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

**Data Sheet**

## Description

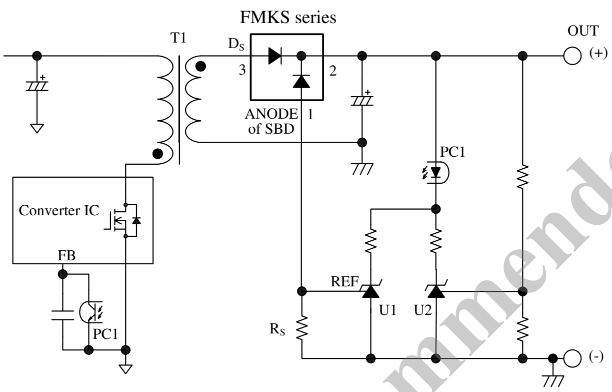
The FMKS Series is the fast recovery diode built-in temperature detection.

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

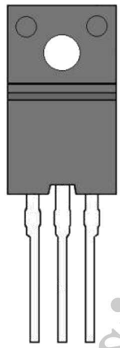
- Built-in temperature detection
- Highly accurate temperature detection of FRD
- Component reduction of temperature detection
- High speed switching
- Low forward voltage drop

## Typical Application

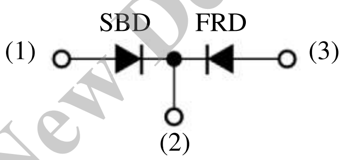



## Package

TO220F-3L




Not to scale




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

## FMKS Series

| Products | $V_{RM}$ | $I_F$ | $V_F$ | $t_{rr}$ |
|---|---|---|---|---|
| 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
$t_{rr}$ 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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## 1. Absolute Maximum Ratings

Unless specifically noted $T_A$ = 25 °C.

| Parameter | Symbol | Conditions | Rating | Unit | Note |
|---|---|---|---|---|---|
| **Fast Recovery Diode (FRD)** | | | | | |
| 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 ms ≤ t ≤10 ms | 50 | $A^2s$ | FMKS-2052 |
| | | | 98 | | FMKS-2102 |
| | | | 144.5 | | FMKS-2152 |
| Junction Temperature | $T_j$ | | −40 to 150 | °C | |
| Storage Temperature | $T_{stg}$ | | −40 to 150 | °C | |
| Isolation Voltage | − | Between the case and each pin, 1 minute, ac | 1.0 | kV | |
| **Schottky Barrier Diode for Temperature Detection (SBD)** | | | | | |
| Transient Peak Reverse Voltage | $V_{RSM}$ | | 90 | V | |
| Peak Repetitive Reverse Voltage | $V_{RM}$ | | 90 | V | |
| Junction Temperature | $T_j$ | | −40 to 150 | °C | |
| Storage Temperature | $T_{stg}$ | | −40 to 150 | °C | |

## 2. Electrical Characteristics

Unless specifically noted $T_A$ = 25 °C.

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit | Note |
|---|---|---|---|---|---|---|---|
| **Fast Recovery Diode (FRD)** | | | | | | | |
| Forward Voltage Drop | $V_F$ | $I_F$ = 5 A | − | − | 0.98 | V | FMKS-2052 |
| | | $I_F$ = 10 A | − | − | 0.98 | | FMKS-2102 |
| | | $I_F$ = 15 A | − | − | 0.98 | | FMKS-2152 |
| Reverse Leakage Current | $I_R$ | $V_R = V_{RM}$ | − | − | 50 | µA | FMKS-2052 |
| | | | − | − | 100 | | FMKS-2102 |
| | | | − | − | 150 | | FMKS-2152 |
| Reverse Leakage Current Under High Temperature | $H \cdot I_R$ | $V_R = V_{RM}$<br>$T_j$ = 150 °C | − | − | 3 | mA | FMKS-2052 |
| | | | − | − | 6 | | FMKS-2102 |
| | | | − | − | 10 | | FMKS-2152 |
| Reverse Recovery Time | $t_{rr1}$ | $I_F = I_{RP}$ = 100 mA,<br>$T_j$ = 25 °C,<br>90 % recovery point | − | − | 50 | ns | |
| | $t_{rr2}$ | $I_F$ = 100 mA,<br>$I_{RP}$ = 200 mA,<br>$T_j$ = 25 °C,<br>75 % recovery point | − | − | 35 | ns | |
| Thermal Resistance* | $R_{th(j-C)}$ | | − | − | 4.0 | °C/W | |
| **Schottky Barrier Diode for Temperature Detection Diode (SBD)** | | | | | | | |
| Reverse Leakage Current | $I_{R1}$ | $V_R$ = 15V | − | − | 50 | µA | |
| | $I_{R2}$ | $V_R$ = 90V | − | − | 2.0 | mA | |
| Reverse Leakage Current Under High Temperature | $H \cdot I_{R1}$ | $V_R$ = 15V, $T_j$ = 130 °C | 1.20 | 1.90 | 2.60 | mA | |
| | $H \cdot I_{R2}$ | $V_R$ = 90V, $T_j$ = 150 °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.

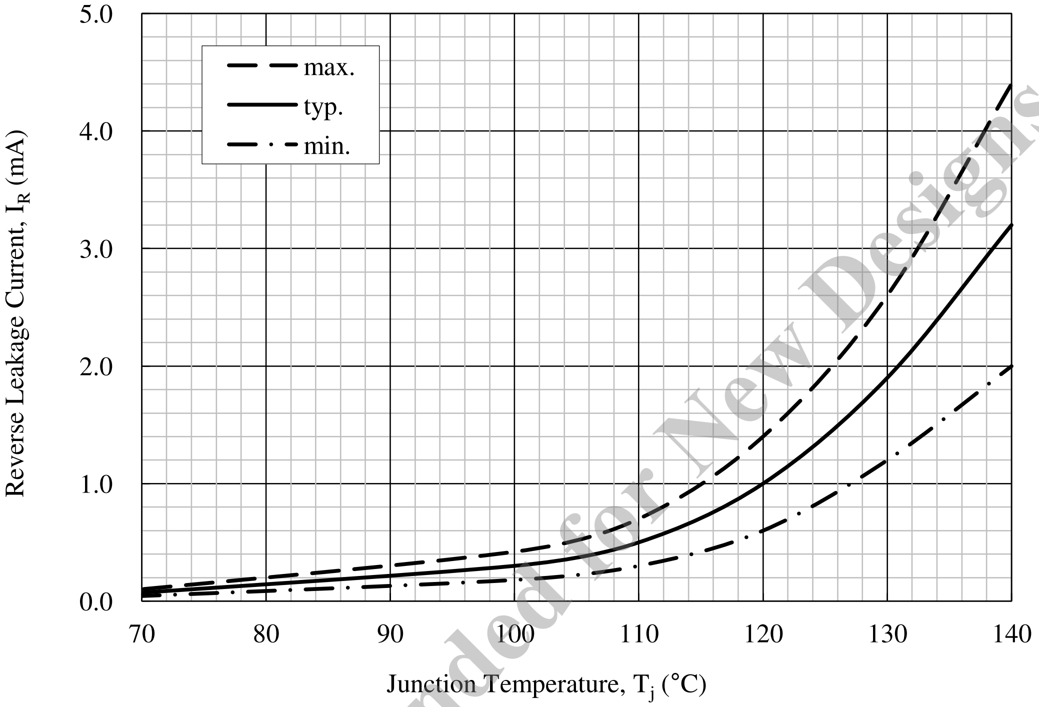



Figure 3-1 Temperature dependent of Reverse Leakage Current, $I_R$ (SBD)

## 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

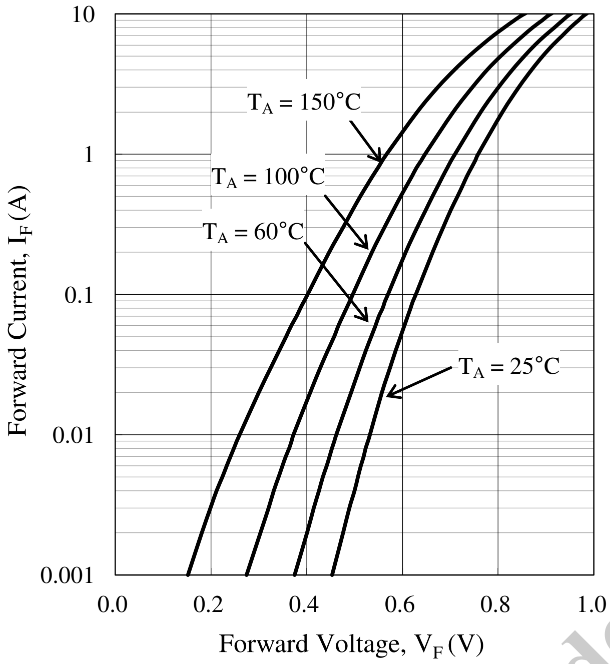



Figure 3-2 $I_F - V_F$ Typical Characteristics

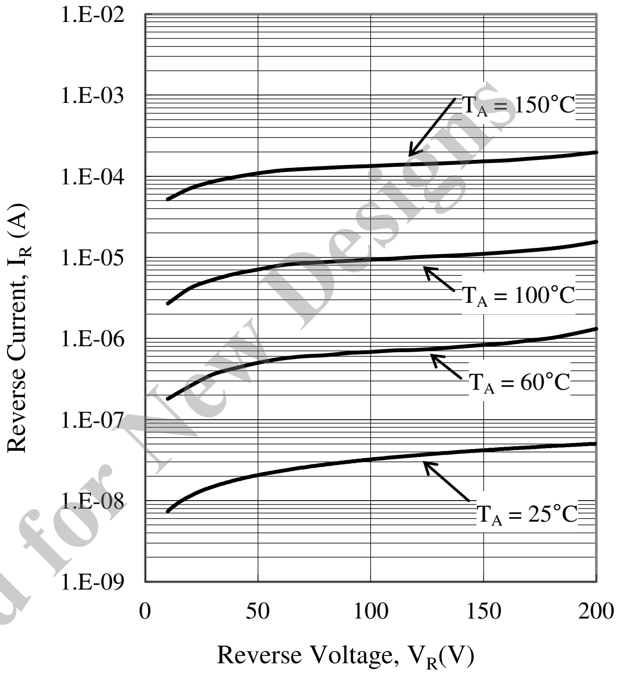



Figure 3-3 $I_R - V_R$ Typical Characteristics

### 3.2.1.2. Power Dissipation Curves ($T_j$ = 150 °C)

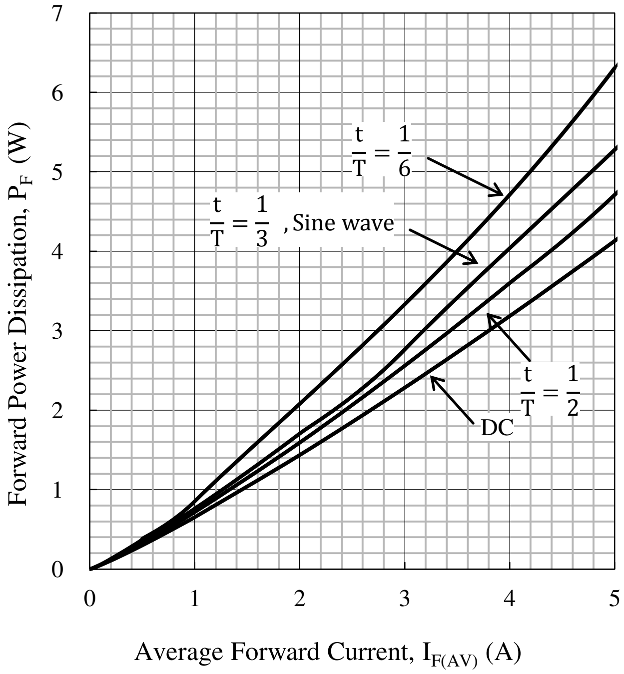



Figure 3-4 $P_F - I_{F(AV)}$

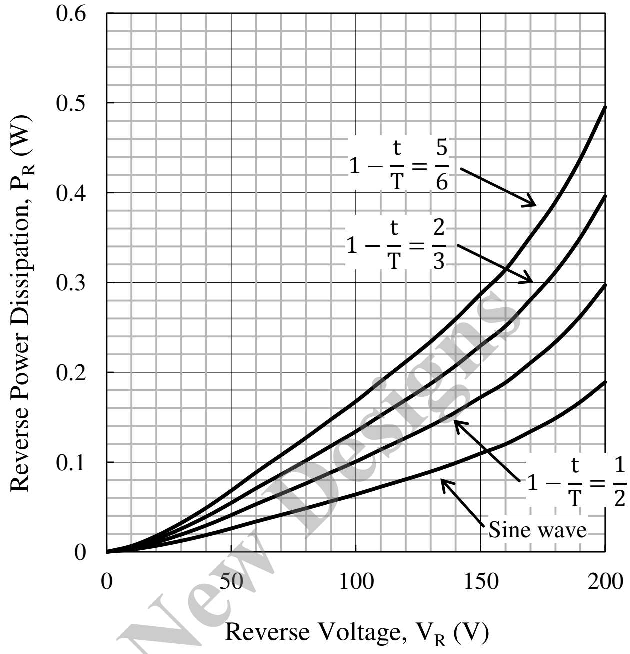



Figure 3-5 $P_R - V_R$



### 3.2.1.3. Derating Curves ($T_j$ = 150 °C)

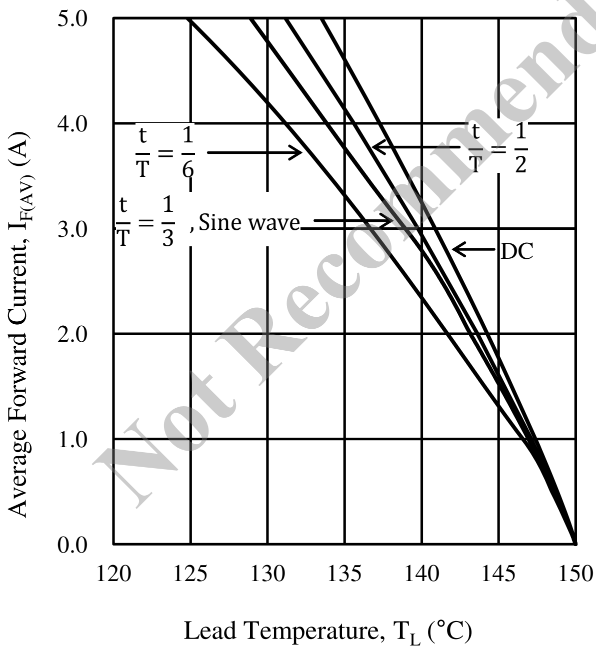



Figure 3-6 $I_{F(AV)} - T_L$ ($V_R$ = 0 V)

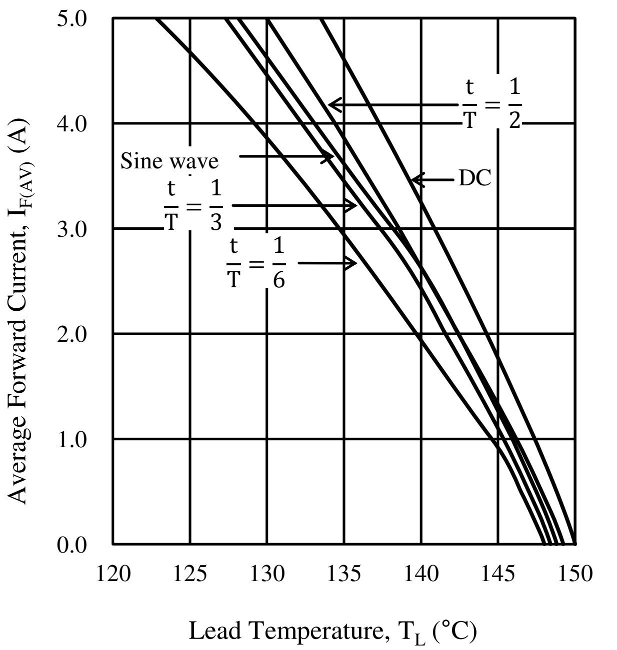



Figure 3-7 $I_{F(AV)} - T_L$ ($V_R$ = 200 V)

### 3.2.2 FMKS-2102

#### 3.2.2.1. Typical Characteristics

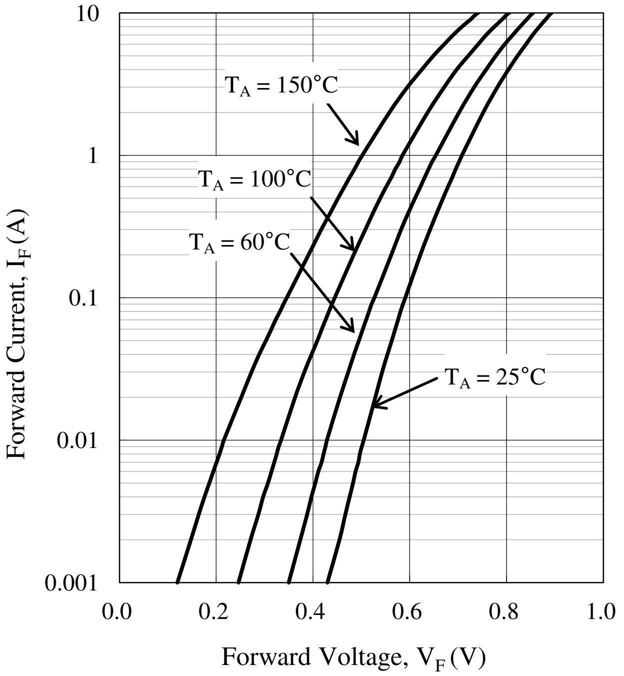



Figure 3-8 $V_F - I_F$ Typical Characteristics

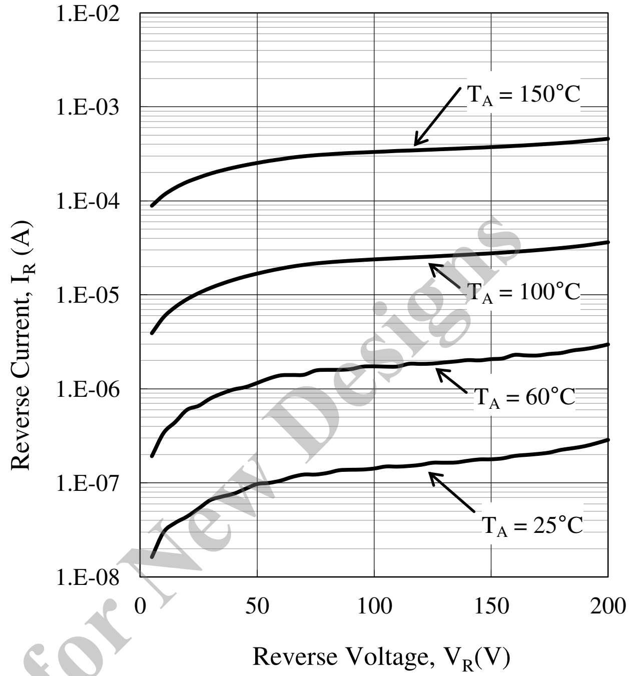



Figure 3-9 $V_R - I_R$ Typical Characteristics



#### 3.2.2.2. Power Dissipation Curves ($T_j$ = 150 °C)

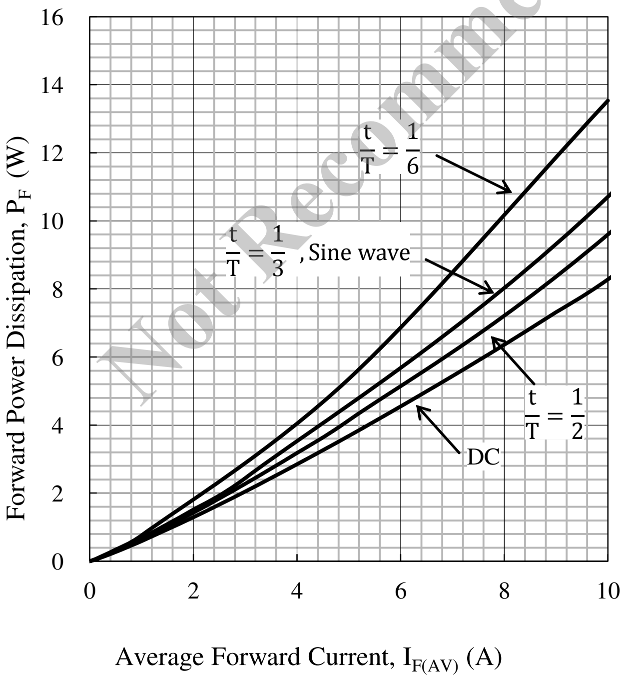



Figure 3-10 $P_F - I_{F(AV)}$

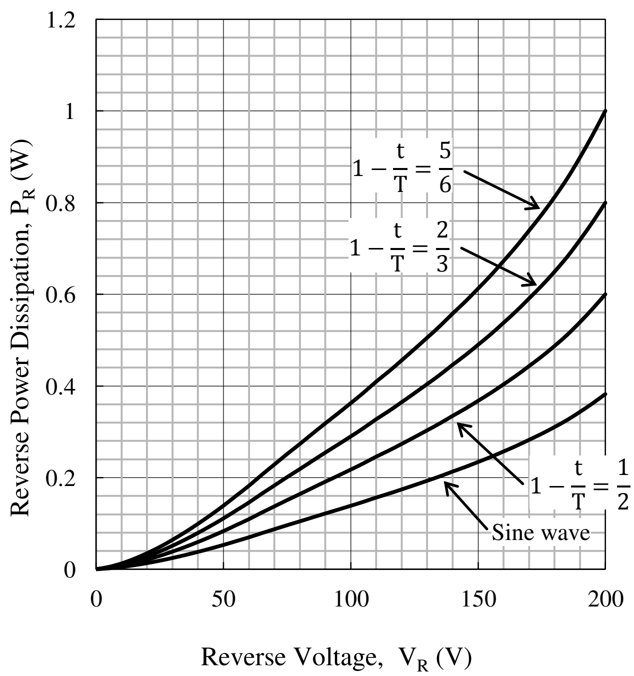



Figure 3-11 $P_R - V_R$

### 3.2.2.3. Derating Curves ($T_j$ = 150 °C)

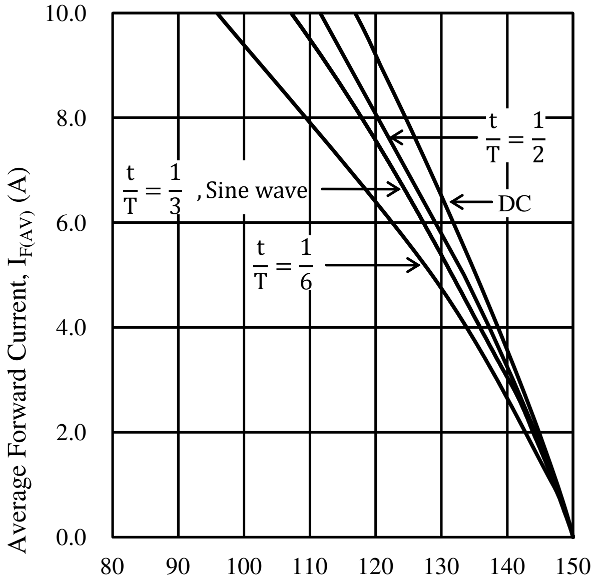



Figure 3-12 $I_{F(AV)}$ — $T_L$ ($V_R$ = 0 V)

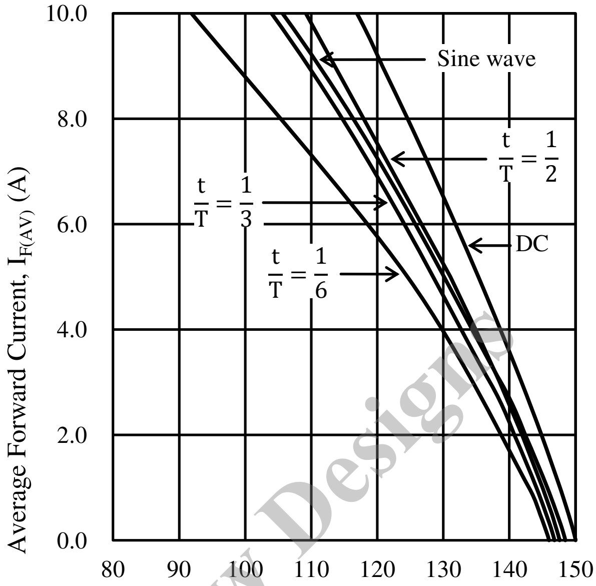



Figure 3-13 $I_{F(AV)}$ — $T_L$ ($V_R$ = 200 V)



## 3.2.3 FMKS-2152

### 3.2.3.1. Typical Characteristics

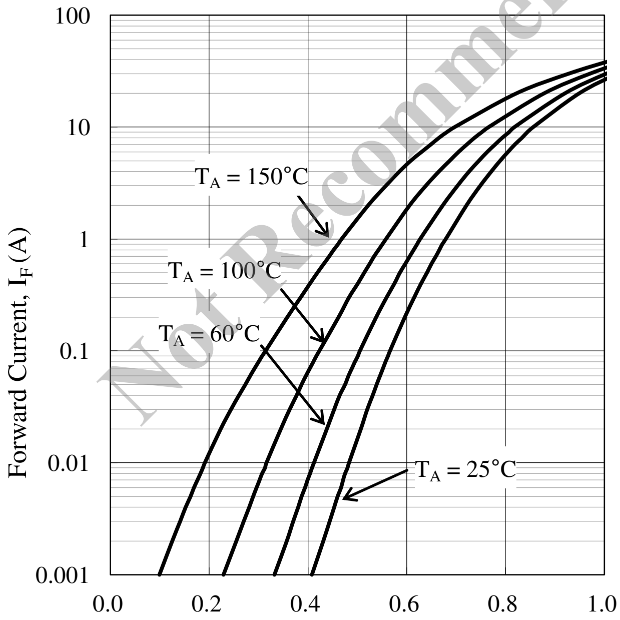



Figure 3-14 $V_F$ — $I_F$ Typical Characteristics

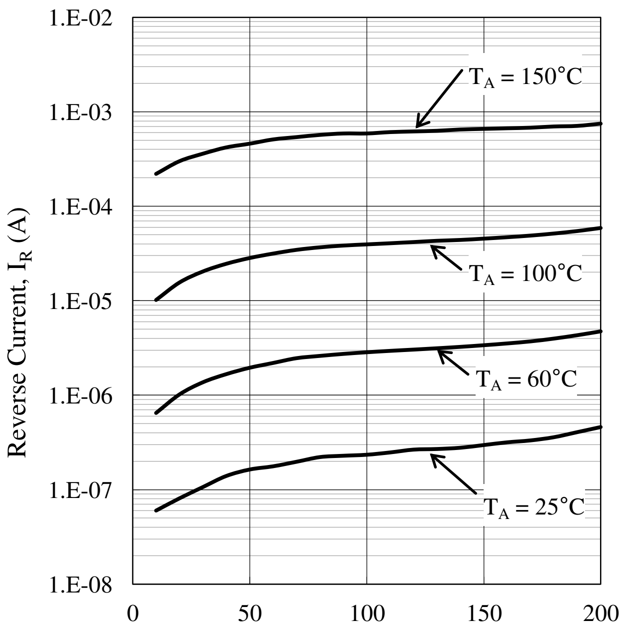



Figure 3-15 $V_R$ — $I_R$ Typical Characteristics

### 3.2.3.2. Power Dissipation Curves ($T_j$ = 150 °C)

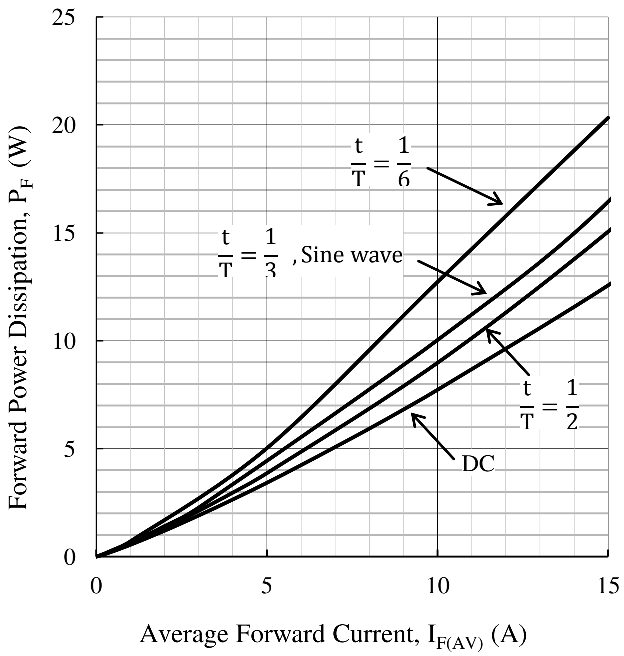



Figure 3-16 $P_F - I_{F(AV)}$

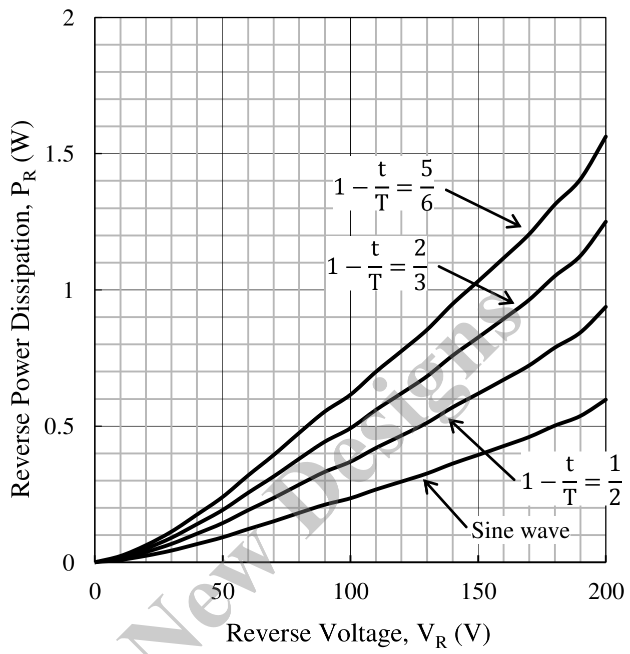



Figure 3-17 $P_R - V_R$

### 3.2.3.3. Derating Curves ($T_j$ = 150 °C)

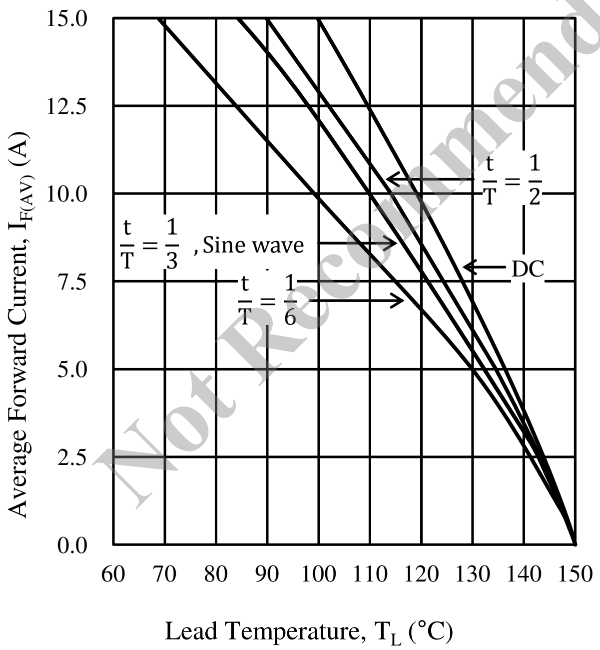



Figure 3-18 $I_{F(AV)} - T_L$ ($V_R$ = 0 V)

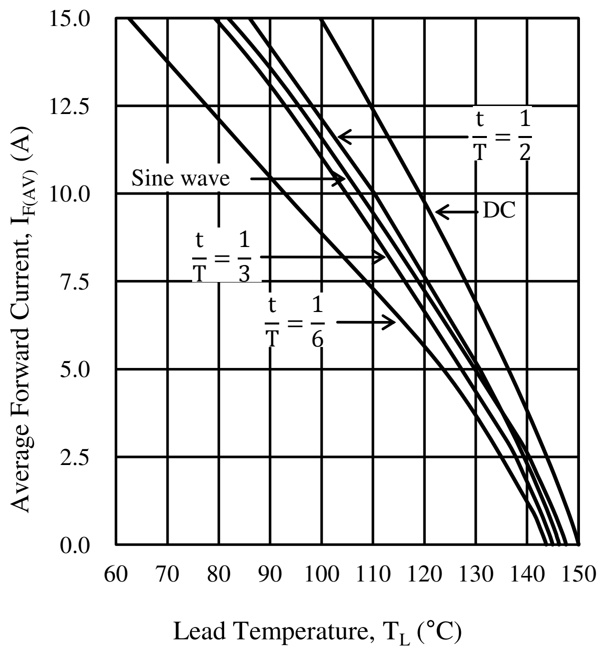
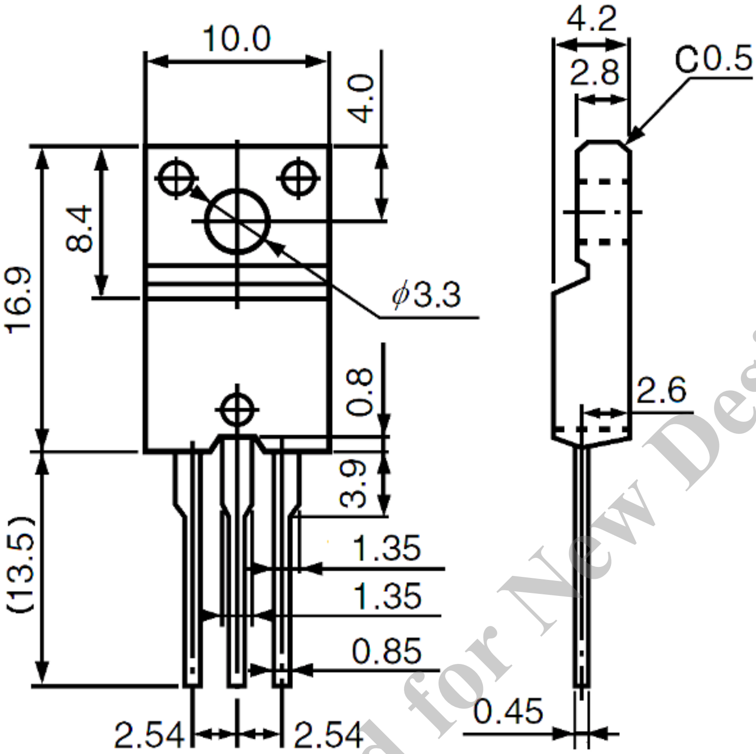



Figure 3-19 $I_{F(AV)} - T_L$ ($V_R$ = 200 V)

## 4. External Dimensions

TO220F-3L




NOTES:

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

## 5. Marking Diagram

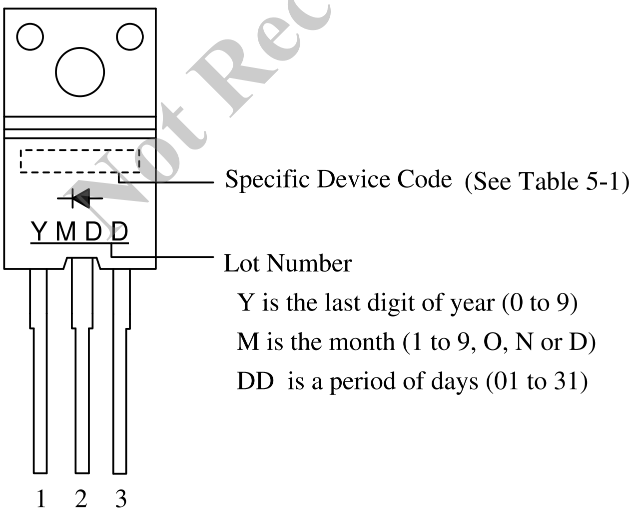



Table 5-1 Specific Device Code

| 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.

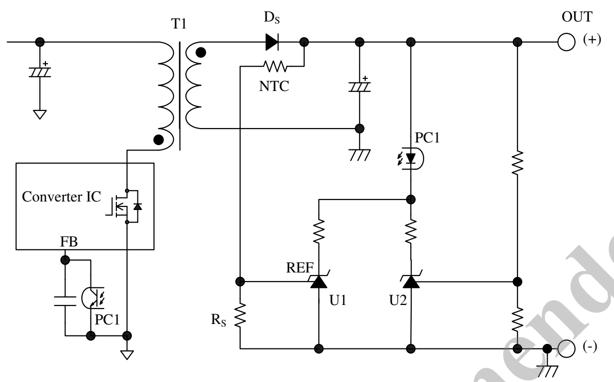



Figure 6-1 Reference temperature detection circuit with NTC thermistor

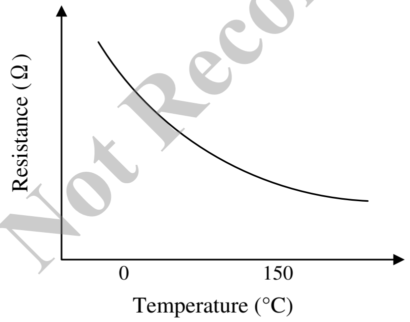



Figure 6-2 Reference characteristics of NTC thermistor

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 conuctivity 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.

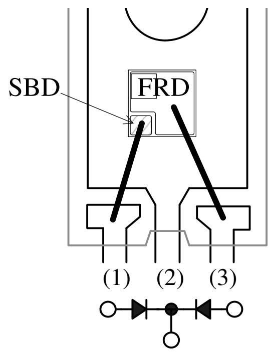



Figure 6-3 Internal structure of FMKS series

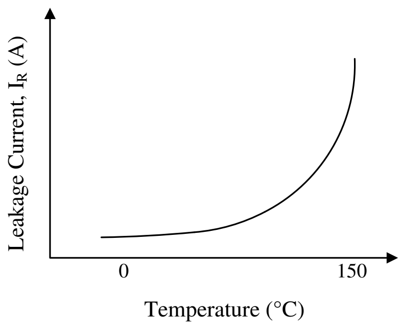



Figure 6-4 Reference temperature characteristics of SBD leakage current

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.

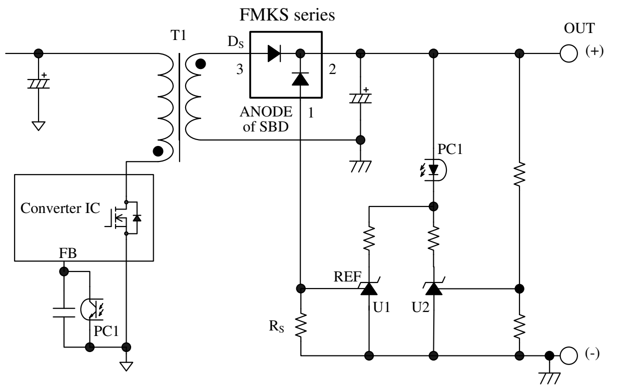



Figure 6-5 Reference temperature detection circuit with FMKS series.

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.

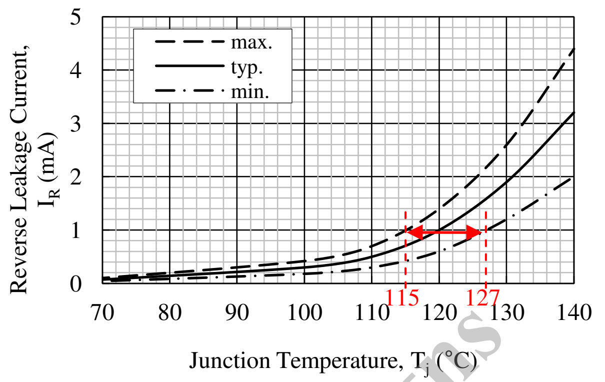



Figure 6-6 Temperature detection range at $I_R$= 1.0mA

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.

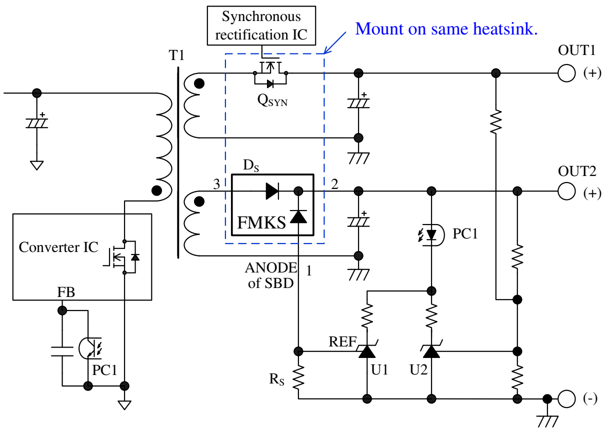



Figure 6-7 Reference circuit with FMKS series in the multi-output flyback converter circuit

# IMPORTANT NOTES

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