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ActivePSR™ Primary Switching Regulators

FEATURES

- Multiple Patent-Pending Primary Side Regulation Technology
- No Opto-coupler
- Best Constant Voltage, Constant Current Over All Accuracy
- Minimum External Components
- Integrated Line and Primary Inductance Compensation
- Integrated Output Cord Resistance Compensation
- Line Under-Voltage Protection
- Short Circuit Protection
- Over Temperature Protection
- Flyback Topology in DCM Operation
- Complies with all Global Energy Efficient Regulations: 0.3W Standby Power and CEC Average Efficiency
- SOT23-5 Package

APPLICATIONS

- Chargers for Cell Phones, PDAs, MP3, Portable Media Players, DSCs, and Other Portable Devices and Appliances
- RCC Adapter Replacements
- Linear Adapter Replacements
- Standby and Auxiliary Supplies

GENERAL DESCRIPTION

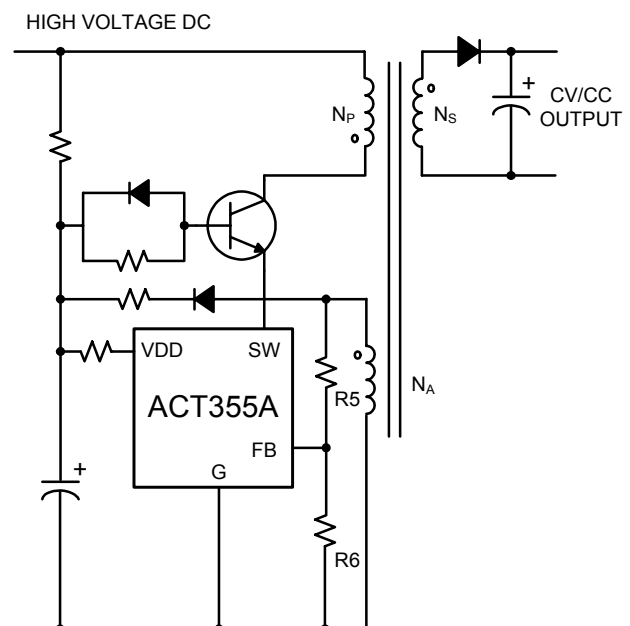
The ACT355A belongs to the high performance, multiple patent-pending *ActivePSR™* Family of universal-input AC/DC off-line controllers for battery charger and adapter applications. It is designed for the flyback topology working in a discontinuous conduction mode (DCM). In addition to being the industry's most accurate primary side regulator, the ACT355A meets all of the global energy efficiency regulations (CEC, European Blue Angel, and US Energy Star standards) while using very few external components.

The ACT355A ensures safe operation with complete protection against all fault conditions. Built-in protection circuitry is provided for output short-circuit, line under-voltage, and over-temperature conditions.

The ACT355A *ActivePSR* is optimized for cost-sensitive applications, and utilizes Active-semi's proprietary primary-side feedback architecture to provide accurate constant voltage, constant current (CV/CC) regulation without the need of an opto-coupler or reference device. Integrated line and primary inductance compensation circuitry provides accurate constant current operation despite wide variations in line voltage and primary inductance. Integrated output cord resistance compensation further enhances output accuracy. These products achieve excellent regulation and transient response, yet requires less than 300mW of standby power.

The ACT355A is optimized for 2.5W to 3.5W applications (such as 5V/500mA to 5V/700mA CV/CC chargers). It is available in a tiny SOT23-5 package.

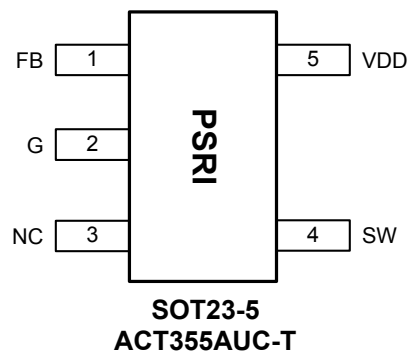
Figure 1:
Typical Application Circuit



ORDERING INFORMATION

| PART NUMBER | TEMPERATURE RANGE | PACKAGE | PINS | PACKING METHOD | TOP MARK |
|-------------|-------------------|---------|------|----------------|----------|
| ACT355AUC-T | -40°C to 85°C | SOT23-5 | 5 | TAPE & REEL | PSRI |

PIN CONFIGURATION



PIN DESCRIPTIONS

| PIN NUMBER | PIN NAME | PIN DESCRIPTION |
|------------|----------|---|
| 1 | FB | Feedback Pin. Connect to a resistor divider network from the auxiliary winding. |
| 2 | G | Ground. |
| 3 | NC | No Connection. |
| 4 | SW | Switch Driver. Connect this pin to the emitter of the power NPN transistor or source of the power MOSFET. |
| 5 | VDD | Power Supply. |

ABSOLUTE MAXIMUM RATINGS^①

| PARAMETER | VALUE | UNIT |
|---|--------------------|------|
| VDD to G | -0.3 to +23.5 | V |
| Maximum Continuous VDD Current | 20 | mA |
| FB to G | -0.3 to +6 | V |
| SW to G | -0.3 to +23.5 | V |
| Continuous SW Current | Internally limited | A |
| Maximum Power Dissipation (derate 5.3mW/°C above T _A = 50°C) | 0.53 | W |
| Junction to Ambient Thermal Resistance (θ_{JA}) | 190 | °C/W |
| Operating Junction Temperature | -40 to 150 | °C |
| Storage Temperature | -55 to 150 | °C |
| Lead Temperature (Soldering, 10 sec) | 300 | °C |

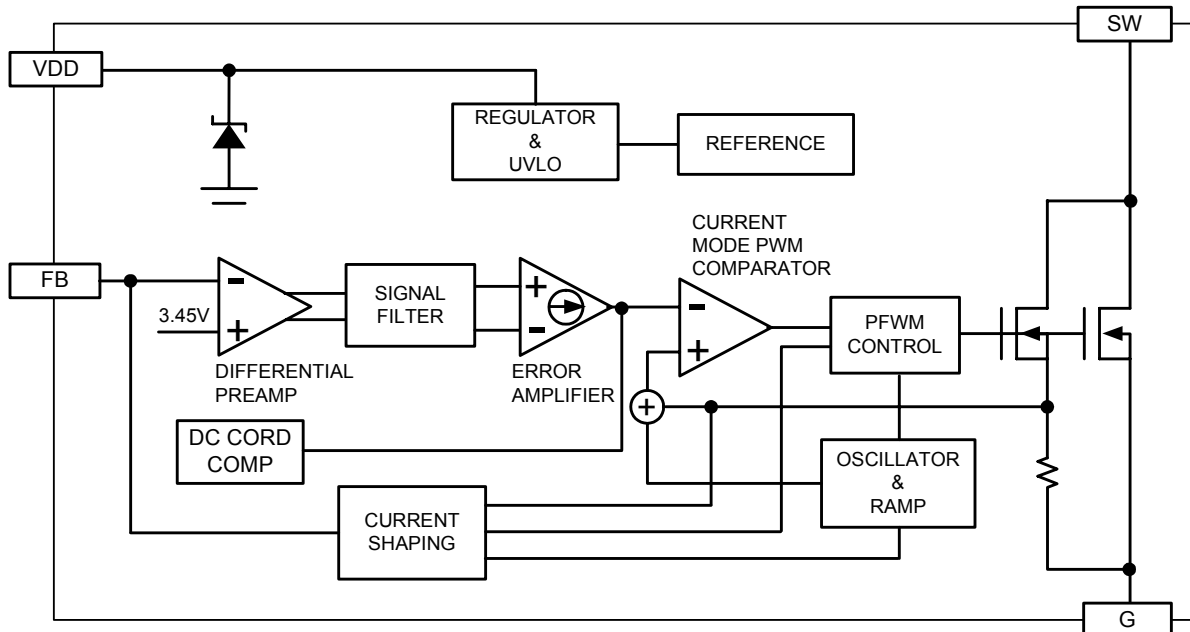
①: Do not exceed these limits to prevent damage to the device. Exposure to absolute maximum rating conditions for long periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{DD} = 15V, V_{OUT} = 5V, L_P = 2mH, N_P = 130, N_S = 10, N_A = 32, T_A = 25°C, unless otherwise specified.)

| PARAMETER | SYMBOL | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|-------------------------------------|--------------------|--|-------|-------|-------|------|
| VDD Turn-On Voltage | V _{DDON} | V _{DD} Rising | 16.4 | 19.4 | 22.0 | V |
| VDD Turn-Off Voltage | V _{DDOFF} | V _{DD} Falling | 7 | 7.5 | 8 | V |
| VDD OVP Trigger Voltage | V _{DDOVP} | | 18.2 | 20.5 | 22.5 | V |
| Supply Current | I _{DD} | | | 0.8 | 1.5 | mA |
| Start Up Supply Current | I _{DDST} | V _{DD} = 15V, before turn-on | | 30 | 55 | μA |
| Clamp Switching Frequency | | | 45 | | 58 | kHz |
| Effective FB Feedback Voltage | V _{FB} | FB in Regulation | 3.415 | 3.467 | 3.520 | V |
| Output Cord Resistance Compensation | | Maximum Output Power | | +3.7 | | % |
| Primary Current Limit | I _{LIM} | | | 320 | | mA |
| Maximum Duty Cycle | D _{MAX} | I _{SW} = 10mA | 80 | 86 | 92 | % |
| Switch On-Resistance | R _{ON} | I _{SW} = 50mA | | 3.5 | 5 | Ω |
| SW Rise Time | | 1nF load, 15Ω pull-up | | 30 | | ns |
| SW Fall Time | | 1nF load, 15Ω pull-up | | 20 | | ns |
| SW Off Leakage Current | | Switch in off-state, V _{SW} = 22V | | 1 | 10 | μA |
| Over-Temperature Threshold | | | | 160 | | °C |

FUNCTIONAL BLOCK DIAGRAM



FUNCTIONAL DESCRIPTION

As shown in the *Functional Block Diagram*, the ACT355A feedback regulation is done via several circuit blocks to pre-amplify the FB pin error voltage relative to an internal reference, filter out the switching transients, and integrate the resulting useful differential error voltage for current mode PFWM (Pulse Frequency and Width Modulation) control.

SW is a driver output that drives the emitter of an external high voltage NPN transistor or N-channel MOSFET. This emitter-drive method takes advantage of the high V_{CBO} of the transistor, allowing a low cost transistor such as '13003 ($V_{CBO} = 700V$) or '13002 ($V_{CBO} = 600V$) to be used for a wide AC input range.

Startup Mode

VDD is the power supply terminal for the IC. During startup, the IC typically draws 30 μ A supply current. The bleed resistor from the rectified high voltage DC rail supplies current to VDD until it exceeds the V_{DDON} threshold of 19.4V. At this point, the IC enters normal operation when switching begins and the output voltage begins to rise. The VDD bypass capacitor must supply the IC and the NPN base drive until the output voltage builds up enough to provide power from the auxiliary winding to sustain the VDD. The V_{DDOFF} threshold is 7.5V, and therefore, the voltage on the VDD capacitor must not drop more than 10V while the output is charging up.

Constant Voltage (CV) Mode

In constant voltage operation, the IC captures the auxiliary flyback signal at FB pin through a resistor divider network R5 and R6 in the simplified application circuit. The FB pin is pre-amplified against the reference voltage, and the secondary side output voltage error is extracted based on Active-Semi's proprietary filter architecture. This error signal is then integrated by the Error Amplifier.

When the secondary output voltage is above regulation, the Error Amplifier output voltage decreases to reduce the switch current. When the secondary side is below regulation, the Error Amplifier output voltage increases to ramp up the switch current to bring the secondary output back to regulation. The output regulation voltage is determined by the following relationship:

$$V_{OUTCV} = 3.45V \times \left(1 + \frac{R5}{R6}\right) \left(\frac{N_S}{N_A}\right) - V_F \quad (1)$$

where R5 and R6 are top and bottom feedback resistor, N_S and N_A are numbers of transformer secondary and auxiliary turns, and V_F is the rectifier diode forward drop voltage at approximately 0.1A bias. The ACT355A includes internal feedback loop compensation to simplify application circuit design.

Constant Current (CC) Mode

When the secondary output current reaches a level set by the internal current limiting circuit, the IC enters current limit condition and causes the secondary output voltage to drop. As the output voltage decreases, so does the flyback voltage in a proportional manner. An internal current shaping circuitry adjusts the switching frequency based on the flyback voltage so that the transferred power remains proportional to the output voltage, resulting in a constant secondary side output current profile. The energy transferred to the output during each switching cycle is $\frac{1}{2}(L_P \times I_{LIM}^2) \times \eta$, where L_P is the transformer primary inductance, I_{LIM} is the primary peak current, and η is the conversion efficiency. From this formula, the constant output current can be derived:

$$I_{OUTCC} = \frac{1}{2} L_P \times I_{LIM}^2 \left(\frac{\eta \times f_{SW}}{V_{OUTCV}} \right) \quad (2)$$

where f_{SW} is the nominal switching frequency and V_{OUTCV} is the nominal secondary output voltage. The constant current operation typically extends down to lower than 40% of output voltage regulation.

Light Load Mode

When the secondary side output load current decreases to an internally set light load level, the IC's switching frequency is also reduced to save power. This enables the application to meet all current green energy standards. The actual minimum switching frequency is programmable with a small dummy load (while still meeting standby power).

Short Circuit Mode

When the secondary side output is short circuited, the ACT355A enters hiccup mode operation. In this condition, the auxiliary supply voltage collapses and the VDD voltage drops below the V_{DDOFF} threshold. This turns off the IC and causes it to restart. This hiccup behavior continues until the short circuit is removed.

Output Over Voltage Protection

The ACT355A includes output over-voltage protection circuitry, which shuts down the IC when the output voltage is 40% above the normal regulation voltage or when no feedback signal is detected for 8 consecutive switching cycles. The IC enters hiccup mode when an output over voltage fault is detected.

Loop Compensation

The ACT355A integrates loop compensation circuitry for simplified application design, optimized transient response, and minimal external components.

Primary Inductance Compensation

The ACT355A includes built-in primary inductance compensation to maintain constant current regulation despite variations in transformer manufacturing.

Peak Inductor Current Limit Compensation

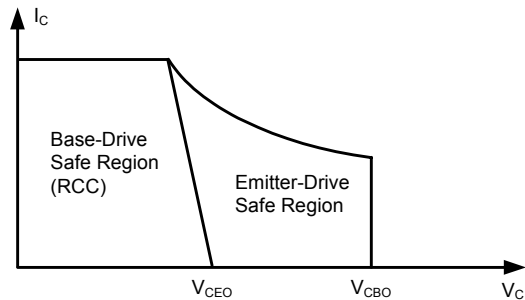
The ACT355A includes peak inductor current limit compensation to achieve constant input power over wide line and wide load range.

Output Cord Resistance Compensation

The ACT355A provides automatic output cord resistance compensation during constant voltage regulation, monotonically adding an output voltage correction up to a typical correction of 3.2% at full power. This feature allows for better output voltage accuracy by compensating for the output voltage droop due to the output cord resistance.

APPLICATIONS INFORMATION

Figure 2:
NPN Transistor Reverse Bias Safe Operation Area



External Power Transistor

The ACT355A allows a low-cost high voltage power NPN transistor such as '13003 or '13002 to be used safely in flyback configuration. The required collector voltage rating for $V_{AC} = 265V$ with full output load is at least 600V to 700V. As seen from Figure 2, *NPN Reverse Bias Safe Operation Area*, the breakdown voltage of an NPN is significantly improved when it

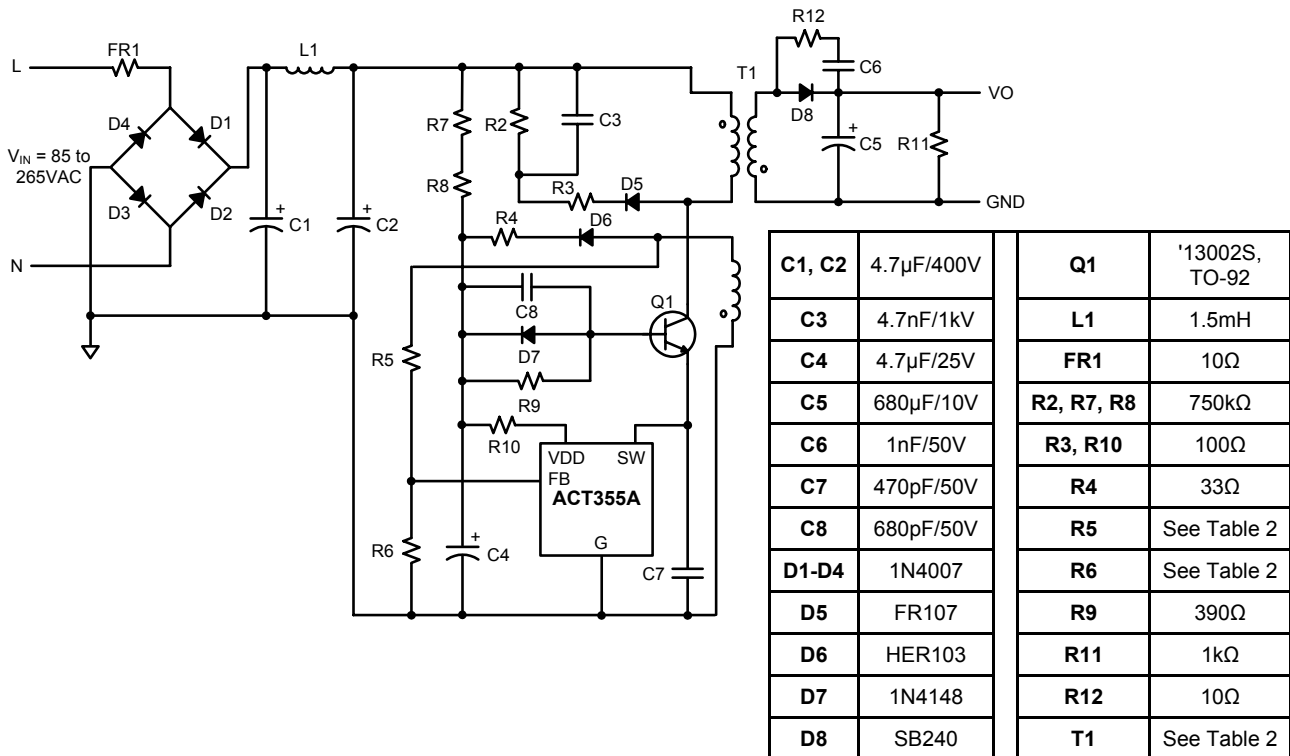
is driven at its emitter. Thus, the ACT355A+'13002 or '13003 combination meets the necessary breakdown safety requirement. Table 1 lists the breakdown voltage of some transistors appropriate for use with the ACT355A.

The power dissipated in the NPN transistor is equal to the collector current times the collector-emitter voltage. As a result, the transistor must always be in saturation when turned on to prevent excessive power dissipation. Select an NPN transistor with sufficiently high current gain ($h_{FEMIN} > 8$) and a base drive resistor low enough to ensure that the transistor easily saturates.

Table 1:
Recommended NPN Transistor

| DEVICE | V_{CBO} | V_{CEO} | I_c | h_{FEMIN} | PACKAGE |
|--------------------|-----------|-----------|-------|-------------|---------|
| MJE13002 | 600V | 300V | 1.5A | 25 | TO-126 |
| MJE13003, KSE13003 | 700V | 400V | 1.5A | 25 | TO-126 |
| STX13003 | 700V | 400V | 1A | 25 | TO-92 |

Figure 3:
Typical Application Circuit



Design Procedure

Figure 3, *Typical Application Circuit*, shows a complete, optimized constant voltage/constant current charger application. The application design procedure for using the ACT355A is simple. Three components determine the output constant voltage and constant current settings: the transformer T₁ and resistors R5 and R6. Refer to Table 2 for selection values for these three key components for different typical design cases. The *Typical Application Circuit* in Figure 3 lists component values of other devices in the a complete charger application.

Design Notes

- 1) Feedback resistors R5 and R6 must meet the $\pm 1\%$ maximum tolerance to have good V_o regulation.
- 2) The value of the feedback resistor can be chosen slightly different from the table according to the actual system efficiencies in different systems.
- 3) C8 must be added to guarantee good CC accuracy.

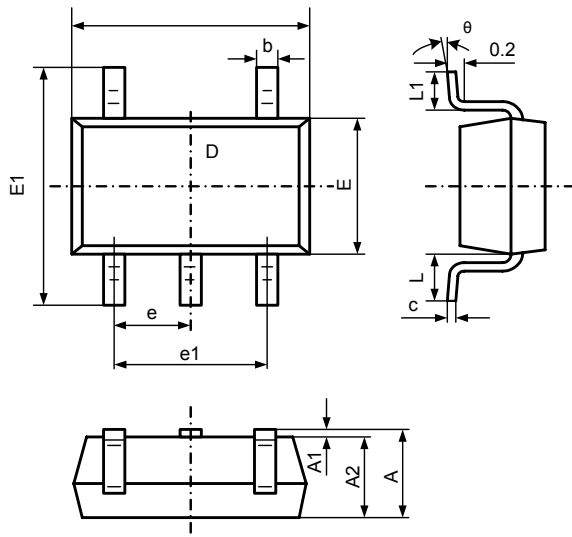
Table 2:

Component Selection Table

| DESIGN CASE | OUTPUT | | ActivePSR™ PART NUMBER | TRANSFORMER | | | | RESISTOR NETWORK | |
|-------------|--------------------|---------------------|------------------------|----------------|----------------|----------------|-------------------------|------------------|------------|
| | V _o (V) | I _o (mA) | | N _P | N _A | N _S | L _P ±7% (mH) | R5±1% (kΩ) | R6±1% (kΩ) |
| 1 | 5.0 | 500 | ACT355A | 130 | 32 | 10 | 1.6 | 26.7 | 6.98 |
| 2 | 5.0 | 600 | ACT355A | 130 | 32 | 10 | 1.8 | 31.6 | 8.25 |
| 3 | 5.0 | 650 | ACT355A | 130 | 32 | 10 | 1.9 | 34.4 | 9.09 |

PACKAGE OUTLINE

SOT23-5 PACKAGE OUTLINE AND DIMENSIONS



| SYMBOL | DIMENSION IN MILLIMETERS | | DIMENSION IN INCHES | |
|--------|--------------------------|-------|---------------------|-------|
| | MIN | MAX | MIN | MAX |
| A | 1.050 | 1.250 | 0.041 | 0.049 |
| A1 | 0.000 | 0.100 | 0.000 | 0.004 |
| A2 | 1.050 | 1.150 | 0.041 | 0.045 |
| b | 0.300 | 0.500 | 0.012 | 0.020 |
| c | 0.100 | 0.200 | 0.004 | 0.008 |
| D | 2.820 | 3.020 | 0.111 | 0.119 |
| E | 1.500 | 1.700 | 0.059 | 0.067 |
| E1 | 2.650 | 2.950 | 0.104 | 0.116 |
| e | 0.950 TYP | | 0.037 TYP | |
| e1 | 1.800 | 2.000 | 0.071 | 0.079 |
| L | 0.700 REF | | 0.028 REF | |
| L1 | 0.300 | 0.600 | 0.012 | 0.024 |
| θ | 0° | 8° | 0° | 8° |

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