Design Example Using STR-A6069HZ:
10.5 W (15 V, 0.7 A)

Isolated Flyback Converter
Precautions for High Voltage

Dangerously high voltages exist inside the demonstration board. Mishandling the demonstration board may cause the death or serious injury of a person. Before using the demonstration board, read the following cautions carefully, and then use the demonstration board correctly.

DO NOT touch the demonstration board being energized.

Dangerously high voltages that can cause death or serious injury exist inside the demonstration board being energized.

Electrical shock may be caused even by accidental short-time contact or by putting hands close to the demonstration board.

Electrical shock can result in death or serious injury.
Before touching the demonstration board, make sure that the capacitors have been discharged.

For safety purpose, an operator familiar with electrical knowledge must handle the demonstration board.

The demonstration board is for evaluation of all the features of the STR-A6069HZ.
The demonstration board shall not be included or used in your mass-produced products.
Before using the demonstration board, see this document and refer to the STR-A6069HZ data sheet.
Be sure to use the demonstration board within the ranges of the ratings for input voltage, frequency, output voltage, and output current.
Be sure to strictly maintain the specified ambient environmental conditions, such as ambient temperature and humidity.
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1. **Introduction**

This document describes the design example of a power supply using the STR-A6069HZ intended for the isolated flyback converter that supports universal inputs and a 15 V/0.7 A output. The STR-A6069HZ is a current mode PWM control IC with a built-in power MOSFET. In addition, the design example uses the SARS05 as a diode for the resistor-capacitor-diode (RCD) snubber, the SJPX-H3 as a fast recovery diode for the IC’s power supply and the secondary rectifier.

This document contains the following: the specifications of the design example, circuit diagrams, the bill of materials, the setting examples of component constants, a pattern layout example, and the evaluation results of the power supply characteristics. For more details on the parts listed in this document, refer to the corresponding data sheets.

2. **Power Supply Features**

- Reduced Number of External Components (Built-in Startup Circuit)
- High Efficiency in Light-load Ranges Achieved by Load-based Auto-shifting Operation Modes
  - Normal Operation: PWM Mode, 100 kHz (Typ.)
  - Standby Operation: Burst Oscillation Mode
- Efficiency: 83% (230 VAC, 10.5 W)
- Input Power at No Load: 47 mW (230 VAC)
- Reduced EMI Noise (Random Switching Function)

3. **Applications**

- Small Home Appliance
- Large Home Appliance
- Auxiliary Power Supply
- Power Supply for Motor Control
- Other SMPSs (Switching Mode Power Supplies)

4. **Design Example: Appearance**

   ![Top View](image1)
   **STR-A6069HZ (700 V, 6 Ω)**
   **48.5 mm**
   **120.5 mm**

   ![Bottom View](image2)
   **SARS05 (800 V, 1 A)**
   **SJPX-H3 (300 V, 2 A)**
5. Design Example

5.1 Power Supply Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
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<td>Input</td>
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<td></td>
<td></td>
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<tr>
<td>Input Voltage</td>
<td>( V_{\text{INAC}} )</td>
<td>85 — 265 V</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
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<tr>
<td>Frequency</td>
<td>( f_{\text{LINE}} )</td>
<td>47 50/60 63 Hz</td>
<td></td>
<td></td>
<td></td>
<td>Hz</td>
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<tr>
<td>Output</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Rated Voltage</td>
<td>( V_{NP} )</td>
<td>13.95 15 16.05 V</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Rated Current</td>
<td>( I_{NP} )</td>
<td>— 0.7 — A</td>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>Output Ripple Voltage</td>
<td>( V_{\text{RIPPLE}} )</td>
<td>20 MHz bandwidth; filter added(^{(1)})</td>
<td>—</td>
<td>600 —</td>
<td>mV(P_P)</td>
<td></td>
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<tr>
<td>Output Power</td>
<td>( P_{\text{OUT}} )</td>
<td>— 10.5 — W</td>
<td></td>
<td></td>
<td></td>
<td>W</td>
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<tr>
<td>Efficiency</td>
<td>( \eta )</td>
<td>Rated load, ( T_{A} = 25 , ^{\circ}C ), 230 VAC</td>
<td>—</td>
<td>83 —</td>
<td>%</td>
<td></td>
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<td>Environment</td>
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<td>Conduction Noise</td>
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<td>( T_{A} = 25 , ^{\circ}C ) As per CISPR22B/EN55022B</td>
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<td>Temperature</td>
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<td></td>
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<tr>
<td>Power Supply IC Temperature Increase(^{(2)})</td>
<td>( \Delta T_{C,IC} )</td>
<td>85 VAC, ( I_{O} = 0.7 , A )</td>
<td>—</td>
<td>33.4 —</td>
<td>°C</td>
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<tr>
<td>Secondary Rectifier Diode Temperature Increase(^{(3)})</td>
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<td>265 VAC, ( I_{O} = 0.7 , A )</td>
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<td>Transformer Temperature Increase</td>
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<td>36.5 —</td>
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5.2 Circuit Diagram

![Figure 5-1. Circuit Diagram](image)

\(^{(1)}\) By connecting an electrolytic capacitor (50 V, 1 μF) and a ceramic capacitor (50 V, 0.1 μF) in parallel to the output connector of the PCB.

\(^{(2)}\) Refers to a case temperature of the STR-A6069HZ.

\(^{(3)}\) Refers to a case temperature of the SJPX-H3.
### 5.3 Bill of Materials

<table>
<thead>
<tr>
<th>Part Symbol</th>
<th>Part Type</th>
<th>Ratings</th>
<th>Part Number*</th>
<th>Manufacturer</th>
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<tbody>
<tr>
<td>F1</td>
<td>Hues</td>
<td>250 V, 2 A</td>
<td>RSTA 2 BULK</td>
<td>BELLEFUSE</td>
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<tr>
<td>TH1</td>
<td>Power thermistor</td>
<td>4.7 Ω, 3 A</td>
<td>B57153S0479M000</td>
<td>TDK-KEPCOS</td>
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<tr>
<td>C1</td>
<td>Film capacitor</td>
<td>310 VAC, 0.1 μF</td>
<td>890334023023CS</td>
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<td>C2</td>
<td>Electrolytic capacitor</td>
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<td>Wurth Electronics</td>
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<tr>
<td>C3</td>
<td>Electrolytic capacitor</td>
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<td>860241375002</td>
<td>Wurth Electronics</td>
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<td>C4</td>
<td>Chip ceramic capacitor</td>
<td>1 kV, 1000 pF, 3216</td>
<td>GRM31BR73A102KW01L</td>
<td>Murata</td>
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<td>C6</td>
<td>Chip ceramic capacitor</td>
<td>X7R, 50 V, 1000 pF, 2012</td>
<td>885012207086</td>
<td>Wurth Electronics</td>
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<td>C7</td>
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<td>C10</td>
<td>Ceramic capacitor</td>
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<td>C51</td>
<td>Electrolytic capacitor</td>
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<td>Chip ceramic capacitor</td>
<td>X7R, 50 V, 0.068 μF, 2012</td>
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<td>Wurth Electronics</td>
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<tr>
<td>BR1</td>
<td>Bridge rectifier diode</td>
<td>1000 V, 1.5 A</td>
<td>DF10S</td>
<td>ON Semiconductor</td>
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<tr>
<td>D1</td>
<td>Snubber diode</td>
<td>800 V, 1.0A</td>
<td>SARS05</td>
<td>Sanke</td>
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<tr>
<td>D2</td>
<td>Fast recovery diode</td>
<td>300 V, 2 A</td>
<td>SJPX-H3</td>
<td>Sanke</td>
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<tr>
<td>D51</td>
<td>Fast recovery diode</td>
<td>300 V, 2 A</td>
<td>SJPX-H3</td>
<td>Sanke</td>
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<td>L1</td>
<td>Inductor</td>
<td>18 mH, 0.5 A</td>
<td>7448640416</td>
<td>Wurth Electronics</td>
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<td>T1</td>
<td>Transformer</td>
<td>ST-6914A</td>
<td>EE-16</td>
<td>Sanshin</td>
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<tr>
<td>R1</td>
<td>Resistor</td>
<td>1 MΩ, 1/2 W</td>
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<td>Akahane Electronics</td>
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<td>R2</td>
<td>Chip resistor</td>
<td>15 Ω, 1/2 W, 3216</td>
<td>RK73B2BT1D150J</td>
<td>KOA</td>
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<td>R3</td>
<td>Resistor</td>
<td>1.2 Ω, 1/2 W</td>
<td>RN12S10R2FK</td>
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<td>R7</td>
<td>Chip resistor</td>
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<td>R8</td>
<td>Resistor</td>
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<td>R53</td>
<td>Chip resistor</td>
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<td>Chip resistor</td>
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<td>CR16TR332F</td>
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<td>R55</td>
<td>Chip resistor</td>
<td>47 kΩ, 1/8 W, 1608</td>
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<td>R56</td>
<td>Chip resistor</td>
<td>10 kΩ, 1/8 W, 1608</td>
<td>CR16TR103F</td>
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<tr>
<td>U1</td>
<td>PWM offline converter IC</td>
<td>700 V, 6 Ω</td>
<td>STR-A6069HZ</td>
<td>Sanke</td>
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<td>U2</td>
<td>Shunt regulator</td>
<td>$V_{REF} = 2.495,V$</td>
<td>TL431A1LPR3431A</td>
<td>Texas Instruments</td>
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<tr>
<td>PC1</td>
<td>Optocoupler</td>
<td>TLP781F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JP1</td>
<td>Jumper wire</td>
<td>Short</td>
<td>φ = 0.6, P = 7 mm</td>
<td></td>
</tr>
<tr>
<td>JP5</td>
<td>Jumper wire</td>
<td>Short</td>
<td>φ = 0.6, P = 7 mm</td>
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<tr>
<td>JP6</td>
<td>Jumper wire</td>
<td>Short</td>
<td>φ = 0.6, P = 7 mm</td>
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<tr>
<td>P1</td>
<td>Connector</td>
<td>250 V</td>
<td>B2P3-VH</td>
<td>JST</td>
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<tr>
<td>P2</td>
<td>Connector</td>
<td>50 V</td>
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<td>Wurth Electronics</td>
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<tr>
<td>P3</td>
<td>Connector</td>
<td>50 V</td>
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<td>—</td>
<td>PCB</td>
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<td>PSA50139, REV. 2</td>
<td>Sanke</td>
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* When multiple parts are listed, any one of them is used.
5.4 Pattern Layout Example

The design example uses only the parts listed in the circuit diagram and the bill of materials.
PCB dimensions: 120.5 mm × 48.5 mm

(a) Top View

(b) Bottom View

Figure 5-2. Pattern Layout Example
6. Design Example: Basic Operations

The connector P1 is connected to an AC power supply. When an AC voltage is applied, the AC input voltage is full-wave rectified via the input filter and the bridge rectifier diode BR1. The rectified voltage is then smoothed to a DC voltage by the electrolytic capacitors C2 and C3. The input filter part includes the following components: C1 for a normal-mode noise filter; L1 for a common-mode noise filter; the power thermistor TH1 for an inrush current limiter.

When a voltage is applied to the D/ST pin of the power supply IC (U1: STR-A6069HZ), the internal startup circuit turns on. Consequently, a startup current flowing out of the VCC pin charges the electrolytic capacitor C7. When the VCC pin voltage increases to the IC operation start voltage, the IC control circuit starts to operate. Then, the internal power MOSFET starts its PMW switching operation. After the switching operation starts, a voltage is induced across the auxiliary winding D of the transformer T1. This induced voltage is rectified by D2 and C7 and is applied to the VCC pin. At this time, the internal startup circuit automatically turns off and the VCC pin power is supplied from the auxiliary winding D afterward. Note that the VCC pin voltage may be increased due to C7, which is charged by the surge voltage induced across the auxiliary winding D. For suppressing such voltage increase, R2 should be connected.

When the internal power MOSFET turns off, a ringing voltage is caused between the drain and source. For reducing such ringing voltage, the clamp snubber circuit (D1, C4, R1, and R8) should be connected across the winding P of the transformer T1. The SARS05, which is used for the diode D1, is a diode dedicated for snubber circuits and is contributory to not only ringing voltage reduction but also to better power supply efficiency by utilizing ringing energy effectively.

The current-sensing resistor R3 connected to the S/OCP pin is for overcurrent detection. The light-receiving element of the optocoupler PC1 is connected to the FB/OLP pin, and a feedback signal is input for controlling the output voltage to be constant. The feedback current, I_F, according to the load runs through PC1. Also, the capacitor C6 is connected to the FB/OLP pin, for high-frequency noise filtering and phase compensation. The resistor R7 and the noise filter capacitor C5 are connected to the BA pin. Connecting the resistor R7 allows the standby operating point to be adjustable by selecting a predetermined load factor.

In flyback converter design, the transformer T1 should consist of the primary and secondary sides whose polarities are connected oppositely. Energy is transferred from the primary side to the secondary side as follows. When the internal power MOSFET turns on, the input voltage, V_IND_C, is applied to the winding P of the transformer T1. The transformer T1 then starts to store energy. As the secondary winding S has the reverse polarity, the secondary rectifier diode D51 does not become conductive at this time. Consequently, no power is transmitted from the primary side to the secondary side. When the internal power MOSFET turns off, the winding P generates a back EMF that conducts electricity to D51 and charges the electrolytic capacitors C51 and C53. Then, the energy stored in the transformer T1 is discharged to the secondary side. The light-emitting element of the optocoupler PC1 is configured as follows: the anode side is connected with the positive output (the connector P2) via the current-sensing resistor R51; the cathode side is connected with the shunt regulator U2. The resistor R52, connected across the anode and cathode of the light-emitting element of the optocoupler PC1, supplies the idling current flowing through PC1 to the shunt regulator U2. In order to enhance the constant voltage control, a high-precision resistor with an allowable tolerance of ±1% or less should be used for the resistors R54 to R56, which produce a voltage to be applied to the reference pin for the shunt regulator U2.
7. Designing the Power Supply

7.1 Setting an Output Voltage

The equation below defines the relation between: the output voltage, $V_{\text{OUT}}$; the reference voltage, $V_{\text{FB(REF)}}$, of the shunt regulator U2; and the resistors R54 to R56.

$$V_{\text{OUT}} = \frac{(R54 + R55 + R56) \times V_{\text{FB(REF)}}}{R56}$$

(1)

Here are example setting values for $V_{\text{FB(REF)}}$ and the resistors R54 to R56 when $V_{\text{OUT}} = 15$ V:

- $V_{\text{FB(REF)}} = 2.495$ V
- $R54 = 3.3$ kΩ
- $R55 = 47$ kΩ
- $R56 = 10$ kΩ

7.2 Selecting the Bridge Rectifier Diode BR1

For the bridge rectifier diode BR1, select the one that has voltage and current ratings with sufficient margin to the upper limits of AC input voltage and current.

When the upper limit of an input voltage is 265 VAC, the voltage to be applied to BR1 is as follows: $V_p = 265$ (VAC) $\times \sqrt{2} \approx 375$ (VDC). When a derating of $\geq 80\%$ is applied to the BR1 breakdown voltage, BR1 requires a breakdown voltage of $\geq 500$ V.

The equation below defines the input current, $I_{\text{IN}}$:

$$I_{\text{IN}} = \frac{P_{\text{OUT}}}{V_{\text{INAC(MIN)}} \times \sqrt{2} \times \eta \times PF}$$

(2)

Where:

- $P_{\text{OUT}}$ is the output power,
- $V_{\text{INAC(MIN)}}$ is the lower limit of the AC input voltage,
- $\eta$ is the efficiency, and
- $PF$ is the power factor.

From Equation (2), when $P_{\text{OUT}} = 10.5$ W, $V_{\text{INAC(MIN)}} = 85$ VAC, $\eta = 0.83$, $PF = 0.6$, hence $I_{\text{IN}} \approx 250$ mA. When a derating of $\geq 80\%$ is applied to the BR1 rated current, BR1 requires a rated current of $\geq 310$ mA.

For the design example, we selected the bridge rectifier diode with a breakdown voltage of 1000 V and a rated current of 1.5 A, from the ones available in the market.

7.3 Selecting the Clamp Snubber Circuit (D1, C4, R1, R8)

For reducing surge voltages between the D/ST and S/OCP pins of the power supply circuit (U1: STR-A6069HZ), a clamp snubber circuit should be connected. As the maximum rated voltage of the internal power MOSFET is 700 V, the capacitor C4 and the discharging resistor R1 should be adjusted so that the power supply IC will have a surge voltage with a peak value of approximately 600 V. The reference capacitance of C4 is 1000 pF to 3300 pF, whereas the reference resistance of R4 is 470 kΩ to 1 MΩ.

For D1 used in the design example, we selected the SARS05, our 800 V/1.0 A diode dedicated for snubber circuits. R8 is the current-limiting resistor for energy discharging and is recommended to use a resistor of about 47 Ω as we selected the SARS05 for the snubber diode.
7.4 Selecting the VCC Pin Rectifier Diode D2

For D2, select a fast recovery diode with a short recovery time because switching currents flow through it. Its rated voltage should have a sufficient margin to the voltage across the auxiliary winding D.

The design example employs the SJPX-H3, a 300 V/2 A fast recovery diode.

7.5 Selecting the Current-sensing Resistor R3

When determining a constant of the current-sensing resistor R3, the OCP threshold voltage, $V_{OCP(H)}$, of the power supply IC (U1: STR-A6069HZ) and resistance loss should be taken into account. Be sure to use a high-precision resistor with an allowable tolerance of ±1% or less for enhancing the constant voltage control.

When $R3 = 1.2 \, \Omega$, the upper limit of $V_{OCP(H)}$ for the STR-A6069HZ is 0.933 V. Hence, the peak current that will flow through R3, $I_{R3,P}$, is obtained by:

$$I_{R3,P} = \frac{0.933 \, (V)}{1.2 \, (\Omega)} = 0.7775 \, (A).$$

When the power supply IC operates at switching duty cycle = 0.5, the effective current that will flow through R3, $I_{R3,RMS}$, is as follows:

$$I_{R3,RMS} = \frac{0.7775 \, (A)}{\sqrt{3}} \times 0.5 \approx 0.224 \, (A).$$

Thus, the resistance loss in R3, $P_{R3}$, is determined by:

$$P_{R3} = I_{R3,RMS}^2 \times R3 = 0.224^2 \times 1.2 \approx 0.06 \, (W).$$

Based on the above calculation results, we selected the resistor with a resistance of 1.2 Ω and a rated power of 1/2 W.

7.6 Selecting the Secondary Rectifier Diode D51

For D51, use a fast recovery diode having low leakage current and low forward voltage characteristics with safety and power supply efficiency taken into account.

The rated current of D51 should have a sufficient margin to the rated load and rated peak current.

The rated voltage of D51, $V_{RM}$, should have sufficient margins as follows: to the winding turns ratio ($N_S/N_P$) of the transformer T1 defined by Equation (3); to the input voltage, $V_{INDC}$; to a voltage determined by the output voltage, $V_{OUT}$.

$$V_{RM} \gg \left( \frac{N_S}{N_P} \times V_{INDC} \right) + V_{OUT}. \quad (3)$$

From Equation (3), when $V_{INDC} = 265 \, V \times \sqrt{2}$, $V_{OUT} = 15 \, V$, $N_S/N_P = 0.1263$, hence $V_{RM} >> 62 \, V$. Based on this calculation result, the design example employs the SJPX-H3, a 300 V/2A fast recovery diode.
7.7 Transformer Specifications

Table 7-1 and Table 7-2 provide the design conditions for the transformer.

Table 7-1. Specifications: Input/Output

<table>
<thead>
<tr>
<th>Winding</th>
<th>Symbol</th>
<th>Specifications</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Winding</td>
<td>P</td>
<td>85 VAC to 265 VAC</td>
<td></td>
</tr>
<tr>
<td>Secondary Winding</td>
<td>S</td>
<td>15 V, 0.7 A</td>
<td>Insulated from the winding P</td>
</tr>
<tr>
<td>Primary Auxiliary Winding</td>
<td>D</td>
<td>19 V</td>
<td>Non-insulated from the winding P; as a power supply for the VCC pin</td>
</tr>
</tbody>
</table>

Table 7-2. Specifications: Power Supply

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Load</td>
<td>10.5 W</td>
<td>Insulated from the winding P</td>
</tr>
<tr>
<td>Input Voltage</td>
<td>265 VAC (max.)</td>
<td>Non-insulated from the winding P; as a power supply for the VCC pin</td>
</tr>
<tr>
<td>Circuit Efficiency</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>Average Input Current</td>
<td>0.15 A</td>
<td>85 VAC (min.)</td>
</tr>
<tr>
<td>Peak Switching Current</td>
<td>0.76 A</td>
<td>85 VAC (min.) at startup</td>
</tr>
<tr>
<td>Switching Frequency</td>
<td>100 kHz</td>
<td></td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td>46%</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-3 lists the specifications of the transformer T1, which is designed from the conditions given in Table 7-1 and Table 7-2.

Table 7-3. Specifications: Transformer

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Inductance, ( L_P )</td>
<td>600 ( \mu )H</td>
</tr>
<tr>
<td>Core Size</td>
<td>EE16J (see Table 7-4)</td>
</tr>
<tr>
<td>Bobbin</td>
<td>Vertical type, 10 pins (see Table 7-5)</td>
</tr>
<tr>
<td>AL-value</td>
<td>67 ( nH/N^2 ) (center gap: 1.0 mm)</td>
</tr>
<tr>
<td>Winding Specifications</td>
<td>See Table 7-6.</td>
</tr>
<tr>
<td>Winding Structure</td>
<td>See Figure 7-1.</td>
</tr>
<tr>
<td>Physical Dimensions</td>
<td>See Figure 7-2.</td>
</tr>
</tbody>
</table>
Table 7-4. Specifications: Core

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core Shape</td>
<td>EE16J</td>
</tr>
<tr>
<td>Core Materials</td>
<td>Mn-Zn, DMR40 materials</td>
</tr>
<tr>
<td>Effective Core Cross-sectional Area, $A_e$</td>
<td>19.8 mm$^2$</td>
</tr>
</tbody>
</table>

Table 7-5. Specifications: Bobbin

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bobbin Shape</td>
<td>Vertical type</td>
</tr>
<tr>
<td></td>
<td>FEI-16-10P-NPB</td>
</tr>
<tr>
<td>Number of Pins</td>
<td>10 pins</td>
</tr>
<tr>
<td>Effective Core Cross-sectional Area, $A_e$</td>
<td>19.8 mm$^2$</td>
</tr>
<tr>
<td>Creepage</td>
<td>Primary side: 4.0 mm</td>
</tr>
<tr>
<td></td>
<td>Secondary side: 4.0 mm</td>
</tr>
</tbody>
</table>

Table 7-6. Specifications: Transformer Windings

<table>
<thead>
<tr>
<th>Winding Name</th>
<th>Symbol</th>
<th>Turn (T)</th>
<th>Pin Numbers</th>
<th>Wire Diameter (mm)</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Winding 1</td>
<td>P1</td>
<td>65</td>
<td>3-2</td>
<td>$\phi$ 0.18</td>
<td>Single-layer solenoidal winding</td>
</tr>
<tr>
<td>Secondary Winding 1</td>
<td>S1</td>
<td>12</td>
<td>9-7</td>
<td>$\phi$ 0.37, TEX-E</td>
<td>Single-layer solenoidal winding</td>
</tr>
<tr>
<td>VCC Auxiliary</td>
<td>D</td>
<td>15</td>
<td>4-5</td>
<td>$\phi$ 0.18</td>
<td>Single-layer solenoidal winding (center-wound)</td>
</tr>
<tr>
<td>Secondary Winding 2</td>
<td>S2</td>
<td>12</td>
<td>10-6</td>
<td>$\phi$ 0.37, TEX-E</td>
<td>Single-layer solenoidal winding</td>
</tr>
<tr>
<td>Primary Winding 2</td>
<td>P2</td>
<td>30</td>
<td>2-1</td>
<td>$\phi$ 0.18</td>
<td>Single-layer solenoidal winding</td>
</tr>
</tbody>
</table>

Figure 7-1. Structure of Windings

The "●" marks denote winding starts.
Figure 7-2. Physical Dimensions of Transformer
8. Performance Data

All the performance data contained in this document were measured at a room temperature and an AC line frequency of 50 Hz.

The maximum load is 10.5 W (15 V, 0.7 A).

8.1 Efficiency

Figure 8-1 shows the characteristics of power supply efficiency vs. input voltage; Figure 8-2 shows the characteristics of power supply efficiency vs. output power.
8.2 Standby Power

Table 8-1. Input Power at No Load

<table>
<thead>
<tr>
<th>Input Voltage</th>
<th>Input Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 VAC</td>
<td>46 mW</td>
</tr>
<tr>
<td>230 VAC</td>
<td>47 mW</td>
</tr>
</tbody>
</table>

Figure 8-3. Input Power vs. Output Power
8.3 Line Regulation

![Image](https://www.sanken.ele.co.jp/en)

Figure 8-4. Output Voltage vs. Input Voltage

8.4 Load Regulation

![Image](https://www.sanken.ele.co.jp/en)

Figure 8-5. Output Voltage vs. Output Power
9. Operation Check

All the performance data contained in this document were measured at a room temperature and an AC line frequency of 50 Hz.

The maximum continuous load is 10.5 W (15 V, 0.7 A).

For more details on the power supply IC (STR-A6069HZ) such as electrical characteristics and operational descriptions, refer to the data sheet.

9.1 Startup Operation

9.1.1 Power Supply IC Switching Operation

When the soft start function is activated at power-on, the D/ST pin current, $I_{D/ST}$, of the power supply IC slowly increases. When the voltage across the current-sensing resistor $R_3$ reaches the OCP threshold voltage of the power supply IC, the overcurrent protection (OCP) is activated to limit the output power.

Figure 9-1 shows the waveform of the D/ST pin voltage, $V_{D/ST}$. The pulsating part of the $V_{D/ST}$ waveform indicates a full-wave rectified input ripple component. The D/ST pin current, $I_{D/ST}$, is and remains limited by the OCP during the period until the output voltage becomes constant. When the output voltage becomes constant after the limitation, $I_{D/ST}$ decreases.

![Operational Waveforms at Startup](image1)

![Operational Waveforms at Startup](image2)

Figure 9-1. Operational Waveforms at Startup
($V_{IN} = 85$ VAC, $I_O = 0.7$ A)

Figure 9-2. Operational Waveforms at Startup
($V_{IN} = 265$ VAC, $I_O = 0.7$ A)

![Operational Waveforms at Startup](image3)

![Operational Waveforms at Startup](image4)

Figure 9-3. Operational Waveforms at Startup
(Expanded Scale of A in Figure 9-1)

Figure 9-4. Operational Waveforms at Startup
(Expanded Scale of A in Figure 9-2)
9.1.2 Output Voltage

When the soft start function is activated at power-on, the output voltage, $V_{OUT}$, gradually decreases. After $V_{OUT}$ reaches its target voltage, $V_{OUT}$ has no overshoot and shifts to the normal operation state within the power supply specifications.

Figure 9-5. Output Voltage Waveform at Startup ($V_{IN} = 85$ VAC, $I_{O} = 0$ A)

Figure 9-6. Output Voltage Waveform at Startup ($V_{IN} = 265$ VAC, $I_{O} = 0$ A)

9.1.3 VCC Pin Voltage

The auxiliary winding D of the transformer T1 is a voltage supply source for the VCC pin. Set the auxiliary winding D so that the VCC pin voltage, $V_{CC}$, will fall within the range of $V_{CC(BIAS)} < V_{CC} < V_{CC(OVP)}$. The reference voltage across the auxiliary winding D, $V_{IN}$, is about 15 V to 20 V. In no-load operation, the power supply IC enters the burst oscillation operation as soon as its normal operation starts after startup. Thus, the VCC pin voltage decreases shortly after it increases once (see Figure 9-7, Figure 9-8). Note that the R2 value should be adjusted so that the VCC pin voltage will not become $V_{CC(BIAS)} = 10.5$ V (max.) or less, under all load ranges including the no-load operation.

Figure 9-7. VCC Pin Voltage Waveform at Startup ($V_{IN} = 85$ VAC, $I_{O} = 0$ A)

Figure 9-8. VCC Pin Voltage Waveform at Startup ($V_{IN} = 265$ VAC, $I_{O} = 0$ A)
9.1.4 D51 and D2 Applied Voltages

Figure 9-9 and Figure 9-10 provide the waveforms of the voltages across D51 and D2 at startup, respectively. In Figure 9-9, D51 yields the repetitive peak reverse voltage, $V_{RM}$, of about 196 V at maximum. This means that D51 (SJPX-H3) ensures a sufficient derating ($\leq$65%) to the maximum rated $V_{RM} = 300$ V.

In Figure 9-10, D2 yields the repetitive peak reverse voltage, $V_{RM}$, of about 182 V at maximum. This means that D2 (SJPX-H3) ensures a sufficient derating ($\leq$61%) to the maximum rated $V_{RM} = 300$ V.

Figure 9-9. D51 Operational Waveforms at Startup
($V_{IN} = 265$ VAC, $I_{O} = 0.7$ A)

Figure 9-10. D2 Operational Waveforms at Startup
($V_{IN} = 265$ VAC, $I_{O} = 0.7$ A)
9.2 Power Supply IC Switching Operation

The STR-A6069HZ automatically shifts its operation modes according to loads and enhances efficiency in all load ranges. Therefore, the power supply IC monitors not only its normal operation but also the operations in all load ranges.

9.2.1 Normal Operation

Figure 9-11 to Figure 9-12 provide the waveforms in normal operation. These waveforms show that the frequency is about 97 kHz regardless of input voltage. Each drain peak current setting has a margin to its overcurrent operating point.

![Figure 9-11. Operational Waveforms in Normal Operation (V_IN = 85 VAC, IO = 0.7 A)](image1)

![Figure 9-12. Operational Waveforms in Normal Operation (V_IN = 265 VAC, IO = 0.7 A)](image2)
9.2.2 Light-load Operation (Burst Oscillation)

The lighter the load becomes, the lower the FB/OLP pin voltage decreases. When the FB/OLP pin voltage decreases to a preset standby operating point, the power supply IC shifts into the burst oscillation operation.

Figure 9-13. Operational Waveforms at Light Load (VIN = 85 VAC, IO = 0.15 A)

Figure 9-14. Operational Waveforms at Light Load (VIN = 265 VAC, IO = 0.15 A)

Figure 9-15. Operational Waveforms at Light Load (VIN = 85 VAC, IO = 50 mA)

Figure 9-16. Operational Waveforms at Light Load (VIN = 265 VAC, IO = 50 mA)
9.2.3 No-load Operation (Burst Oscillation)

The burst oscillation period changes according to loads. The burst oscillation period at no load, $T_{STBOP}$, of the design example is defined as follows: 3.3 ms when $V_{IN} = 85$ VAC, and 3.7 ms when $V_{IN} = 265$ VAC.

![Operational Waveforms at No Load](image)

9.3 Output Ripple Voltage

The design example has output ripple voltages as follows: about 540 mV when $V_{IN} = 85$ VAC, and about 600 mV when $V_{IN} = 265$ VAC. Below are the measurement conditions:

- Added a filter to the output connector of the PCB (by connecting a 50 V, 1 μF electrolytic capacitor and a 50 V, 0.1 μF ceramic capacitor in parallel)
- Set a bandwidth of the oscilloscope to 20 MHz

![Output Ripple Voltage Waveform](image)
9.4 OCP and OLP Operations

When the power supply IC reaches a certain load level, the overcurrent protection (OCP) limits the internal power MOSFET drain current, \( I_{D/ST} \), to the drain current limit, \( I_{DLIM} \). The equation below defines the relationship between \( I_{DLIM} \) and the current-sensing resistor R3:

\[
I_{DLIM} = \frac{V_{OCP(H)}}{R3}.
\]

(4)

Where:

- \( V_{OCP(H)} \) is the OCP threshold voltage when STR-A6069HZ = 36% duty cycle, and
- R3 is the resistance of the current-sensing resistor R3.

When the FB/OLP pin voltage exceeds the OLP threshold voltage, \( V_{FB(OLP)} = 7.3 \) V (typ.), and remains exceeded for the OLP delay time, \( t_{OLP} = 75 \) ms (typ.) or longer, the overload protection (OLP) is activated to stop switching operation. During the OLP operation, the intermittent oscillation operation repeated by the VCC pin voltage will reduce stresses on components such as the power MOSFET and the secondary rectifier diode. When the causes of the overload condition are eliminated, the power supply IC automatically returns to its normal operation.

![Figure 9-21. OCP and OLP Operational Waveforms (V_IN = 85 VAC, I_O > 0.7 A)](image1)

![Figure 9-22. OCP and OLP Operational Waveforms (V_IN = 265 VAC, I_O > 0.7 A)](image2)

![Figure 9-23. OCP and OLP Operational Waveforms (Expanded Scale of A in Figure 9-21)](image3)

![Figure 9-24. OCP and OLP Operational Waveforms (Expanded Scale of A in Figure 9-22)](image4)
9.5 OVP Operation

When the voltage between the VCC and S/GND pins of the power supply IC increases to the OVP threshold voltage, $V_{CC(OVP)} = 29.1$ V (typ.) or more, the overvoltage protection (OVP) is activated and power supply IC shifts to the OVP operation. In the OVP operation, an intermittent oscillation operation is repeated by the UVLO function of the VCC pin. When the causes of the overvoltage condition are eliminated, the power supply IC automatically returns to its normal operation.

![Figure 9-25. OVP Operational Waveforms](image1)

![Figure 9-26. OVP Operational Waveforms](image2)

9.6 Case Temperature

Table 9-1 lists the individual component case temperatures at input voltage upper and lower limits, measured under the ambient temperatures 25 °C and 50 °C respectively.

<table>
<thead>
<tr>
<th>Ambient Temperature (°C)</th>
<th>Input Voltage (VAC)</th>
<th>Care Temperatures in Normal Operation (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Power Supply IC (U1)</td>
</tr>
<tr>
<td>25</td>
<td>85</td>
<td>58.4</td>
</tr>
<tr>
<td></td>
<td>265</td>
<td>50.6</td>
</tr>
<tr>
<td>50°</td>
<td>85</td>
<td>83.4</td>
</tr>
<tr>
<td></td>
<td>265</td>
<td>75.6</td>
</tr>
</tbody>
</table>

*Refers to case temperatures converted from the ones at an ambient temperature of 25 °C.
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