

$V_{RM} = 200\text{ V}$ ,  $I_F = 5\text{ A}$ ,  $10\text{ A}$ ,  $15\text{ A}$   
**Fast Recovery Diode Built-in Temperature Detection**  
**FMKS Series**

**Description**

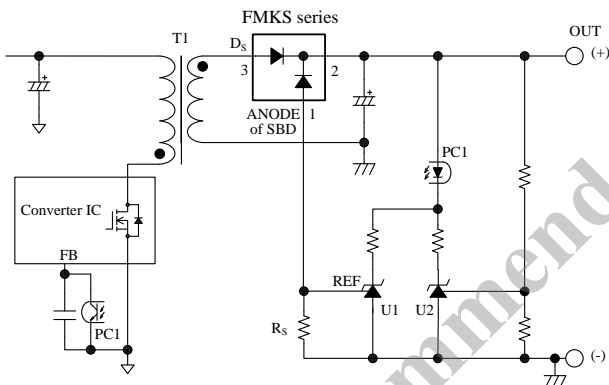
The FMKS Series is the fast recovery diode built-in temperature detection.

A fast recovery diode and a Schottky barrier diode for temperature detection are formed on the same die. Thus, the FMKS Series achieves highly accurate temperature detection that is higher than that with a thermistor, component reduction, power supply downsizing, and easy attachment.

**Features**

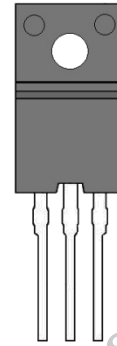
- Built-in temperature detection
- Highly accurate temperature detection of FRD
- Component reduction of temperature detection
- High speed switching
- Low forward voltage drop

**Typical Application**



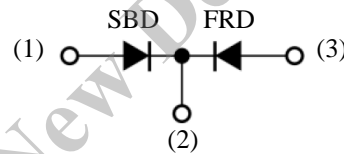
**Package**

TO220F-3L



(1)(2)(3)

Not to scale



- (1) Anode of Schottky barrier diode, SBD, for temperature detection
- (2) Cathode
- (3) Anode of fast recovery diode, FRD

**FMKS Series**

Products	$V_{RM}$	$I_F$	$V_F$	$t_r$
FMKS-2052	200 V	5 A	0.98 V	50 ns
FMKS-2102		10 A		
FMKS-2152		15 A		

where,  
 $V_{RM}$  is peak reverse voltage,  
 $I_F$  is average forward current,  
 $V_F$  is forward voltage drop, and  
 $t_r$  is reverse recovery time

**Application**

The following with thermal protection circuit and peak power limiting circuit, and so forth

- Audio
- White goods
- Power Supplies

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Not Recommended for New Designs

## FMKS Series

### 1. Absolute Maximum Ratings

Unless specifically noted  $T_A = 25\text{ }^\circ\text{C}$ .

Parameter	Symbol	Conditions	Rating	Unit	Note
<b>Fast Recovery Diode (FRD)</b>					
Transient Peak Reverse Voltage	$V_{RSM}$		200	V	
Peak Repetitive Reverse Voltage	$V_{RM}$		200	V	
Average Forward Current	$I_{F(AV)}$		5	A	FMKS-2052
			10		FMKS-2102
			15		FMKS-2152
Surge Forward Current	$I_{FSM}$	10 ms, half sine wave, one shot	100	A	FMKS-2052
			140		FMKS-2102
			170		FMKS-2152
$I^2t$ Limiting Value	$I^2t$	$1\text{ ms} \leq t \leq 10\text{ ms}$	50	$A^2s$	FMKS-2052
			98		FMKS-2102
			144.5		FMKS-2152
Junction Temperature	$T_j$		-40 to 150	$^\circ\text{C}$	
Storage Temperature	$T_{stg}$		-40 to 150	$^\circ\text{C}$	
Isolation Voltage	-	Between the case and each pin, 1 minute, ac	1.0	kV	
<b>Schottky Barrier Diode for Temperature Detection (SBD)</b>					
Transient Peak Reverse Voltage	$V_{RSM}$		90	V	
Peak Repetitive Reverse Voltage	$V_{RM}$		90	V	
Junction Temperature	$T_j$		-40 to 150	$^\circ\text{C}$	
Storage Temperature	$T_{stg}$		-40 to 150	$^\circ\text{C}$	

## FMKS Series

### 2. Electrical Characteristics

Unless specifically noted  $T_A = 25\text{ }^\circ\text{C}$ .

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit	Note
<b>Fast Recovery Diode (FRD)</b>							
Forward Voltage Drop	$V_F$	$I_F = 5\text{ A}$	–	–	0.98	V	FMKS-2052
		$I_F = 10\text{ A}$	–	–	0.98		FMKS-2102
		$I_F = 15\text{ A}$	–	–	0.98		FMKS-2152
Reverse Leakage Current	$I_R$	$V_R = V_{RM}$	–	–	50	$\mu\text{A}$	FMKS-2052
			–	–	100		FMKS-2102
			–	–	150		FMKS-2152
Reverse Leakage Current Under High Temperature	$H \cdot I_R$	$V_R = V_{RM}$ $T_j = 150\text{ }^\circ\text{C}$	–	–	3	mA	FMKS-2052
			–	–	6		FMKS-2102
			–	–	10		FMKS-2152
Reverse Recovery Time	$t_{r1}$	$I_F = I_{RP} = 100\text{ mA}$ , $T_j = 25\text{ }^\circ\text{C}$ , 90 % recovery point	–	–	50	ns	
	$t_{r2}$	$I_F = 100\text{ mA}$ , $I_{RP} = 200\text{ mA}$ , $T_j = 25\text{ }^\circ\text{C}$ , 75 % recovery point	–	–	35	ns	
Thermal Resistance*	$R_{th(j-c)}$		–	–	4.0	$^\circ\text{C/W}$	
<b>Schottky Barrier Diode for Temperature Detection Diode (SBD)</b>							
Reverse Leakage Current	$I_{R1}$	$V_R = 15\text{ V}$	–	–	50	$\mu\text{A}$	
	$I_{R2}$	$V_R = 90\text{ V}$	–	–	2.0	mA	
Reverse Leakage Current Under High Temperature	$H \cdot I_{R1}$	$V_R = 15\text{ V}$ , $T_j = 130\text{ }^\circ\text{C}$	1.20	1.90	2.60	mA	
	$H \cdot I_{R2}$	$V_R = 90\text{ V}$ , $T_j = 150\text{ }^\circ\text{C}$	–	–	55	mA	

\*  $R_{th(j-c)}$  is thermal resistance between junction and case.

3. Performance Curves

3.1 Schottky Barrier Diode for Temperature Detection Diode Characteristics

In Figure 3-1, the reverse voltage of Schottky Barrier Diode for temperature detection (SBD),  $V_R$ , is 15V. The temperature of fast recovery diode (FRD) can be estimated by using Figure 3-1.

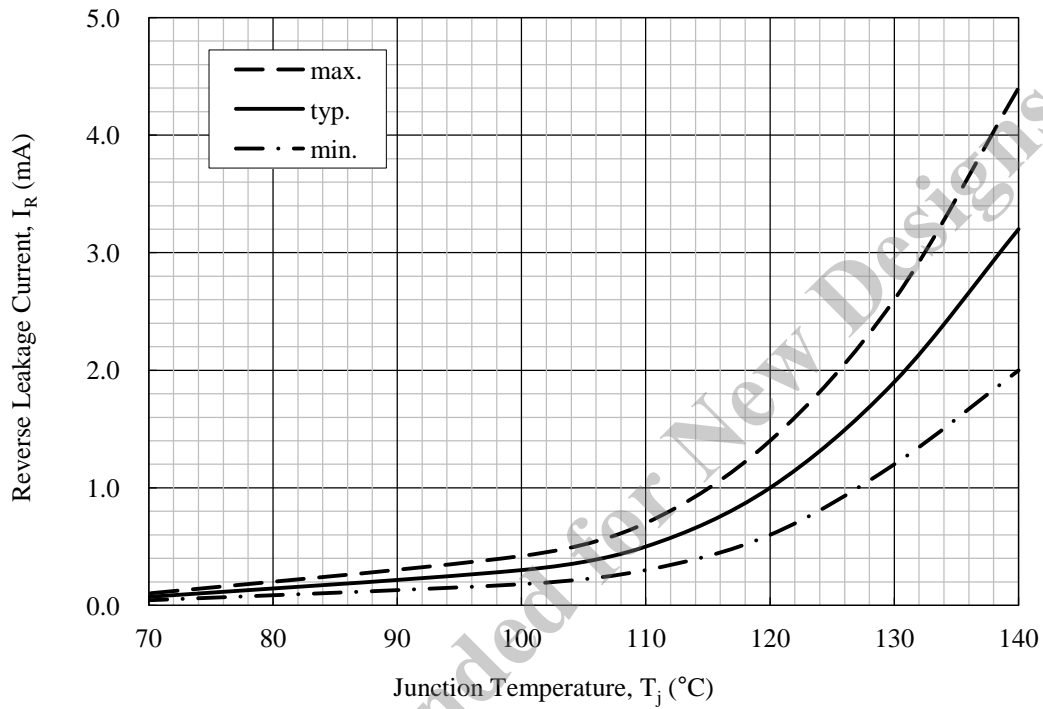


Figure 3-1 Temperature dependent of Reverse Leakage Current,  $I_R$  (SBD)

### 3.2 Fast Recovery Diode Characteristics

T is a pulse cycle, t is a pulse width.

#### 3.2.1 FMKS-2052

##### 3.2.1.1. Typical Characteristics

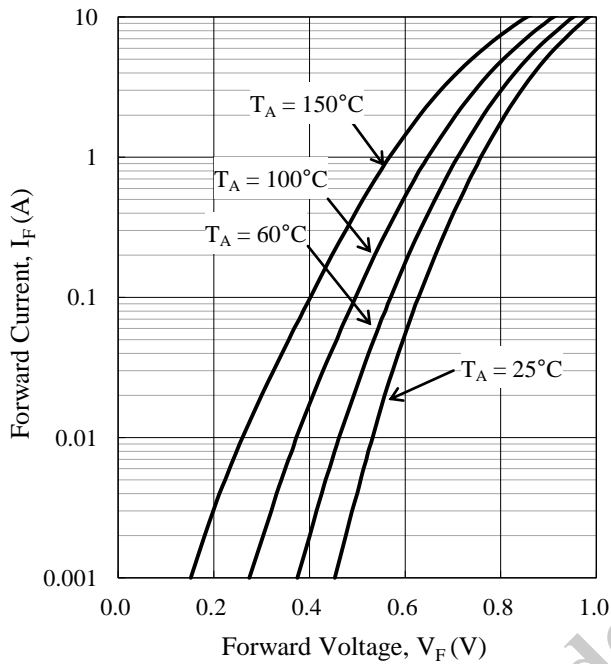


Figure 3-2  $I_F - V_F$  Typical Characteristics

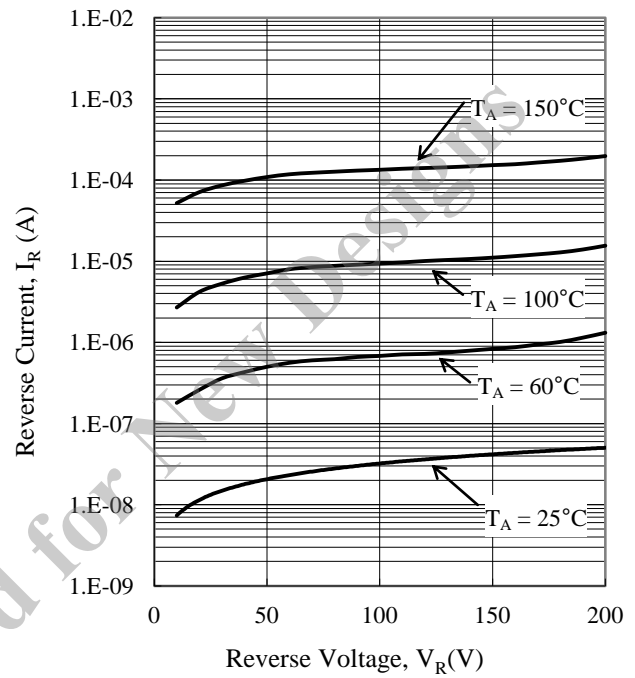


Figure 3-3  $I_R - V_R$  Typical Characteristics

Not Recommended for New Designs

3.2.1.2. Power Dissipation Curves ( $T_j = 150\text{ }^\circ\text{C}$ )

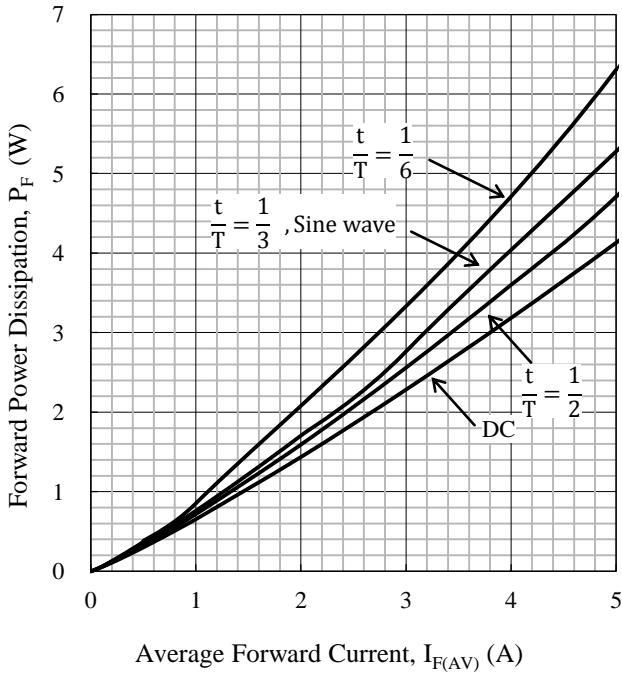


Figure 3-4  $P_F - I_{F(AV)}$

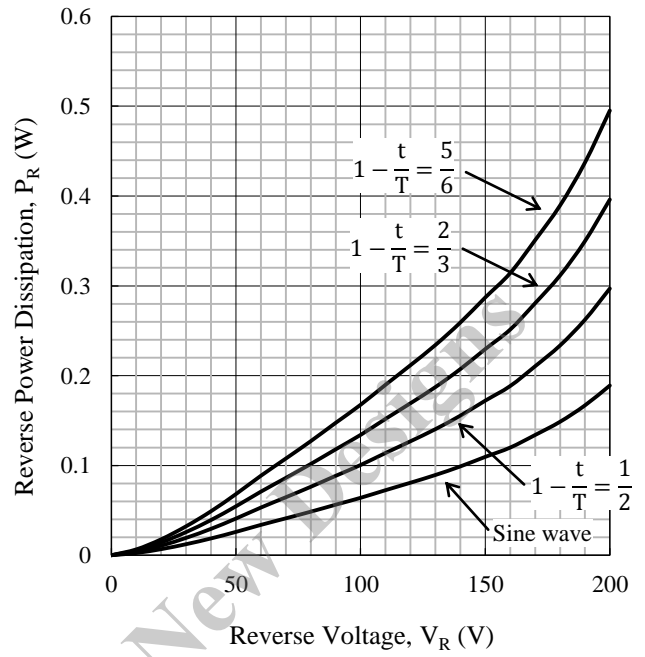


Figure 3-5  $P_R - V_R$

3.2.1.3. Derating Curves ( $T_j = 150\text{ }^\circ\text{C}$ )

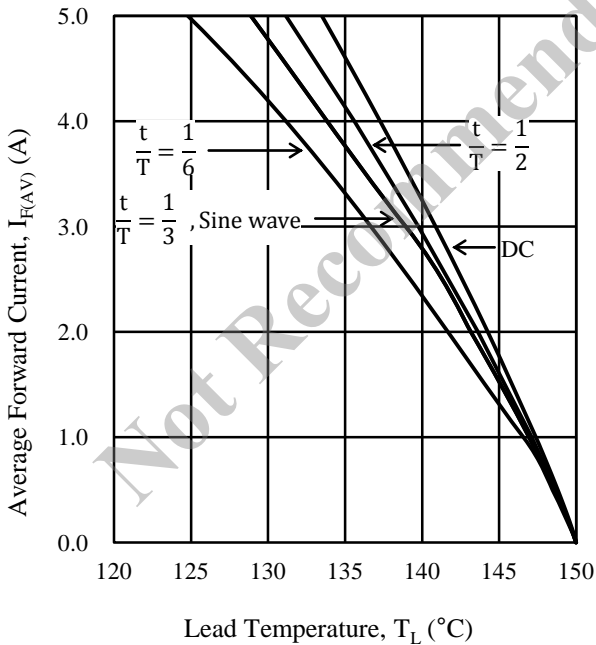


Figure 3-6  $I_{F(AV)} - T_L (V_R = 0\text{ V})$

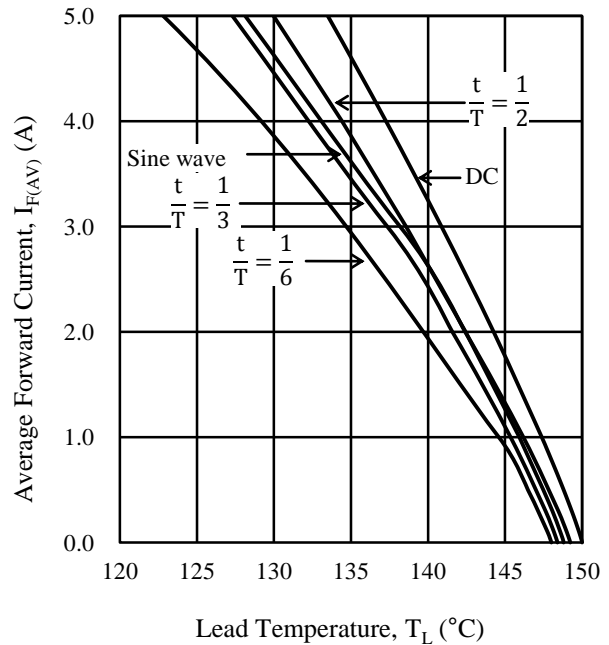


Figure 3-7  $I_{F(AV)} - T_L (V_R = 200\text{ V})$

3.2.2 FMKS-2102

3.2.2.1. Typical Characteristics

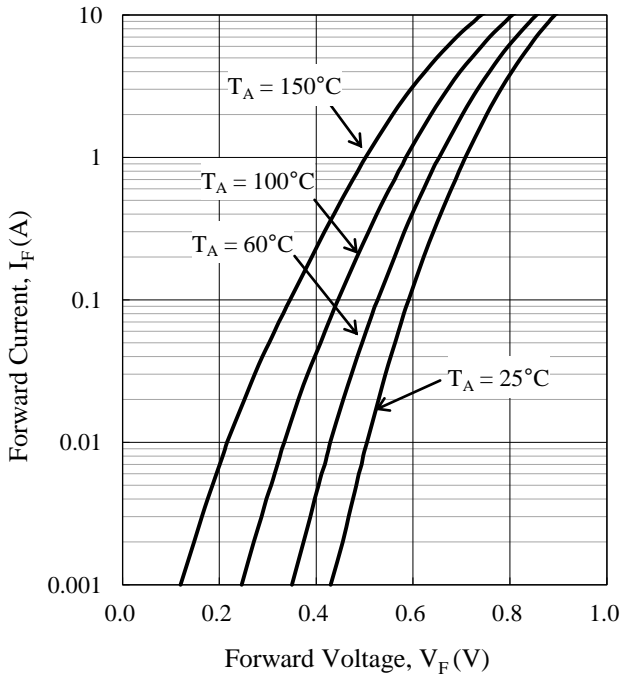


Figure 3-8  $V_F - I_F$  Typical Characteristics

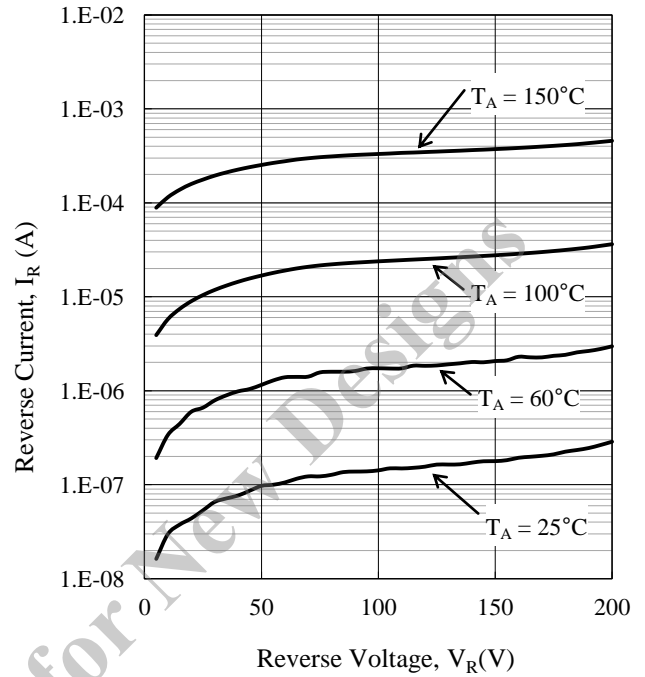


Figure 3-9  $V_R - I_R$  Typical Characteristics

3.2.2.2. Power Dissipation Curves ( $T_j = 150^\circ\text{C}$ )

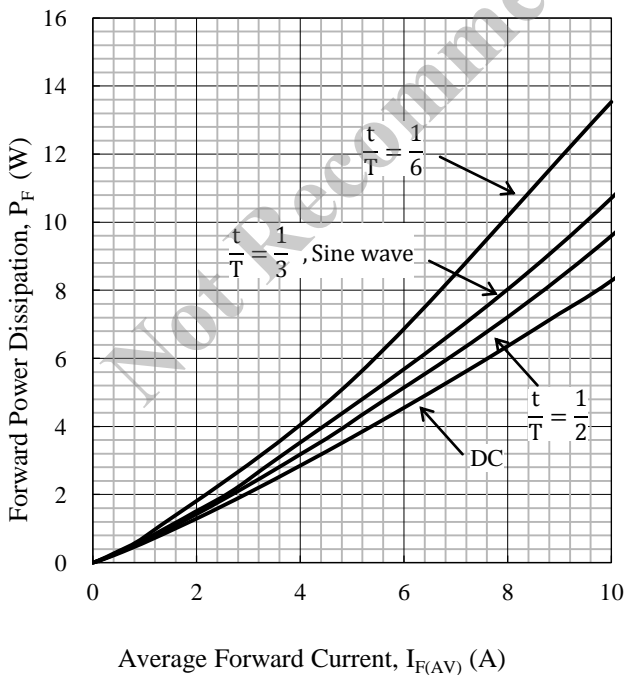


Figure 3-10  $P_F - I_{F(AV)}$

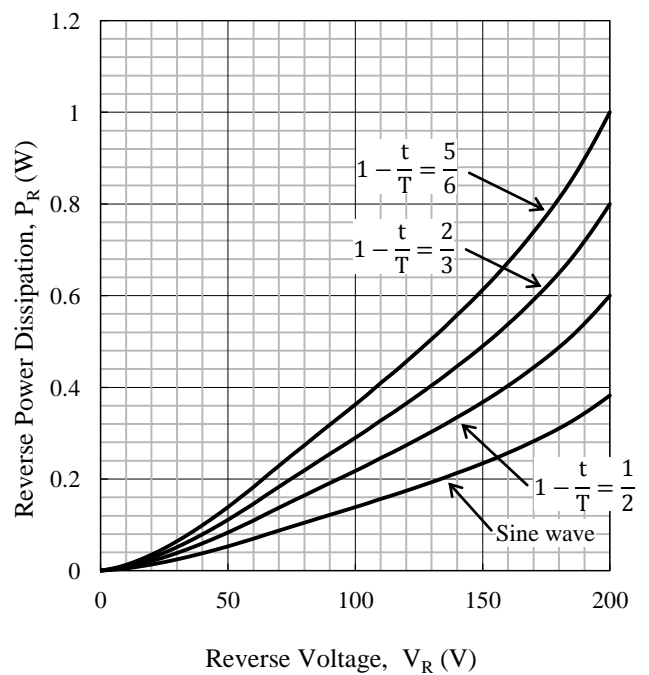


Figure 3-11  $P_R - V_R$



3.2.2.3. Derating Curves ( $T_j = 150^\circ\text{C}$ )

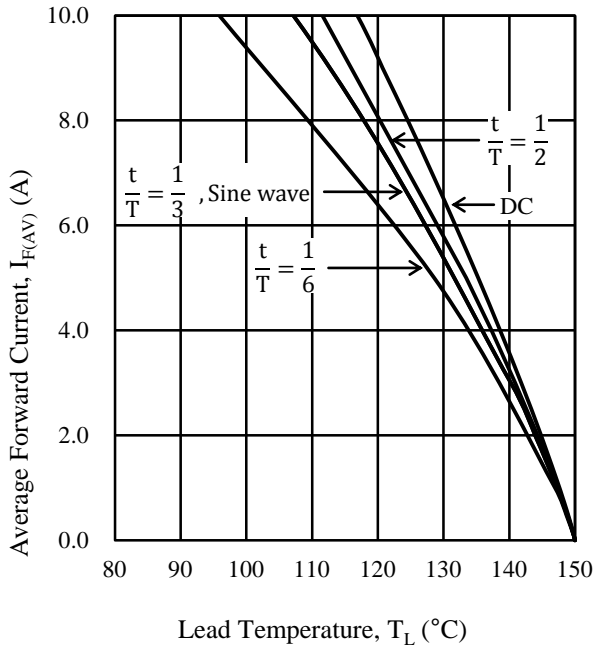


Figure 3-12  $I_{F(AV)} - T_L$  ( $V_R = 0\text{ V}$ )

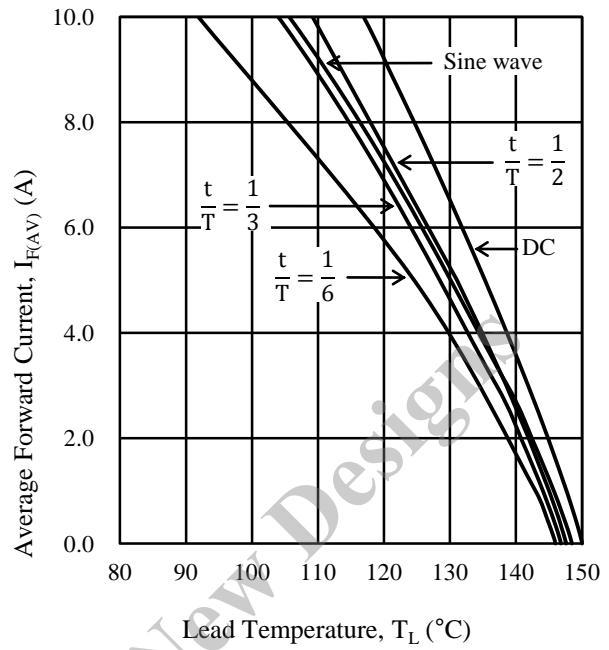


Figure 3-13  $I_{F(AV)} - T_L$  ( $V_R = 200\text{ V}$ )

3.2.3 FMKS-2152

3.2.3.1. Typical Characteristics

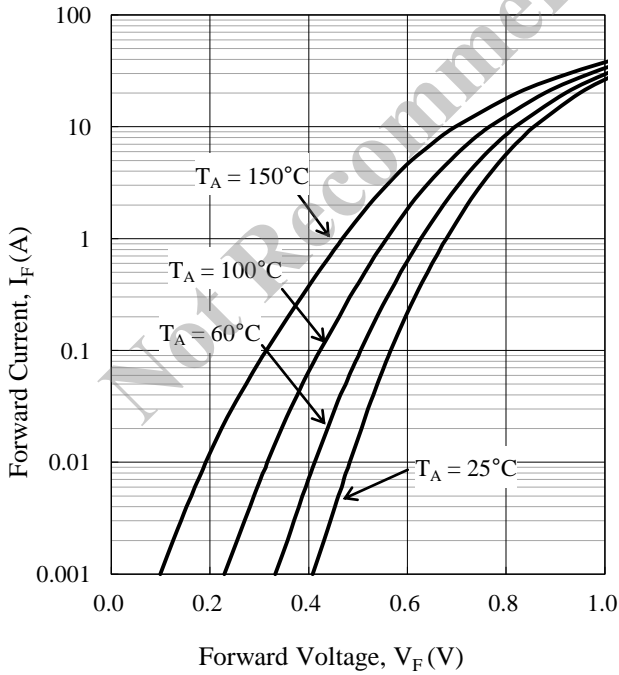


Figure 3-14  $V_F - I_F$  Typical Characteristics

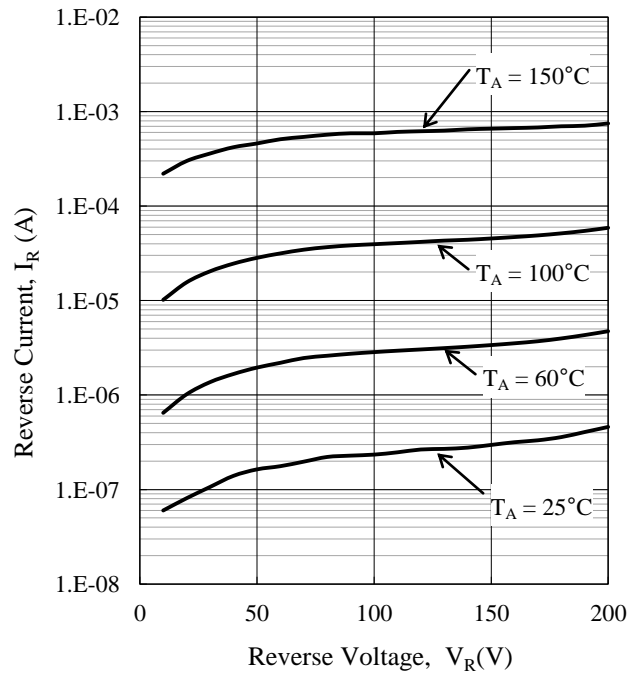


Figure 3-15  $V_R - I_R$  Typical Characteristics

3.2.3.2. Power Dissipation Curves ( $T_j = 150\text{ }^\circ\text{C}$ )

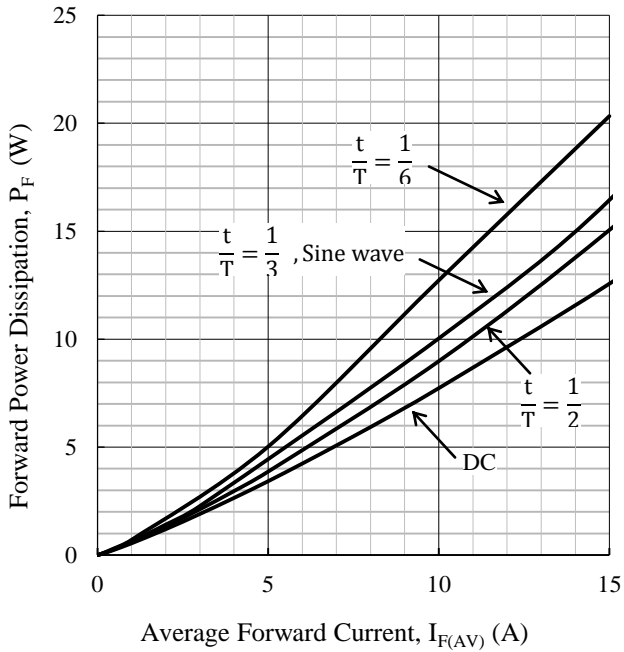


Figure 3-16  $P_F - I_{F(AV)}$

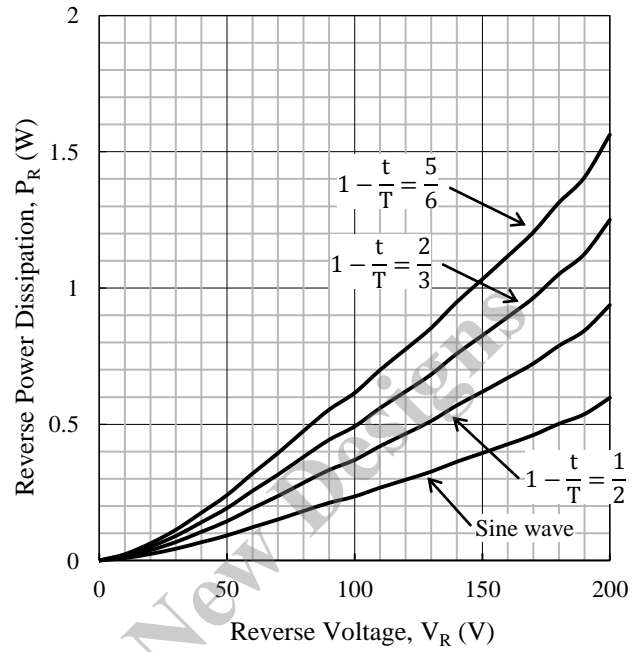


Figure 3-17  $P_R - V_R$

3.2.3.3. Derating Curves ( $T_j = 150\text{ }^\circ\text{C}$ )

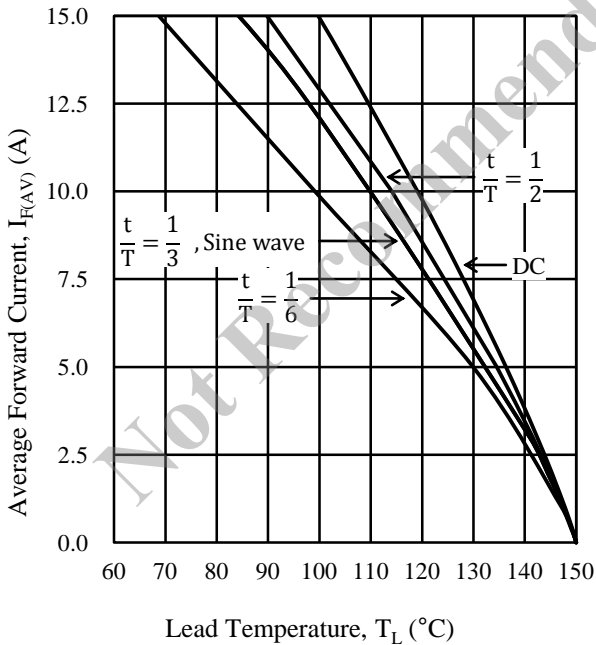


Figure 3-18  $I_{F(AV)} - T_L$  ( $V_R = 0\text{ V}$ )

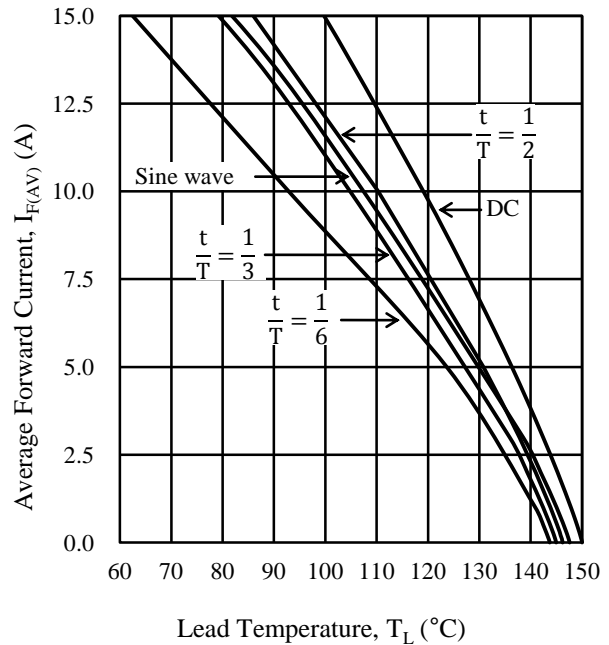
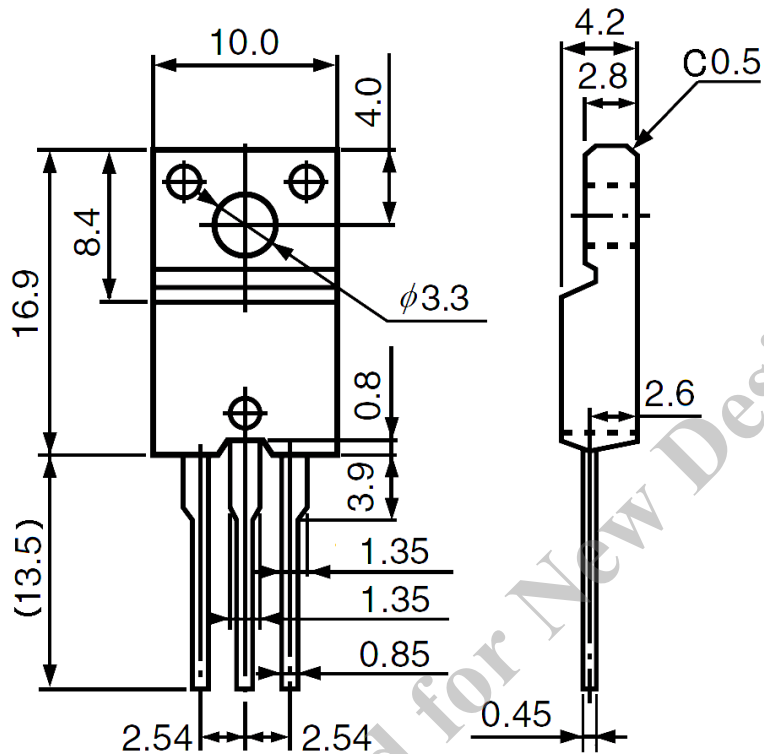


Figure 3-19  $I_{F(AV)} - T_L$  ( $V_R = 200\text{ V}$ )

4. External Dimensions

TO220F-3L



NOTES:

- Dimension is in millimeters.
- Lead treatment Pb-free. Device composition compliant with the RoHS directive.

5. Marking Diagram

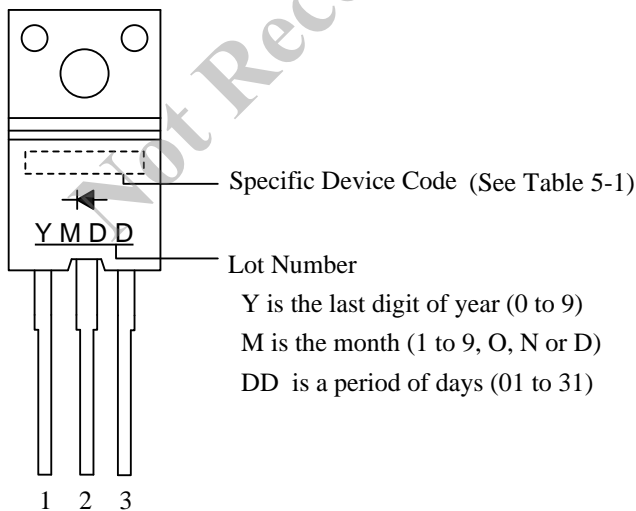


Table 5-1 Specific Device Code

Specific Device Code	Products
KS2052	FMKS-2052
KS2102	FMKS-2102
KS2152	FMKS-2152

## 6. Temperature Detection Application of FMKS Series

This section shows an example about a temperature detection circuit of a secondary rectifier diode in off-line flyback converters.

Figure 6-1 shows the reference of temperature detection circuit with a NTC thermistor. The NTC thermistor, coupled thermally with  $D_S$  secondary rectifier diode, is connected to the REF pin of the output voltage detection circuit in the converter.

As shown in Figure 6-2, as the temperature rises, the resistance of the NTC thermistor decreases.

When the temperature of  $D_S$  rises due to such a cause as overload state, the resistance of NTC thermistor decreases, and the ratio of resistance voltage divider is changed. When the voltage of  $R_S$  shown in Figure 6-1 reaches the reference voltage of U1 shunt regulator, the current flows to PC1 optocoupler, and the converter IC in the primary limits the output power. Thus, the rise of  $D_S$  temperature can be limited.

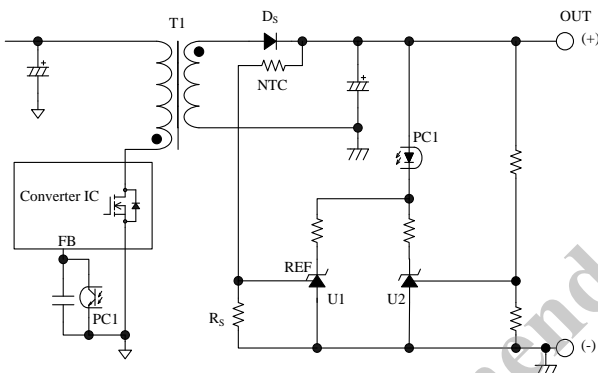


Figure 6-1 Reference temperature detection circuit with NTC thermistor

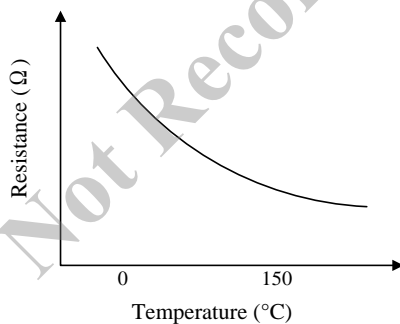


Figure 6-2 Reference characteristics of NTC thermistor

The temperature detection circuit with thermistor has the following issues.

- Since some attachment distance occurs between the thermistor and  $D_S$ , the accurate temperature of  $D_S$  cannot be detected.
- Thermistor cannot follow the rapid temperature change.

- Increasing the accuracy of temperature detection by reducing the thermal resistance between  $D_S$  and the thermistor, it is necessary to attach the thermistor to  $D_S$  with high thermal conductivity material between them.

In contrast with the temperature detection of thermistor, the FMKS series can achieve high accuracy of temperature detection by the following.

- The internal structure is formed a Schottky barrier diode for temperature detection, SBD, and a fast recovery diode, FRD, on the same die as shown in Figure 6-3. Thus, the temperature is about the same between SBD and FRD.
- The temperature detection uses the temperature characteristics of the leakage current for SBD, which increases as the temperature rises as shown in Figure 6-4.

The temperature detection circuit with FMKS series has the following advantages.

- Highly accurate and stable temperature detection of FRD.
- Real time temperature detection of FRD.
- Circuit component reduction such as thermistor, and easy attachment.
- Power supply downsizing.

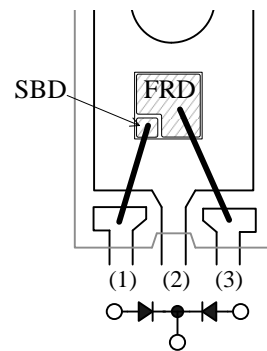


Figure 6-3 Internal structure of FMKS series

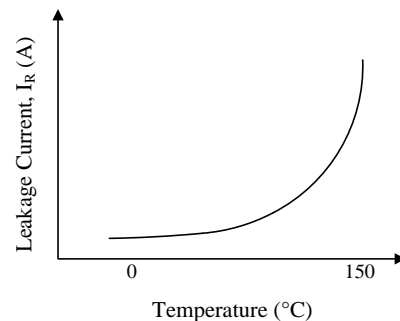


Figure 6-4 Reference temperature characteristics of SBD leakage current

Figure 6-5 shows the reference of temperature detection circuit with FMKS series. The ANODE pin of SBD for the temperature detection in  $D_S$  secondary rectifier diode is connected to the REF pin of the shunt regulator of the output voltage detection circuit in the converter.

When the temperature of  $D_S$  rises due to such a cause as overload state, the leakage current,  $I_R$ , of SBD for temperature detection increases, and the voltage of  $R_S$  shown in Figure 6-5 increases. When  $R_S$  voltage reaches the reference voltage of U1 shunt regulator, the current flows to PC1 optocoupler, and the converter IC in the primary limits the output power. Thus, the rise of  $D_S$  temperature can be limited.

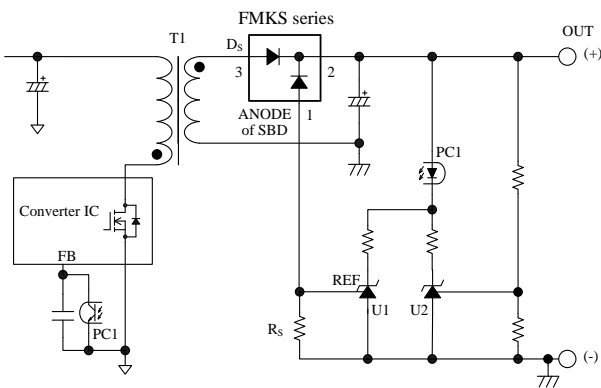


Figure 6-5 Reference temperature detection circuit with FMKS series.

In Figure 6-5,  $R_S$  value is calculated as follows.

$$R_S = \frac{V_{REF}}{I_{R(TD)MAX}}$$

where,

$V_{REF}$  is the reference voltage of U1 shunt regulator,  
 $I_{R(TD)MAX}$  is the maximum leakage current of SBD at the temperature detection value of  $T_D$  in Figure 6-6 or Section 3.1.

When  $T_D$  is 115 °C,  $I_{R(TD)MAX}$  is 1 mA as shown Figure 6-6. Thus, when  $V_{REF}$  is 2.5 V,  $R_S$  value is 2.5 kΩ, and thus the FMKS series can detect in the range of 115 °C to 127 °C.

When  $R_S$  value is chosen 2.7 kΩ from E24 series close to the above value,  $I_{R(TD)MAX}$  is 0.93 mA, and thus the temperature detection range is 114 °C to 126 °C.

When the junction temperature of SBD rises close to 150 °C, the leakage current of SBD increases rapidly and the power dissipation increases. Thus,  $R_S$  should be set so that the temperature is detected in 140 °C or less including variation.

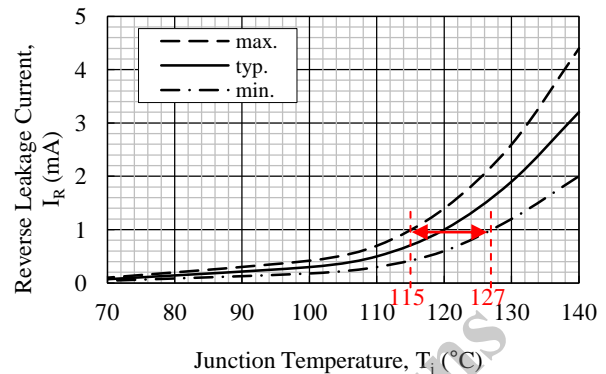


Figure 6-6 Temperature detection range at  $I_R=1.0mA$

Figure 6-7 shows the reference circuit for multi-outputs with FMKS series in off-line flyback converter.

In the case that FMKS series and the synchronous rectification device,  $Q_{SYN}$ , for the other output are attached on the same heatsink so that the temperature from  $Q_{SYN}$  is conducted to FMKS series, the FMKS series can detect the temperature in the following.

- The overload state of  $Q_{SYN}$ .
- The rectification state by the rectifier diode in  $Q_{SYN}$  because the synchronous rectification IC malfunctions and thus  $Q_{SYN}$  is kept off.

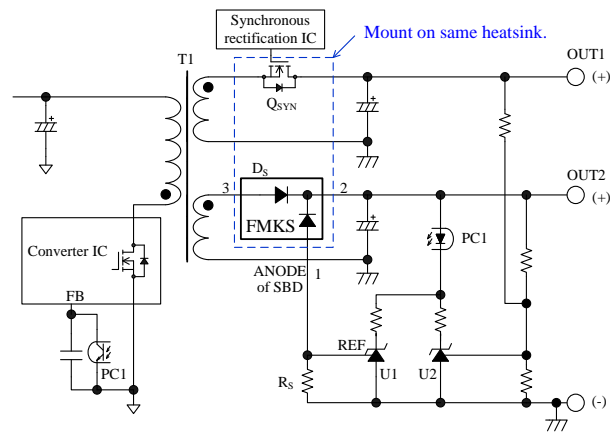


Figure 6-7 Reference circuit with FMKS series in the multi-output flyback converter circuit

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