



# FSCM0465R

## Green Mode Fairchild Power Switch (FPS™)

### Features

- Internal Avalanche Rugged SenseFET
- Low Start-up Current (max. 40μA)
- Low Power Consumption; under 1W at 240VAC and 0.4W Load
- Precise Fixed Operating Frequency (66kHz)
- Frequency Modulation for Low EMI
- Pulse-by-Pulse Current Limiting (Adjustable)
- Over-Voltage Protection (OVP)
- Overload Protection (OLP)
- Thermal Shutdown Function (TSD)
- Auto-Restart Mode
- Under-Voltage Lock Out (UVLO) with Hysteresis
- Built-in Soft-Start (15ms)

### Applications

- SMPS for VCR, SVR, STB, DVD, and DVCD
- Adaptor
- SMPS for LCD Monitor

### Related Application Notes

- **AN-4137:** Design Guidelines for Off-line Flyback Converters Using Fairchild Power Switch (FPS)
- **AN-4140:** Transformer Design Consideration for Off-line Flyback Converters using Fairchild Power Switch
- **AN-4141:** Troubleshooting and Design Tips for Fairchild Power Switch Flyback Applications
- **AN-4148:** Audible Noise Reduction Techniques for FPS Applications

### Description

The FSCM0465R is an integrated Pulse-Width Modulator (PWM) and SenseFET specifically designed for high-performance offline Switch Mode Power Supplies (SMPS) with minimal external components. This device is an integrated high-voltage power-switching regulator that combines an avalanche rugged SenseFET with a current mode PWM control block. The PWM controller includes an integrated fixed-frequency oscillator, under-voltage lockout, leading edge blanking (LEB), optimized gate driver, internal soft-start, temperature-compensated precise current sources for a loop compensation, and self-protection circuitry. Compared with a discrete MOSFET and PWM controller solution, it can reduce total cost, component count, size, and weight while simultaneously increasing efficiency, productivity, and system reliability. This device is a basic platform well suited for cost-effective designs of flyback converters.

### Ordering Information

| Product Number                | Package   | Pb-Free | Marking Code | BV <sub>DSS</sub> | R <sub>DS(ON)</sub> Max. | Packing Method |
|-------------------------------|-----------|---------|--------------|-------------------|--------------------------|----------------|
| FSCM0465RJ                    | D2-PAK-6L | Yes     | CM0465R      | 650V              | 2.6 Ω                    | Tube           |
| FSCM0465RJX                   | D2-PAK-6L | Yes     |              |                   |                          | Tape & Reel    |
| FSCM0465RIWDTU <sup>(1)</sup> | I2-PAK-6L | Yes     |              |                   |                          | Tube           |
| FSCM0465RGWDTU <sup>(1)</sup> | TO-220-6L | Yes     |              |                   |                          | Tube           |

**Note:**

1. WDTU: Forming Type

FPS™ is a trademark of Fairchild Semiconductor Corporation.

## Typical Circuit

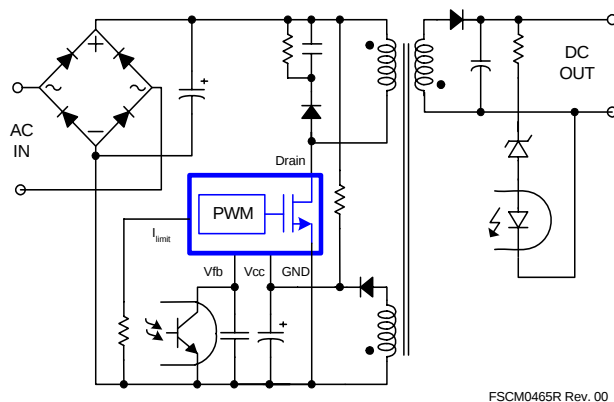


Figure 1. Typical Flyback Application

## Output Power Table

| Product    | 230VAC $\pm 15\%$ <sup>(3)</sup> |                           | 85–265VAC              |                           |
|------------|----------------------------------|---------------------------|------------------------|---------------------------|
|            | Adapter <sup>(1)</sup>           | Open Frame <sup>(2)</sup> | Adapter <sup>(1)</sup> | Open Frame <sup>(2)</sup> |
| FSCM0465RJ | 40W                              | 55W                       | 30W                    | 40W                       |
| FSCM0565RJ | 50W                              | 65W                       | 40W                    | 50W                       |
| FSCM0765RJ | 65W                              | 70W                       | 50W                    | 60W                       |
| FSCM0465RI | 60W                              | 70W                       | 40W                    | 50W                       |
| FSCM0465RG | 60W                              | 70W                       | 40W                    | 50W                       |
| FSCM0565RG | 70W                              | 85W                       | 60W                    | 70W                       |
| FSCM0765RG | 85W                              | 95W                       | 70W                    | 85W                       |

### Notes:

1. Typical continuous power in a non-ventilated enclosed adapter measured at 50°C ambient
2. Maximum practical continuous power in an open-frame design at 50°C ambient
3. 230 VAC or 100/115 VAC with doubler

## Internal Block Diagram

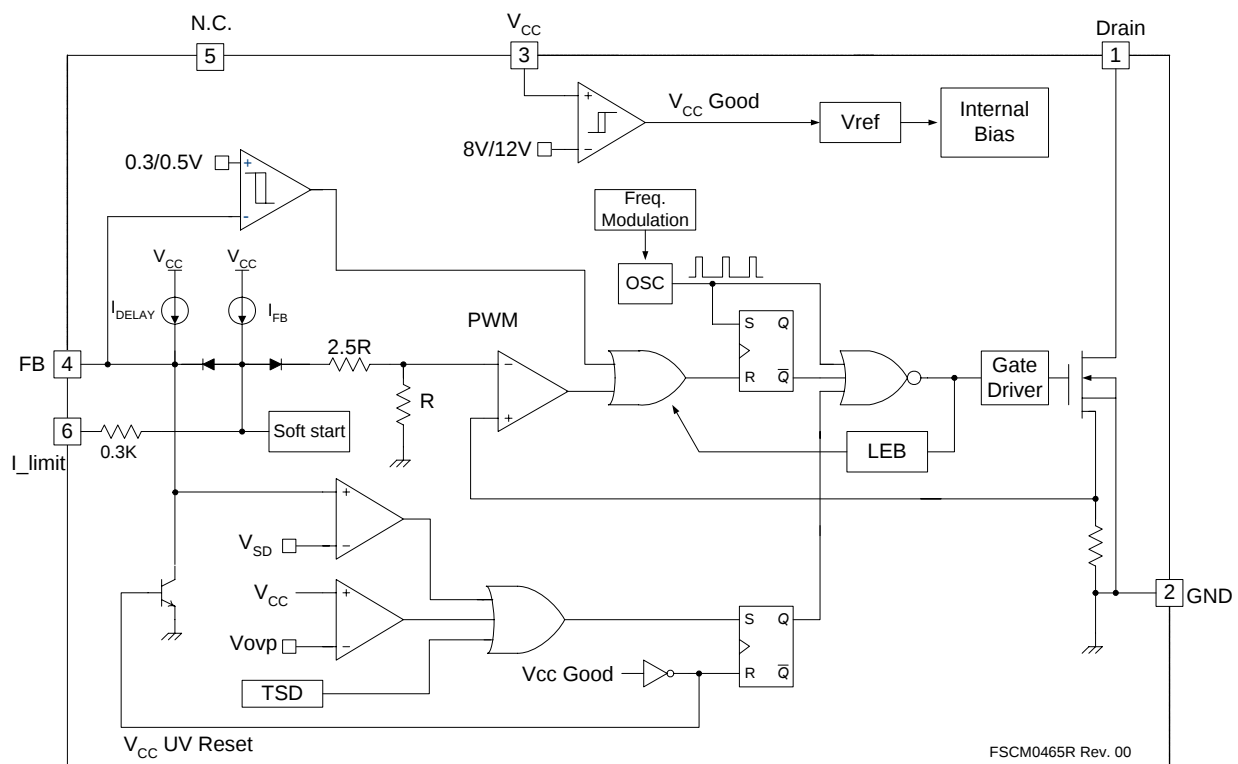


Figure 2. Functional Block Diagram of FSCM0465R

## Pin Configuration

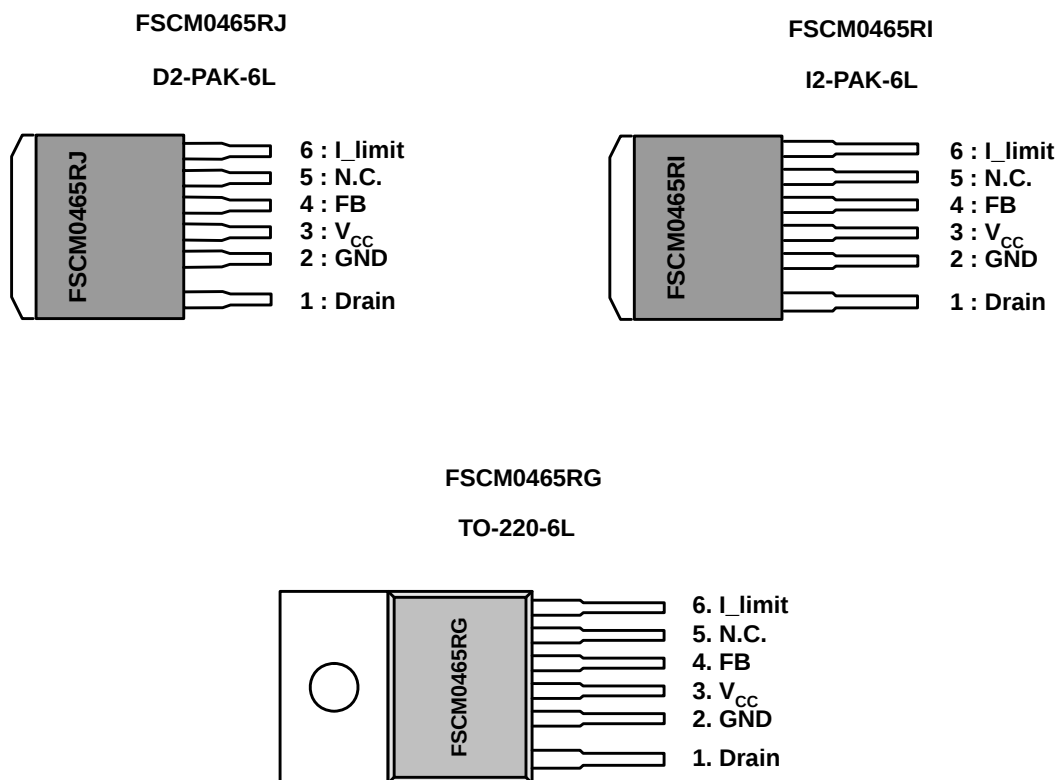


Figure 3. Pin Configuration (Top View)

## Pin Definitions

| Pin Number | Pin Name           | Pin Function Description                                                                                                                                                                                                                                                                                                                                      |
|------------|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1          | Drain              | <b>SenseFET Drain.</b> This pin is the high-voltage power SenseFET drain. It is designed to drive the transformer directly.                                                                                                                                                                                                                                   |
| 2          | GND                | <b>Ground.</b> This pin is the control ground and the SenseFET source.                                                                                                                                                                                                                                                                                        |
| 3          | V <sub>CC</sub>    | <b>Power Supply.</b> This pin is the positive supply voltage input. During startup, the power is supplied through the startup resistor from DC link. When V <sub>CC</sub> reaches 12V, the power is supplied from the auxiliary transformer winding.                                                                                                          |
| 4          | Feedback (FB)      | <b>Feedback.</b> This pin is internally connected to the inverting input of the PWM comparator. The collector of an opto-coupler is typically tied to this pin. For stable operation, a capacitor should be placed between this pin and GND. If the voltage of this pin reaches 6.0V, the overload protection is activated, resulting in shutdown of the FPS. |
| 5          | N.C.               | This pin is not connected.                                                                                                                                                                                                                                                                                                                                    |
| 6          | I <sub>limit</sub> | <b>Current Limit.</b> This pin is for the pulse-by-pulse current limit level programming. By using a resistor to GND on this pin, the current limit level can be changed. If this pin is left floating, the typical current limit is 2.0A.                                                                                                                    |

## Absolute Maximum Ratings

The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the Electrical Characteristics tables are not guaranteed at the absolute maximum ratings.

$T_A = 25^\circ\text{C}$  unless otherwise specified.

| Symbol     | Parameter                                           |                           | Value                                                | Unit                |
|------------|-----------------------------------------------------|---------------------------|------------------------------------------------------|---------------------|
| $BV_{DSS}$ | Drain-Source Breakdown Voltage <sup>(1)</sup>       |                           | 650                                                  | V                   |
| $V_{DGR}$  | Drain-Gate Voltage ( $R_{GS}=1M\Omega$ )            |                           | 650                                                  | V                   |
| $V_{GS}$   | Gate-Source (GND) Voltage                           |                           | $\pm 30$                                             | V                   |
| $I_{DM}$   | Drain Current Pulsed <sup>(2)</sup>                 |                           | 16                                                   | $A_{DC}$            |
| $I_D$      | Continuous Drain Current (TO-220-6L, I2-PAK-6L)     | $T_C = 25^\circ\text{C}$  | 4.0                                                  | $A_{DC}$            |
|            |                                                     | $T_C = 100^\circ\text{C}$ | 2.5                                                  | $A_{DC}$            |
|            | Continuous Drain Current (D2-PAK-6L)                | $T_C = 25^\circ\text{C}$  | 2.3                                                  | $A_{DC}$            |
|            |                                                     | $T_C = 100^\circ\text{C}$ | 1.4                                                  | $A_{DC}$            |
| $V_{CC}$   | Supply Voltage                                      |                           | 20                                                   | V                   |
| $V_{FB}$   | Feedback Voltage Range                              |                           | -0.3 to $V_{CC}$                                     | V                   |
| $P_D$      | Total Power Dissipation (TO-220-6L)                 |                           | 140                                                  | W                   |
| Derating   |                                                     |                           | -1.1                                                 | W/ $^\circ\text{C}$ |
| $P_D$      | Total Power Dissipation (I2-PAK-6L)                 |                           | 75                                                   | W                   |
| Derating   |                                                     |                           | -1.5                                                 | W/ $^\circ\text{C}$ |
| $P_D$      | Total Power Dissipation (D2-PAK-6L)                 |                           | 80                                                   | W                   |
| Derating   |                                                     |                           | -0.64                                                | W/ $^\circ\text{C}$ |
| $T_J$      | Operating Junction Temperature                      |                           | Internally limited                                   | $^\circ\text{C}$    |
| $T_A$      | Operating Ambient Temperature                       |                           | -25 to +85                                           | $^\circ\text{C}$    |
| $T_{STG}$  | Storage Temperature                                 |                           | -55 to +150                                          | $^\circ\text{C}$    |
|            | ESD Capability, HBM Model (All pins except Vfb)     |                           | 2.0<br>(GND-Vfb = 1.5kV)<br>( $V_{CC}$ -Vfb = 1.0kV) | kV                  |
|            | ESD Capability, Machine Model (All pins except Vfb) |                           | 300<br>(GND-Vfb = 250V)<br>( $V_{CC}$ -Vfb = 100V)   | V                   |

### Notes:

1.  $T_J = 25^\circ\text{C}$  to  $150^\circ\text{C}$
2. Repetitive rating: Pulse-width limited by maximum junction temperature
3.  $T_C$ : Case back surface temperature with infinite heat sink

## Electrical Characteristics

$T_A = 25^\circ\text{C}$  unless otherwise specified.

| Symbol               | Parameter                                        | Condition                                                    | Min. | Typ. | Max. | Unit |
|----------------------|--------------------------------------------------|--------------------------------------------------------------|------|------|------|------|
| SenseFET SECTION     |                                                  |                                                              |      |      |      |      |
| I <sub>DSS</sub>     | Zero Gate Voltage Current                        | V <sub>DS</sub> = Max, Rating V <sub>GS</sub> = 0V           | -    | -    | 250  | μA   |
| R <sub>DS(ON)</sub>  | Static Drain Source on Resistance <sup>(1)</sup> | V <sub>GS</sub> = 10V, I <sub>D</sub> = 2.3A                 | -    | 2.2  | 2.6  | Ω    |
| C <sub>OSS</sub>     | Output Capacitance                               | V <sub>GS</sub> = 0V, V <sub>DS</sub> = 25V, f = 1MHz        | -    | 60   | -    | pF   |
| t <sub>d(on)</sub>   | Turn-on Delay Time                               | V <sub>DD</sub> = 325V, I <sub>D</sub> = 3.2A <sup>(4)</sup> | -    | 23   | -    | ns   |
| t <sub>r</sub>       | Rise Time                                        |                                                              | -    | 20   | -    |      |
| t <sub>d(off)</sub>  | Turn-off Delay Time                              |                                                              | -    | 65   | -    |      |
| t <sub>f</sub>       | Fall Time                                        |                                                              | -    | 27   | -    |      |
| CONTROL SECTION      |                                                  |                                                              |      |      |      |      |
| f <sub>OSC</sub>     | Switching Frequency                              | V <sub>CC</sub> = 14V, V <sub>FB</sub> = 5V                  | 60   | 66   | 72   | kHz  |
| Δf <sub>MOD</sub>    | Switching Frequency Modulation Range             |                                                              | -    | ±3   | -    | kHz  |
| t <sub>MOD</sub>     | Switching Frequency Modulation Cycle             |                                                              | -    | 4    | -    | ms   |
| f <sub>STABLE</sub>  | Switching Frequency Stability                    | 10V ≤ V <sub>CC</sub> ≤ 17V                                  | 0    | 1    | 3    | %    |
| Δf <sub>OSC</sub>    | Switching Frequency Variation <sup>(2)</sup>     | -25°C ≤ T <sub>A</sub> ≤ +85°C                               | -    | ±5   | ±10  | %    |
| D <sub>MAX</sub>     | Maximum Duty Cycle                               |                                                              | 75   | 80   | 85   | %    |
| D <sub>MIN</sub>     | Minimum Duty Cycle                               |                                                              | -    | -    | 0    | %    |
| V <sub>START</sub>   | UVLO Threshold Voltage                           | V <sub>FB</sub> = GND                                        | 11   | 12   | 13   | V    |
| V <sub>STOP</sub>    |                                                  |                                                              | 7    | 8    | 9    | V    |
| I <sub>FB</sub>      | Feedback Source Current                          | V <sub>FB</sub> = GND                                        | 0.7  | 0.9  | 1.1  | mA   |
| t <sub>S/S</sub>     | Internal Soft-Start Time                         |                                                              | 10   | 15   | 20   | ms   |
| BURST MODE SECTION   |                                                  |                                                              |      |      |      |      |
| V <sub>BURH</sub>    | Burst Mode Voltages                              | V <sub>CC</sub> = 14V                                        | 0.4  | 0.5  | 0.6  | V    |
| V <sub>BURL</sub>    |                                                  | V <sub>CC</sub> = 14V                                        | 0.24 | 0.3  | 0.36 | V    |
| PROTECTION SECTION   |                                                  |                                                              |      |      |      |      |
| I <sub>LIMIT</sub>   | Peak Current Limit <sup>(3)</sup>                | V <sub>CC</sub> = 14V, V <sub>FB</sub> = 5V                  | 2.2  | 2.5  | 2.8  | A    |
| V <sub>OVP</sub>     | Over-Voltage Protection                          |                                                              | 18   | 19   | 20   | V    |
| T <sub>SD</sub>      | Thermal Shutdown Temperature <sup>(2)</sup>      |                                                              | 130  | 145  | 160  | °C   |
| I <sub>DELAY</sub>   | Shutdown Delay Current                           | V <sub>FB</sub> = 4V                                         | 3.5  | 5.3  | 7    | μA   |
| V <sub>SD</sub>      | Shutdown Feedback Voltage                        | V <sub>FB</sub> ≥ 5.5V                                       | 5.5  | 6    | 6.5  | V    |
| TOTAL DEVICE SECTION |                                                  |                                                              |      |      |      |      |
| I <sub>start</sub>   | Startup Current                                  |                                                              | -    | 20   | 40   | μA   |
| I <sub>OP(MIN)</sub> | Operating Supply Current                         | V <sub>CC</sub> = 10V, V <sub>FB</sub> = 0V                  | -    | 2.5  | 5    | mA   |
| I <sub>OP(MAX)</sub> |                                                  | V <sub>CC</sub> = 20V, V <sub>FB</sub> = 0V                  |      |      |      |      |

### Notes:

1. Pulse Test: Pulse width  $\leq 300\mu\text{s}$ , duty  $\leq 2\%$
2. These parameters, although guaranteed at the design, are not tested in mass production.
3. These parameters indicate the inductor current. Where packages are I2PAK or D2PAK, this should be decreased to 2.0A by external resistor.
4. MOSFET switching time is essentially independent of operating temperature.

## Comparison Between FSDM0465RB and FSCM0465R

| Function                     | FSDM0465RB                   | FSCM0465R                                                                                                                        |
|------------------------------|------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Frequency Modulation         | N/A                          | Available<br>- Frequency modulation range ( $\Delta f_{MOD}$ ) = $\pm 3$ kHz<br>- Frequency modulation cycle ( $t_{MOD}$ ) = 4ms |
| Pulse-by-pulse Current Limit | Internally fixed (2.0A max.) | Programmable using external resistor (2.8A max.)                                                                                 |
| Internal Startup Circuit     | Available                    | N/A (Requires a startup resistor)<br>Startup current: 40 $\mu$ A (max.)                                                          |
| Packages                     | TO-220F-6L                   | TO-220-6L<br>I2-PAK-6L<br>D2-PAK-6L                                                                                              |

## Typical Performance Characteristics

These characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ .

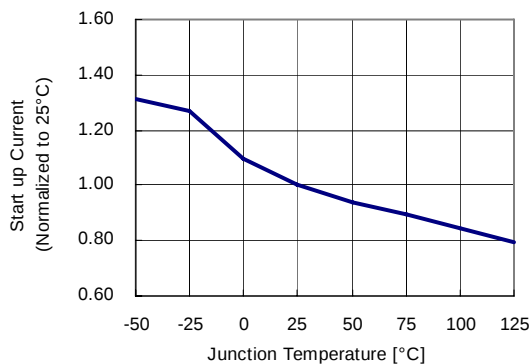


Figure 4. Startup Current vs. Temp.

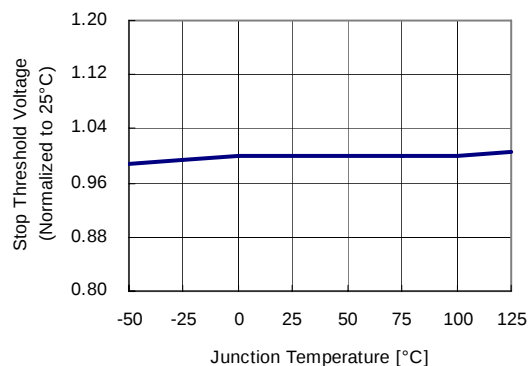


Figure 5. Stop Threshold voltage vs. Temp.

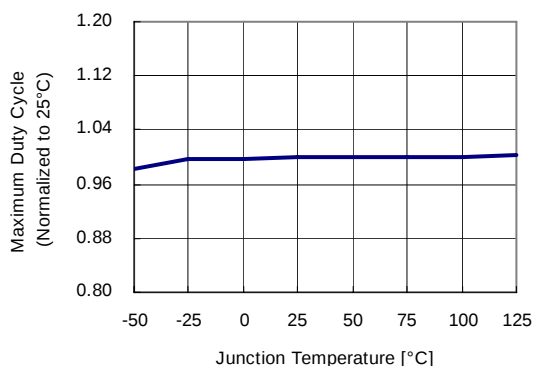


Figure 6. Maximum Duty Cycle vs. Temp.

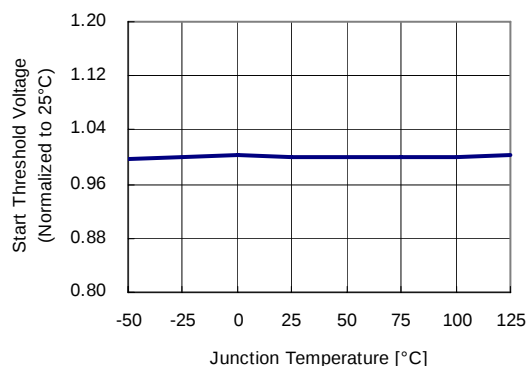


Figure 7. Start Threshold Voltage vs. Temp.

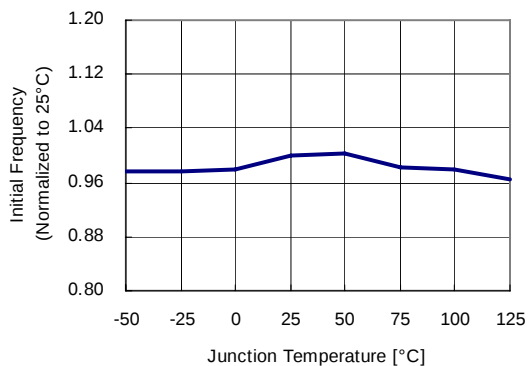


Figure 8. Initial Frequency vs. Temp.

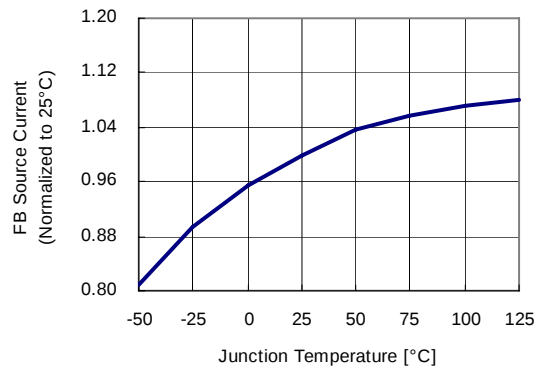


Figure 9. Feedback Source Current vs. Temp.

## Typical Performance Characteristics (Continued)

These characteristic graphs are normalized at  $T_A = 25^\circ\text{C}$ .

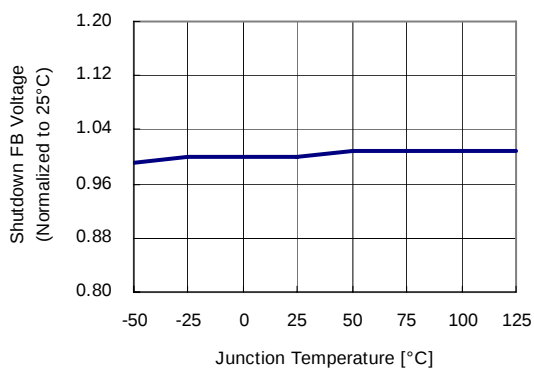


Figure 10. Shutdown Feedback voltage vs. Temp.

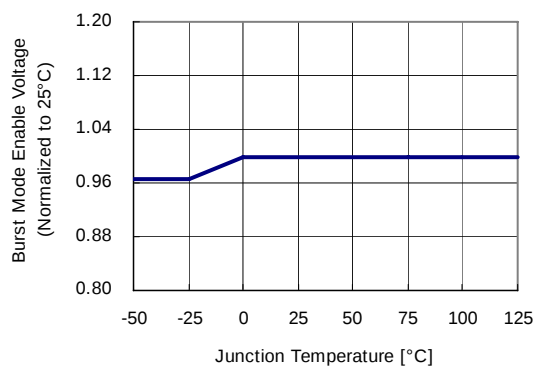


Figure 11. Burst Mode Enable Voltage vs. Temp.

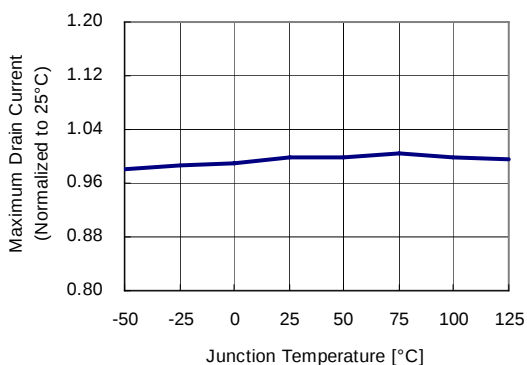


Figure 12. Maximum Drain Current vs. Temp.

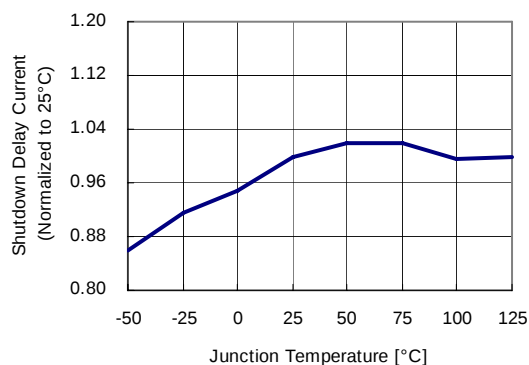


Figure 13. Shutdown Delay Current vs. Temp.

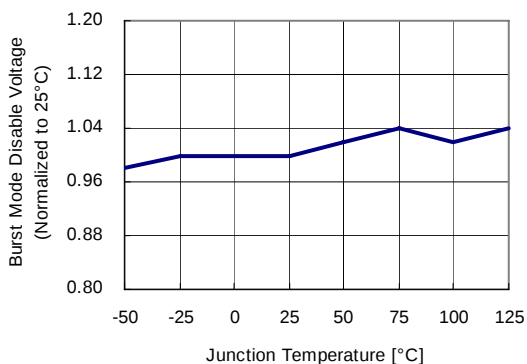


Figure 14. Burst Mode Disable Voltage vs. Temp.

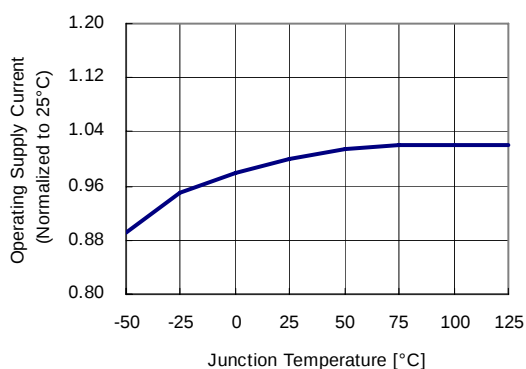
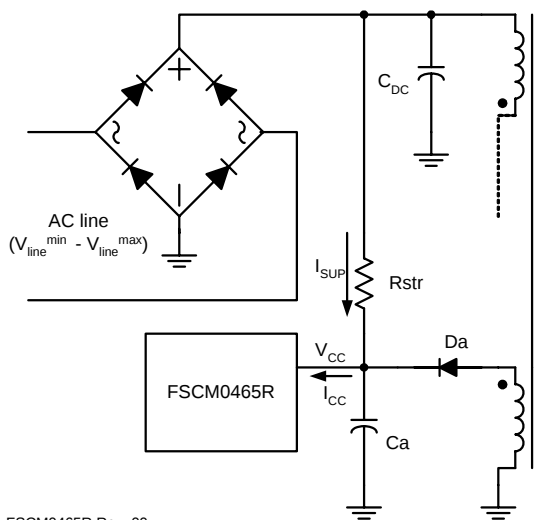


Figure 15. Operating Supply Current vs. Temp.

## Functional Description

**1. Startup:** Figure 16 shows the typical startup circuit and transformer auxiliary winding for the FSCM0465R application. Before the FSCM0465R begins switching, it consumes only startup current (typically 20μA) and the current supplied from the DC link supply current consumed by the FPS ( $I_{CC}$ ) and charges the external capacitor ( $C_a$ ) connected to the  $V_{CC}$  pin. When  $V_{CC}$  reaches start voltage of 12V ( $V_{START}$ ), the FSCM0465R begins switching and the current consumed by the FSCM0465R increases to 2.5mA. Then the FSCM0465R continues its normal switching operation and the power required for this device is supplied from the transformer auxiliary winding, unless  $V_{CC}$  drops below the stop voltage of 8V ( $V_{STOP}$ ). To guarantee the stable operation of the control IC,  $V_{CC}$  has under-voltage lockout (UVLO) with 4V hysteresis. Figure 17 shows the relationship between the current consumed by the FPS ( $I_{CC}$ ) and the supply voltage ( $V_{CC}$ ).



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Figure 16. Startup Circuit

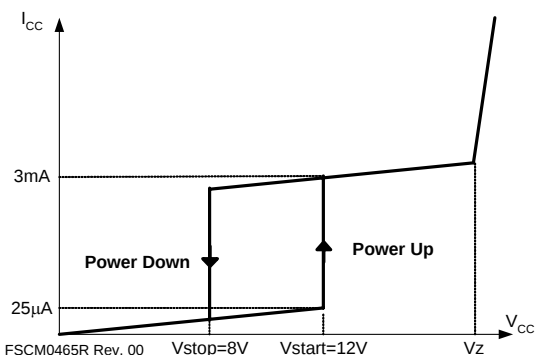


Figure 17. Relation Between Operating Supply Current and  $V_{CC}$  Voltage

The minimum current supplied through the startup resistor is given by:

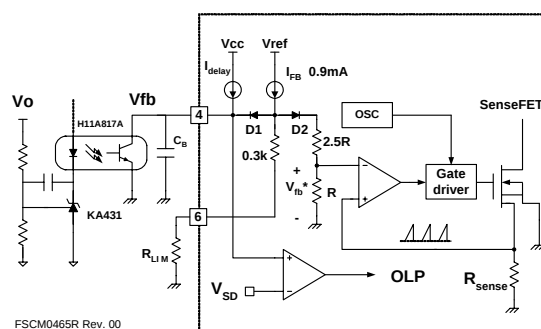
$$I_{sup}^{min} = \left( \sqrt{2} \cdot V_{line}^{min} - V_{start} \right) \cdot \frac{1}{R_{str}} \quad (1)$$

where  $V_{line}^{min}$  is the minimum input voltage,  $V_{start}$  is the start voltage (12V) and  $R_{str}$  is the startup resistor. The startup resistor should be chosen so that  $I_{sup}^{min}$  is larger than the maximum startup current (40μA). If not,  $V_{CC}$  can not be charged to the start voltage and FPS fails to start.

**2. Feedback Control:** The FSCM0465R employs current mode control, as shown in Figure 18. An optocoupler (such as the H11A817A) and a shunt regulator (such as the KA431) are typically used to implement the feedback network. Comparing the feedback voltage with the voltage across the  $R_{sense}$  resistor makes it possible to control the switching duty cycle. When the reference pin voltage of the KA431 exceeds the internal reference voltage of 2.5V, the H11A817A LED current increases, pulling down the feedback voltage and reducing the duty cycle. This event typically happens when the input voltage is increased or the output load is decreased.

**2.1 Pulse-by-pulse Current Limit:** Because current mode control is employed, the peak current through the SenseFET is determined by the inverting input of the PWM comparator ( $V_{fb}^*$ ) as shown in Figure 18. When the current through the opto-transistor is zero and the current limit pin (#5) is left floating, the feedback current source ( $I_{FB}$ ) of 0.9mA flows only through the internal resistor ( $R + 2.5R = 2.8k$ ). In this case, the cathode voltage of diode D2 and the peak drain current have maximum values of 2.5V and 2.5A, respectively. The pulse-by-pulse current limit can be adjusted using a resistor to GND on the current limit pin (#5). The current limit level using an external resistor ( $R_{LIM}$ ) is given by:

$$I_{LIM} = \frac{R_{LIM} \cdot 2.5A}{2.8K\Omega + R_{LIM}} \quad (2)$$



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Figure 18. Pulse Width Modulation (PWM) Circuit

**2.2 Constant Power Limit Circuit:** Due to the circuit delay of FPS, the pulse-by-pulse limit current increases a little bit when the input voltage increases. This means unwanted excessive power is delivered to the secondary side. To compensate, the auxiliary power compensation network in Figure 19 can be used.  $R_{LIM}$  can adjust pulse-by-pulse current by absorbing internal current source ( $I_{FB}$ : typical value is 0.9mA), depending on the ratio between resistors. With the suggested compensation circuit, additional current from  $I_{FB}$  is absorbed more proportionally to the input voltage ( $V_{DC}$ ) and achieves constant power in wide input range. Choose  $R_{LIM}$  for proper current to the application, then check the pulse-by-pulse current difference between minimum and maximum input voltage. To eliminate the difference (to gain constant power),  $R_y$  can be calculated by:

$$R_y \cong \frac{I_{lim\_spec} \times V_{dc} \times \frac{N_a}{N_p}}{I_{fb} \times \Delta I_{lim\_comp}} \quad (3)$$

where,  $I_{lim\_spec}$  is the limit current stated on the specification;  $N_a$  and  $N_p$  are the number of turns for  $V_{CC}$  and primary side, respectively;  $I_{fb}$  is the internal current source at feedback pin with a typical value of 0.9mA; and  $\Delta I_{lim\_comp}$  is the current difference which must be eliminated. In case of capacitor in the circuit 1 $\mu$ F, 100V is good choice for all applications.

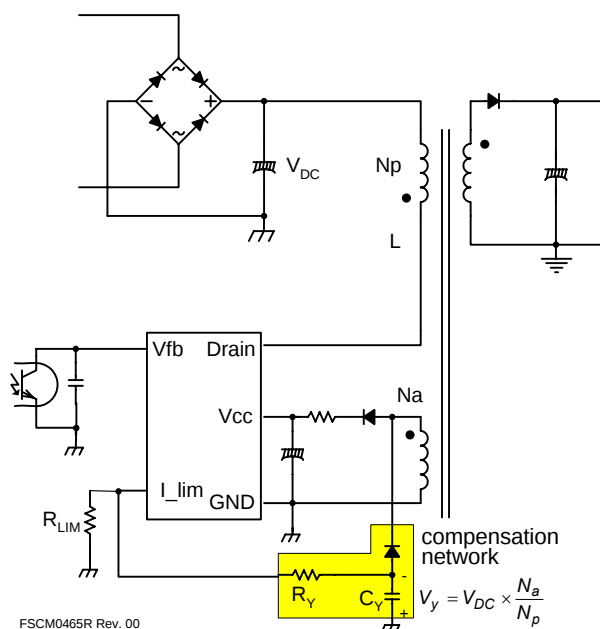


Figure 19. Constant power limit circuit

**2.3 Leading Edge Blanking (LEB):** At the instant the internal SenseFET is turned on, a high-current spike through the SenseFET usually occurs, caused by primary-side capacitance and secondary-side rectifier reverse recovery. Excessive voltage across the Rsense resistor can lead to incorrect feedback operation in the current mode PWM control. To counter this effect, the FSCM0465R employs a leading edge blanking (LEB) circuit. This circuit inhibits the PWM comparator for a short time after the SenseFET is turned on.

**3. Protection Circuit:** The FSCM0465R has several self-protective functions, such as overload protection (OLP), over-voltage protection (OVP) and thermal shutdown (TSD). Because these protection circuits are fully integrated into the IC without external components, the reliability is improved without increasing cost. Once the fault condition occurs, switching is terminated and the SenseFET remains off. This causes  $V_{CC}$  to fall. When  $V_{CC}$  reaches the UVLO stop voltage of 8V, the current consumed by the FSCM0465R decreases to the startup current (typically 20 $\mu$ A) and the current supplied from the DC link charges the external capacitor ( $C_a$ ) connected to the  $V_{CC}$  pin. When  $V_{CC}$  reaches the start voltage of 12V, the FSCM0465R resumes normal operation. In this manner, the auto-restart can alternately enable and disable the switching of the power SenseFET until the fault condition is eliminated (see Figure 20).

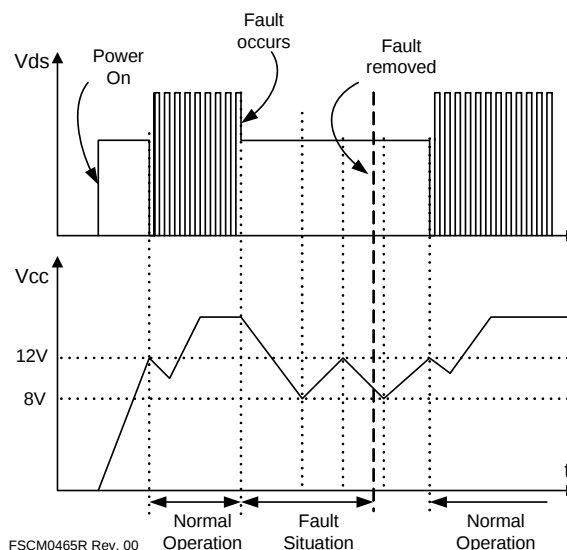


Figure 20. Auto Restart Operation

**3.1 Overload Protection (OLP):** Overload is defined as the load current exceeding a preset level due to an unexpected event. In this situation, the protection circuit should be activated to protect the SMPS. However, even when the SMPS is in the normal operation, the overload protection circuit can be activated during the load

transition. To avoid this undesired operation, the overload protection circuit is designed to be activated after a specified time to determine whether it is a transient situation or an overload situation. Because of the pulse-by-pulse current limit capability, the maximum peak current through the SenseFET is limited and the maximum input power is restricted with a given input voltage. If the output consumes beyond this maximum power, the output voltage ( $V_O$ ) decreases below the set voltage. This reduces the current through the opto-coupler LED, which also reduces the opto-coupler transistor current, increasing the feedback voltage ( $V_{fb}$ ). If  $V_{fb}$  exceeds 2.5V, D1 is blocked and the 5.3 $\mu$ A current source ( $I_{delay}$ ) starts to charge  $C_B$  slowly up to  $V_{CC}$ . In this condition,  $V_{fb}$  continues increasing until it reaches 6V, when the switching operation is terminated as shown in Figure 21. The delay time for shutdown is the time required to charge  $C_B$  from 2.5V to 6.0V with 5.3 $\mu$ A ( $I_{delay}$ ). A 10 ~ 50ms delay time is typical for most applications.

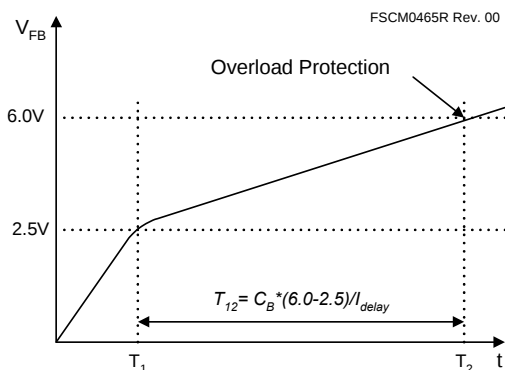


Figure 21. Overload Protection

**3.2 Over-Voltage Protection (OVP):** If the secondary-side feedback circuit were to malfunction or a solder defect causes an opening in the feedback path, the current through the opto-coupler transistor becomes almost zero. In this case,  $V_{fb}$  climbs up in a similar manner to the overload situation, forcing the preset maximum current to be supplied to the SMPS until the overload protection is activated. Because more energy than required is provided to the output, the output voltage may exceed the rated voltage before the overload protection is activated, resulting in the breakdown of the devices in the secondary side. To prevent this situation, an over-voltage protection (OVP) circuit is employed. In general,  $V_{CC}$  is proportional to the output voltage and the FSCM0465R uses  $V_{CC}$  instead of directly monitoring the output voltage. If  $V_{CC}$  exceeds 19V, an OVP circuit is activated, resulting in the termination of the switching operation. To avoid undesired activation of OVP during normal operation,  $V_{CC}$  should be designed to be below 19V.

**3.3 Thermal Shutdown (TSD):** The SenseFET and the control IC are built in one package. This makes it easy for the control IC to detect the heat generation from the SenseFET. When the temperature exceeds approximately 145°C, the thermal protection is triggered, resulting in shutdown of the FPS.

**4. Frequency Modulation:** EMI reduction can be accomplished by modulating the switching frequency of a switched power supply. Frequency modulation can reduce EMI by spreading the energy over a wider frequency range than the bandwidth measured by the EMI test equipment. The amount of EMI reduction is directly related to the depth of the reference frequency. As can be seen in Figure 22, the frequency changes from 63KHz to 69KHz in 4ms.

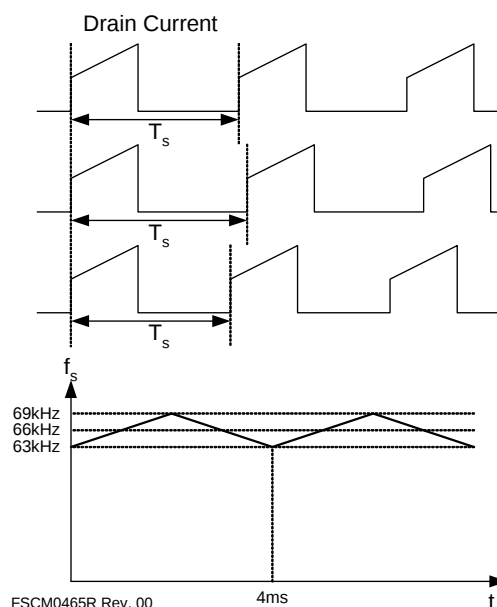
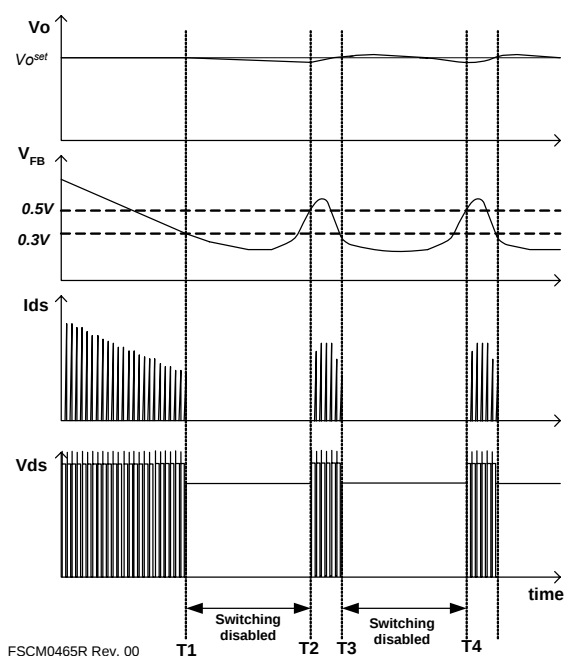


Figure 22. Frequency Modulation

**5. Soft-Start:** The FSCM0465R has an internal soft-start circuit that increases PWM comparator inverting input voltage, together with the SenseFET current, slowly after it starts up. The typical soft-start time is 15ms. The pulse width to the power switching device is progressively increased to establish the correct working conditions for transformers, rectifier diodes, and capacitors. The voltage on the output capacitors is progressively increased with the intention of smoothly establishing the required output voltage. Preventing transformer saturation and reducing stress on the secondary diode during startup is also helpful.

**6. Burst Operation:** To minimize power dissipation in standby mode, the FSCM0465R enters into burst-mode operation at light load condition. As the load decreases, the feedback voltage decreases. As shown in Figure 23, the device automatically enters burst mode when the feedback voltage drops below  $V_{BURL}$  (300mV). 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  $V_{BURH}$  (500mV), switching resumes. The feedback voltage then falls and the process repeats. Burst mode operation alternately enables and disables switching of the power SenseFET, thereby reducing switching loss in standby mode.



**Figure 23. Waveforms of Burst Operation**



## 2. Transformer

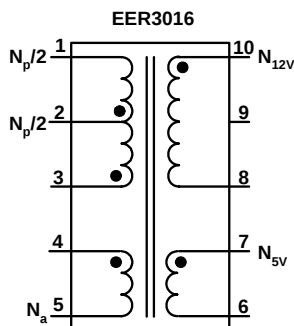


Figure 25. Transformer Schematic Diagram

## 3. Winding Specification

| No                                                               | Pin (s→f) | Wire                | Turns | Winding Method   |
|------------------------------------------------------------------|-----------|---------------------|-------|------------------|
| Na                                                               | 4 → 5     | $0.2^\phi \times 1$ | 8     | Center Winding   |
| Insulation: Polyester Tape $t = 0.050\text{mm}$ , 2 Layers       |           |                     |       |                  |
| Np/2                                                             | 2 → 1     | $0.4^\phi \times 1$ | 18    | Solenoid Winding |
| Insulation: Polyester Tape $t = 0.050\text{mm}$ , 2 Layers       |           |                     |       |                  |
| N <sub>12V</sub>                                                 | 10 → 8    | $0.3^\phi \times 3$ | 7     | Center Winding   |
| Insulation: Polyester Tape $t = 0.050\text{mm}$ , 2 Layers       |           |                     |       |                  |
| N5V                                                              | 7 → 6     | $0.3^\phi \times 3$ | 3     | Center Winding   |
| Insulation: Polyester Tape $t = 0.050\text{mm}$ , 2 Layers       |           |                     |       |                  |
| Np/2                                                             | 3 → 2     | $0.4^\phi \times 1$ | 18    | Solenoid Winding |
| Outer Insulation: Polyester Tape $t = 0.050\text{mm}$ , 2 Layers |           |                     |       |                  |

## 4. Electrical Characteristics

|                    | Pin   | Specification             | Remarks                   |
|--------------------|-------|---------------------------|---------------------------|
| Inductance         | 1 - 3 | $520\mu\text{H} \pm 10\%$ | 100kHz, 1V                |
| Leakage Inductance | 1 - 3 | 10μH Max                  | 2 <sup>nd</sup> all Short |

## 5. Core & Bobbin

- Core: EER 3016
- Bobbin: EER3016
- Ae(mm<sup>2</sup>): 96

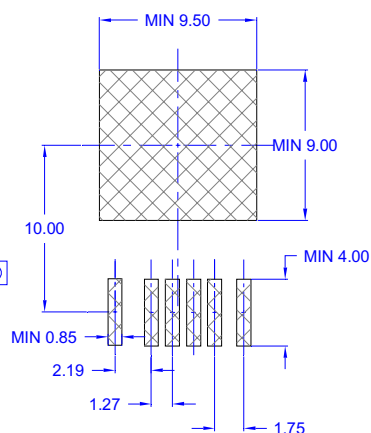
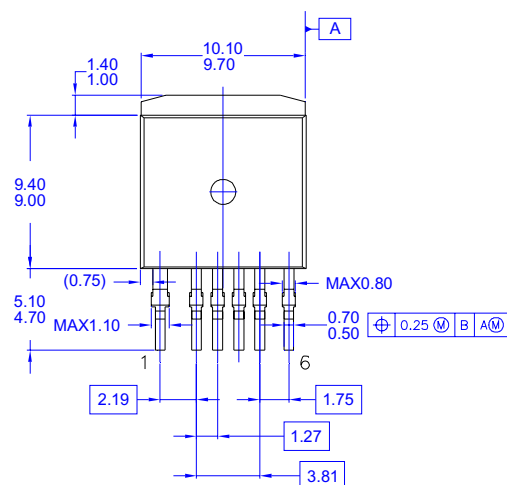
## 6. Demo Circuit Part List

| Part             | Value        | Note                   | Part                | Value         | Note                |
|------------------|--------------|------------------------|---------------------|---------------|---------------------|
| <b>Fuse</b>      |              |                        | C301                | 4.7nF         | Polyester Film Cap. |
| F101             | 2A/250V      |                        |                     |               |                     |
| <b>NTC</b>       |              |                        | <b>Inductor</b>     |               |                     |
| RT101            | 5D-9         |                        | L201                | 5μH           | Wire 1.2mm          |
| <b>Resistor</b>  |              |                        | L202                | 5μH           | Wire 1.2mm          |
| R101             | 560kΩ        | 0.5W                   |                     |               |                     |
| R103             | 56kΩ         | 2W                     |                     |               |                     |
| R104             | 20Ω          | 1/4W                   | <b>Diode</b>        |               |                     |
| R107             | 330kΩ        | 1/4W                   | D101                | UF4007        |                     |
| R108             | 330kΩ        | 1/4W                   | D102                | UF4004        |                     |
| R201             | 1kΩ          | 1/4W                   | D201                | MBRF1060      |                     |
| R202             | 1.2kΩ        | 1/4W                   | D202                | MBRF10H100    |                     |
| R203             | 10kΩ         | 1/4W                   |                     |               |                     |
| R204             | 5.6kΩ        | 1/4W                   |                     |               |                     |
| R205             | 5.6kΩ        | 1/4W                   | <b>Bridge Diode</b> |               |                     |
|                  |              |                        | BD101               | 2KBP06M 3N257 | Bridge Diode        |
| <b>Capacitor</b> |              |                        |                     |               |                     |
| C101             | 220nF/275VAC | Box Capacitor          | <b>Line Filter</b>  |               |                     |
| C102             | 220nF/275VAC | Box Capacitor          | LF101               | 23mH          | Wire 0.4mm          |
| C103             | 100μF/400V   | Electrolytic Capacitor | <b>IC</b>           |               |                     |
| C104             | 3.3nF/630V   | Ceramic Capacitor      | IC101               | FSCM0465R     | FPS™ (2.5A, 650V)   |
| C105             | 22μF/50V     | Electrolytic Capacitor | IC201               | KA431(TL431)  | Voltage Reference   |
| C106             | 100nF/50V    | Ceramic Capacitor      | IC301               | H11A817A      | Opto-coupler        |
| C201             | 1000μF/25V   | Electrolytic Capacitor |                     |               |                     |
| C202             | 1000μF/25V   | Electrolytic Capacitor |                     |               |                     |
| C203             | 1000μF/10V   | Electrolytic Capacitor |                     |               |                     |
| C204             | 1000μF/10V   | Electrolytic Capacitor |                     |               |                     |
| C205             | 47nF/50V     | Ceramic Capacitor      |                     |               |                     |

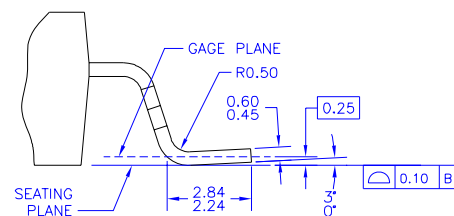
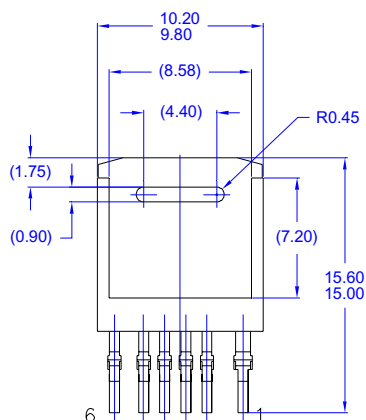
# Package Dimensions

## D2-PAK-6L

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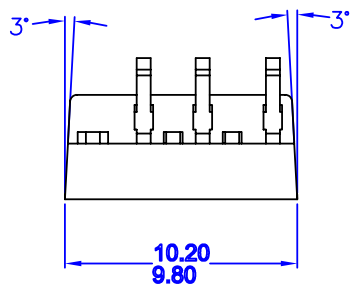
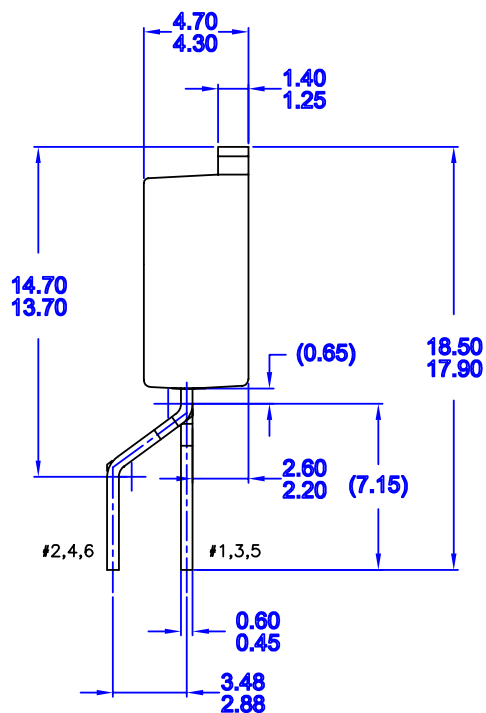
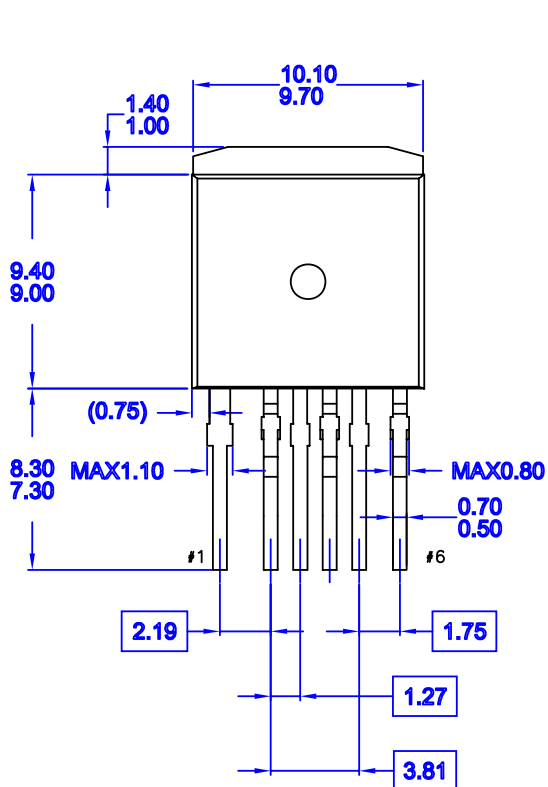
DETAIL A, ROTATED 90°  
SCALE: 2X

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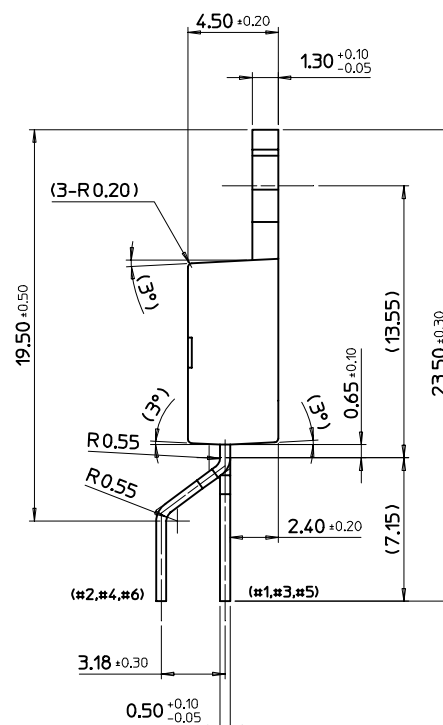
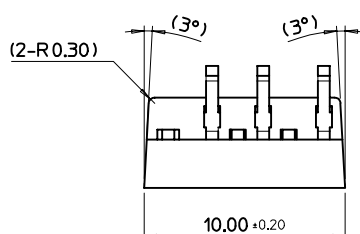
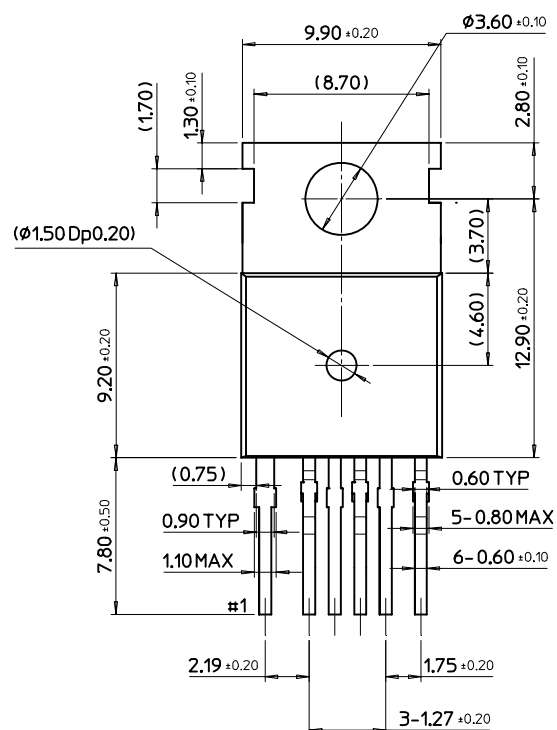
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