC Input, Achieving a PF Around 0.9 (Class A)

Refer to the complete application note, AN-42047, for additional information on:
- Inefficiency causes
- Boost converters
- Modes of operation

For the complete Application Note, please visit us at www.fairchildsemi.com/an/AN/AN-42047.pdf

Application Note Highlight

Choosing Power Switching Devices for SMPS Designs (AN-7010)

This application note identifies the key parametric considerations for comparing IGBT and MOSFET performance in specific switch mode power supply (SMPS) applications. Parameters such as switching losses are investigated in both hard-switched and soft-switched zero voltage switching (ZVS) topologies. The three main power switch losses: turn-on, conduction and turn-off are described relative to both circuit and device characteristics. The differences in gate drive requirements are explained for the two voltage controlled products. Finally, the impact of the specific cooling system on device selection is explored.

Turn-On Losses

The turn-on characteristics of IGBTs and power MOSFETs are quite similar except that IGBTs have a longer voltage fall time. Referencing the basic IGBT equivalent circuit, Figure 1, the time required to fully modulate the minority carrier PNP BJT collector base region results in a turn-on voltage tail.

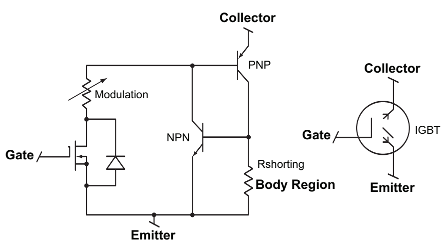


Figure 1 - IGBT Equivalent Circuit

This delay results in a Quasi-Saturation effect wherein the collector-emitter voltage does not immediately fall to its $V_{CE(SAT)}$ value[1]. This turn-on effect also results in a V_{CE} voltage bump under ZVS conditions at the point where the load current transitions from the co-packed inverse parallel diode to the IGBT collector. The E_{ON} energy losses specified in datasheets is the time integral of $I_{collector}$ times V_{CE} in joules per switching cycle and includes the additional losses associated with quasi-saturation.

Two E_{ON} energy parameters E_{ON1} and E_{ON2} are provided in IGBT datasheets. E_{ON1} is the energy loss without the losses associated with hard-switched diode recovery. E_{ON2} includes the hard-switched turn-on energy loss do to diode recovery. E_{ON2} is measured recovering a diode identical to the co-packed diode associated with the device. A typical E_{ON2} test circuit is illustrated in Figure 2. The test is performed with the diode at the same T_j as the DUT. The IGBT is switched through two pulses to measure E_{ON}. The first pulse raises the inductor to the desired test current and the second pulse then measures the E_{ON} loss recovering this current from the diode.

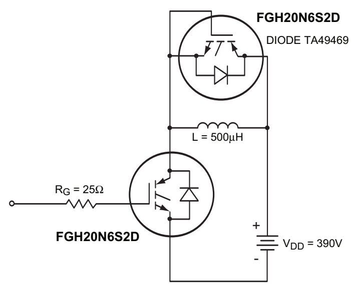


Figure 2 - Typical E_{ON} and E_{OFF} Test Circuit

Under hard-switched turn-on the gate drive voltage and impedance and the recovery characteristics of the commutated diode determine the E_{ON} switching loss. For circuits such as the conventional CCM boost PFC circuit the boost diode recovery characteristics are extremely important in controlling E_{ON} (turn-on) energy losses. In addition to selecting a boost diode with minimal T_{rr} and Q_{RR} it is also important to ensure that the diode has soft recovery characteristics. Softness, the ratio of t_b/t_a, has a considerable impact on the electrical noise and voltage spikes generated across the switching device. Snappy diodes with a high t_b period d_i/d_t fall from $I_{RM(REC)}$ create large voltage spikes in the circuit parasitic inductances. These voltage spikes create EMI and can result in excessive reverse voltage across the diode.

In hard-switched circuits such as the full-bridge and half bridge topologies where the IGBT co-packed or MOSFET body diodes are conducting when the alternate switching device is turned on, the diode recovery characteristics determine the E_{ON} loss. For this reason it is important to select MOSFETs with Fast body diode recovery characteristics such as the Fairchild FQA28N50F FRFET™. Unfortunately, MOSFET parasitic or body diodes are relatively slow compared to state-of-the-industry discrete diodes. For hard-switched MOSFET applications the body diode is often the limiting factor determining the SMPS operating frequency.

Typically IGBT co-packed diodes are selected for compatibility with their intended applications. Slower Ultrafast diodes with lower forward conduction losses are co-packed with slower lower $V_{CE(SAT)}$ motor drive IGBTs. Conversely soft

Application Note Highlight

Choosing Power Switching Devices for SMPS Designs *(Continued)* (AN-7010)

recovery Hyperfast diodes such as the Fairchild Stealth™ series are co-packed with the high frequency SMPS2 switched mode IGBTs.

Beyond selecting the right diode the designer can control Eon losses by adjusting the gate drive turn-on source resistance. Decreasing the drive source resistance will increase the IGBT or MOSFET turn-on di/dt and decrease the Eon loss. The tradeoff is between Eon losses and EMI since the higher di/dt will result in increased voltage spikes and radiated and conducted EMI. Selecting the correct gate drive resistance to meet a desired turn-on di/dt may require in-circuit testing and verification. A ballpark value may be determined from the MOSFET transfer curve, Figure 3. Assuming the FET current will rise to 10A at turn-on and looking at the 25°C curve of Figure 3, the gate voltage must transition from 5.2V to 6.7V to reach the 10A and the average G_{FS} is (10A/6.7V - 5.2V) = 6.7Ω.

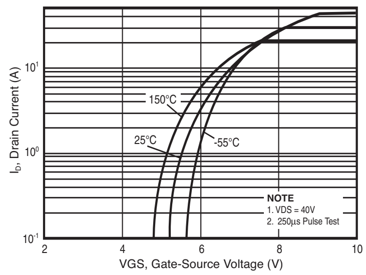


Figure 3 - FCP11N60 Transfer Characteristics

$$R_{gate} = [V_{drive} - V_{GS(avg)}] \bullet \frac{G_{FS}}{(di/dt) \bullet C_{iss}}$$

Eq. 1 - Gate drive resistance for desired turn-on di/dt

Applying this average G_{FS} value to Equation 1 with a gate drive of V_{drive} = 10V, a desired di/dt = 600 A/μs and typical FCP11N60 values $V_{GS(avg)}$ = 6V, C_{iss} = 1200pF; a 37Ω turn-on gate drive resistance is calculated. Since the instantaneous G_{FS} value is the slope in Figure 3 curves, G_{FS} will vary during the Eon period, which implies a varying di/dt. The exponentially decaying gate drive current and decreasing C_{iss} as a function of V_{FS} also enter into this equation with an overall effect of surprisingly linear current rise.

Similar Gate drive turn-on resistance may be calculated for the IGBT. Again $V_{GE(avg)}$ and G_{FS} may be determined from the IGBT transfer characteristic curve and the C_{IES} value at $V_{GE(avg)}$ should be substituted for C_{iss}. The comparable calculated IGBT turn-on gate drive resistance is 100Ω. This higher ohm requirement is indicative of the higher IGBT G_{FS} and lower C_{IES}. A key point here is that gate drive circuit adjustments must be made for a transition from MOSFET to IGBT.

Refer to the complete application note, AN-7010, that continues with the comparisons between MOSFETs and IGBTs on the following subjects:

- Conduction losses
- Turn off losses
- Gate drive requirements
- Thermal management

[1] Pittet, Serge and Rufer, Alfred "Analytical analysis of Quasi-Saturation Effect in PT and NPT IGBTs" PCIM Europe 2002 *http://leiwww.epfl.ch/publications/pittet_rufer_pcim_02.pdf*

For the complete Application Note, please visit us at *www.fairchildsemi.com/an/AN/AN-7010.pdf*

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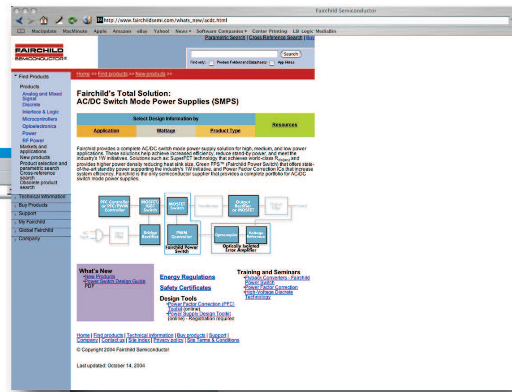

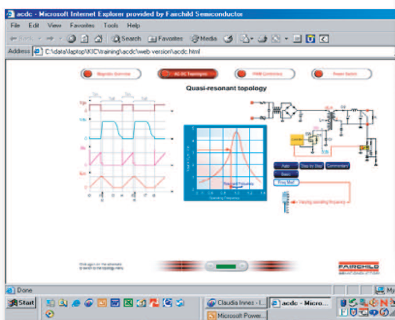

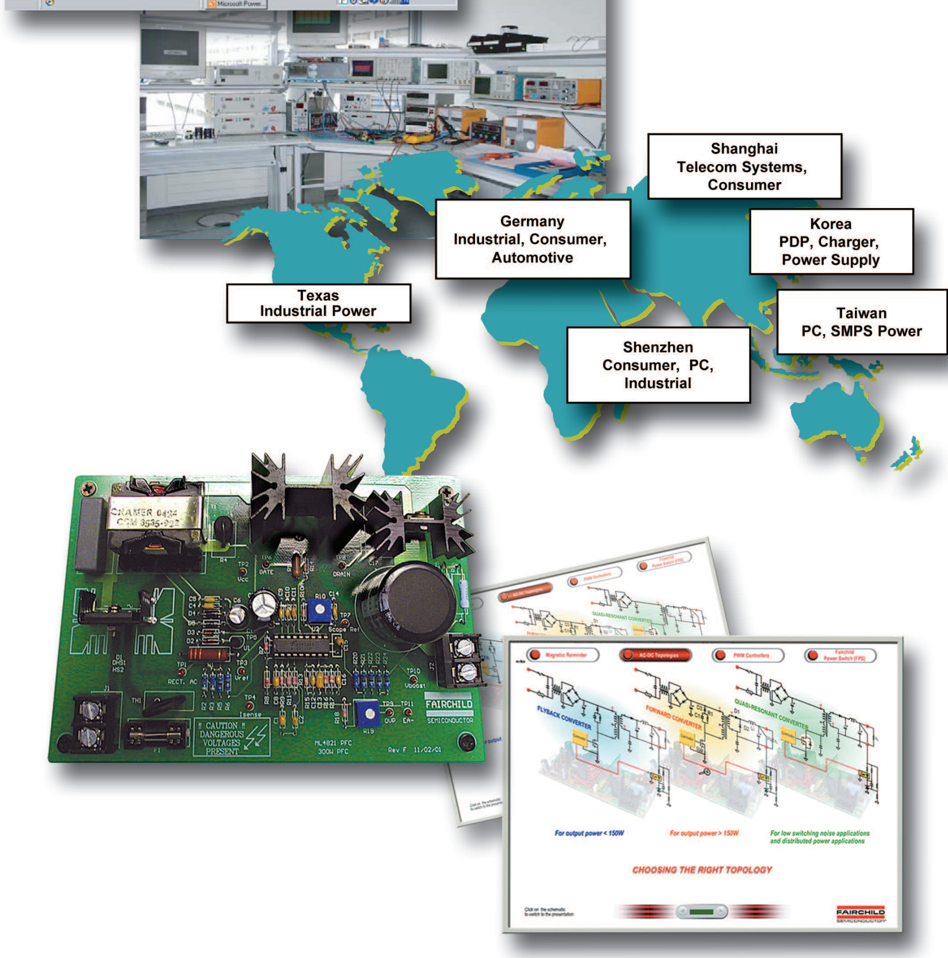

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