APPLICATION NOTE 7338

MAX38888- PROGRAMMABLE SUPER CAPACITOR VOLTAGE DISCHARGE THRESHOLD FOR POWER BACKUP APPLICATIONS

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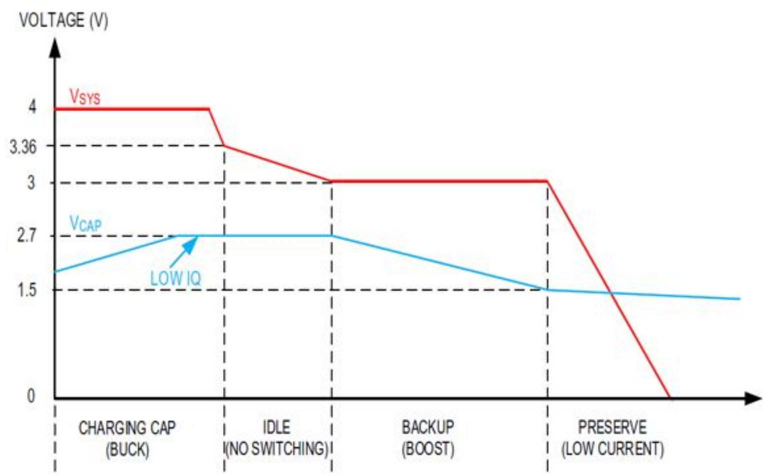
Abstract: In this application note, a reference circuit design is proposed using the MAX38888. While the MAX38888 provides a supercapacitor-based backup in the absence of a system rail (V_{SYS}) by discharging its stored charge, the integrated circuit (IC) only supports supercapacitor-discharge function after it is fully charged to its maximum programmable voltage, set by a string of resistors. The reference design presented in this application note would enable the MAX38888-based supercap backup regulator to discharge once $V_{SUPERCAP}$ = 1.7V and indicate through the toggled status of the RDY pin of the MAX38888. This application enhancement enables cut down in production test times and enables discharge at programmable supercap voltage threshold

Introduction

As the demand for high-performance portable electronic devices, Internet of Things (IoT), metering devices, and handheld devices is growing, the need for backup power applications is also on an unabated rise. It often becomes essential to have backup power supplied efficiently and quickly with user indication of backup availability. The MAX38888 is a super capacitor-based bidirectional power transfer regulator with a shared inductor used in power backup applications. The MAX38888 eliminates the need for an additional power converter, while combining buck and boost operations in a single IC with minimal external component count, thereby maximizing cost savings. This application note discusses the MAX38888-based super capacitor backup regulator with programmable voltage discharge threshold set through the resistor strings and MOSFET switch, with the status indication of voltage changing through the IC RDY pin.

About the MAX38888-Reversible Buck-Boost Regulator

The MAX38888 is a storage capacitor or capacitor bank backup regulator designed to efficiently transfer power between a storage element and a system supply rail in reversible buck and boost operations using the same inductor, see **Figure 1**. By providing bidirectional power transfer, the IC eliminates the need for a separate additional power converter and simplifies cost savings. A typical application circuit is shown in **Figure 2**.

Features	**Performance**
• 2.5V to 5V System Output Voltage • 0.8V to 4.5V Cap Voltage Range • Up to 2.5A Peak Inductor Discharge Current • Programmable Voltage, Current Thresholds • ±2% Threshold Accuracy • Up to 95% Efficiency, Charge or Discharge • 2.5µA Ready Quiescent Current • Small Solution Size 3mm × 3mm × 0.75mm Thin, Dual-in-line Flat, No Lead (TDFN) Package	 *Figure 1. MAX38888 operating modes.*

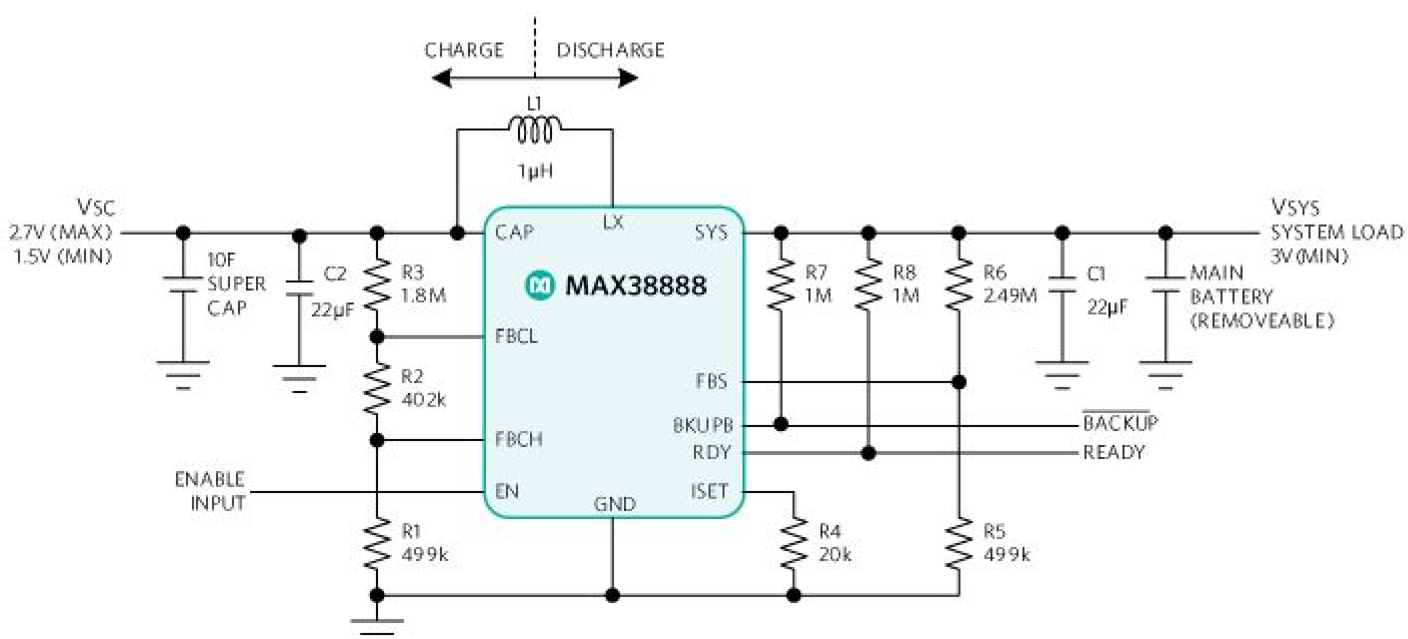


Figure 2. MAX38888 typical application circuit with indicative component values.

Need for Programmable Supercap Discharge Voltage Threshold

In this application note, the reference circuit described in **Figure 3** provides the following application improvements:

- It provides a programmable supercap discharge potential along with the RDY status pin indication.
- It resolves the wait time associated with the supercap's readiness to discharge until the supercap charging to max voltage is complete.
- It resolves the following hot plug-in/out use case.

For example: a removable battery (V_{SYS}) is used to trickle charge the Super cap and quickly disconnected. If the max super cap programmable voltage set by Resistor at FBCH pin, is never attained due to insufficient charge drawn from V_{SYS}, the supercap discharge circuit will be incapable to regulate minimum V_{SYS} rail and Vsupercap discharge cycle never activates as the max programmable $V_{supercap}$ was not attained.

For this study, consider the following use case:

V_{SYS} = 2.99V to 4.2V
$V_{SUPERCAP}$ range = 1.42V to 2.71V
Inductor peak discharge current = 2.5A peak

Circuit Description
Square blocks (see **Figure 3**) describe the modified/added components to achieve the programmable V discharge threshold from a typical application schematic mentioned in the MAX38888 EV kit data sheet.

The maximum super capacitor voltage is set using a resistor divider from CAP to FBCH to GND. Because the resistor tolerance has a direct effect on the voltage accuracy, these resistors should have 1% accuracy or better.

During startup in the Figure 3 schematic, the MOSFET gate being driven by the RDY pin is low, i.e., $V_{GS} < V_{GSTHRESHOLD}$ of the MOSFET, and is nonconducting. This makes both the resistor R25 and the MOSFET M1 not a part of the active resistor divider circuit from V_{CAP} to GND. The max supercap voltage is set using a resistor divider from CAP to FBCH to GND formed by resistors R1, R2 and R3. Setting a value of 910kΩ for R1, $V_{CAP\ MAX}$ is derived as 1.7V during the MOSFET OFF state as shown below in the equation

The turn-on criteria for MOSFET is $V_{GSTHRESHOLD}$ max ≤ V_{SYS_min}. The max super cap voltage is given by the following equation:

$$R2 + R3 = R1 \times [(V\mathbf{CAP\ MAX}/0.5) - 1]$$

During the MOSFET OFF (nonconducting) state, the max supercap voltage for Figure 3 schematic can be calculated as follows:

$$\text{VCAP MAX\_FET\_OFF} = 0.5 * \left[\frac{(R2 + R3)}{R1} + 1\right] = 0.5 * \left[\frac{(0.402+1.8)}{0.910} + 1\right] = 1.7\text{V}$$

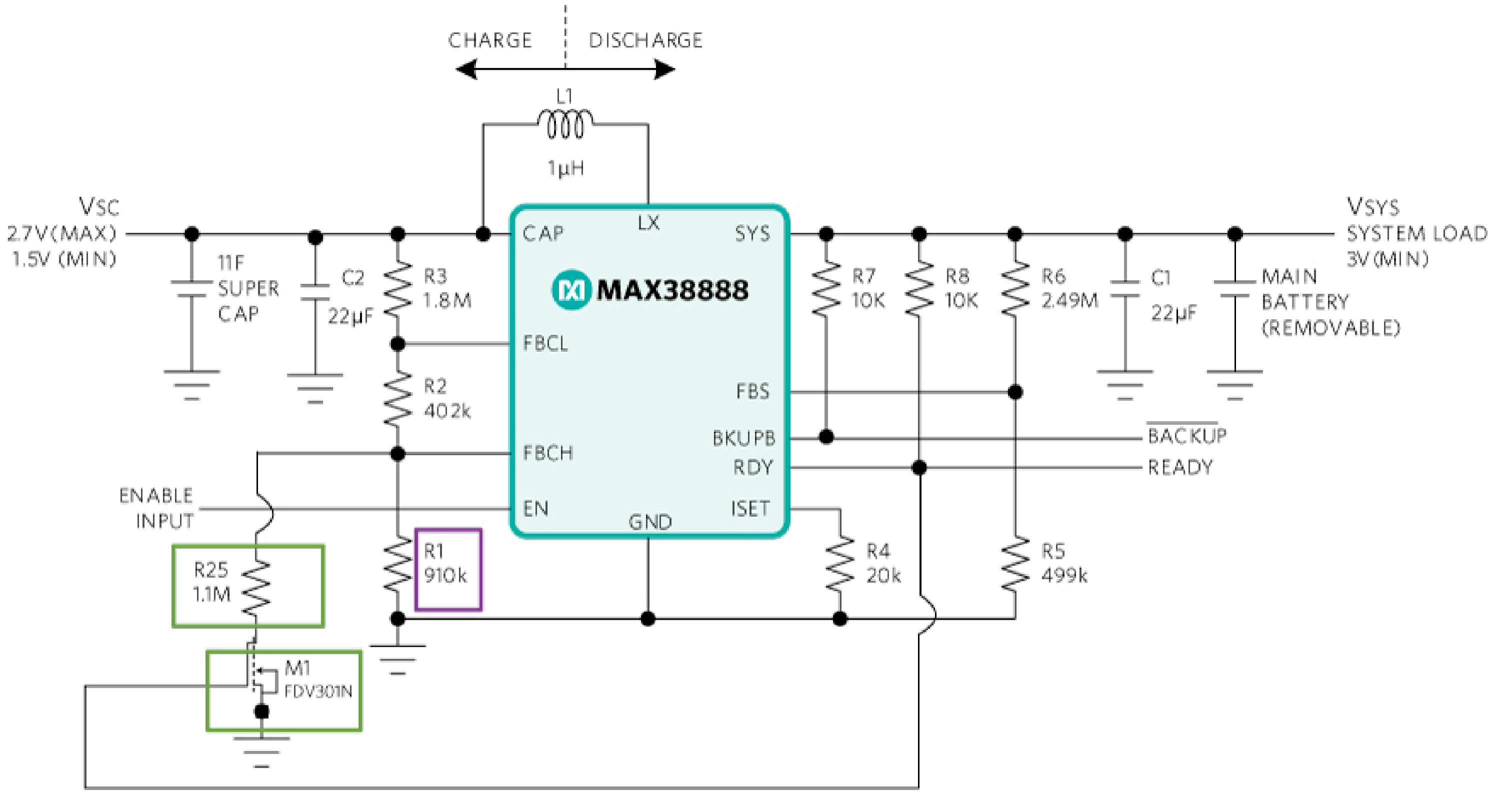


Figure 3. MAX38888—Schematic circuit for $V_{SUPERCAP}$ discharge programmability.

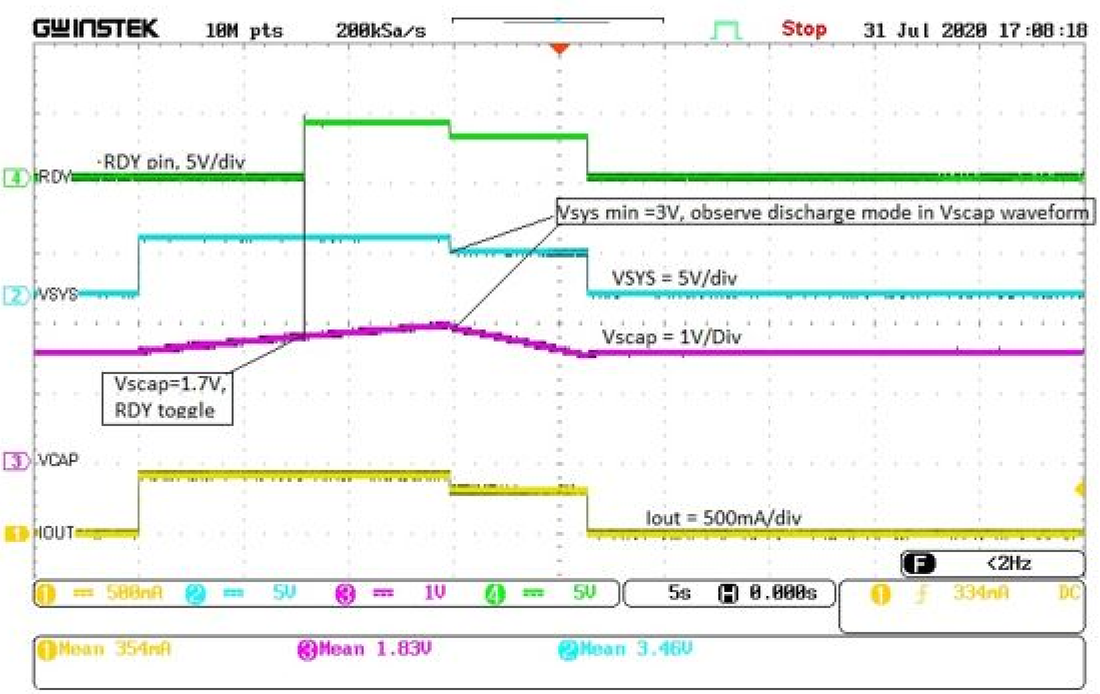


Figure 4. Supercap discharge readiness at 1.7V. V_{SYS} = 4V, I_{OUT} = 500mA peak.

Once the circuit attains the supercap voltage of 1.7V, the RDY status pin is pulled high, indicating that the supercap is now ready for discharge. Once the RDY pin toggles high and above the minimum $V_{GSTHRESHOLD}$, the MOSFET M1 turns ON and connects the R25 across R1. The magnitude of RDS_{ON} is very less in comparison to R25 and can be ignored.

So, now R25 is parallel to R1:

R25 = 1.1MΩ
R1 = 910kΩ
R25 || R1 ⟶ Req = 498kΩ

Substituting a 498kΩ equivalent resistance in the VCAP max equation, the supercap maximum discharge voltage is 2.71V during the MOSFET ON state.

$$\text{VCAP MAX\_FET\_ON} = 0.5 * \left[\frac{(\text{R2} + \text{R3})}{Req} + 1\right] = 0.5 * \left[\frac{(0.402+1.8)}{0.498} + 1\right] = 2.71\text{V}$$

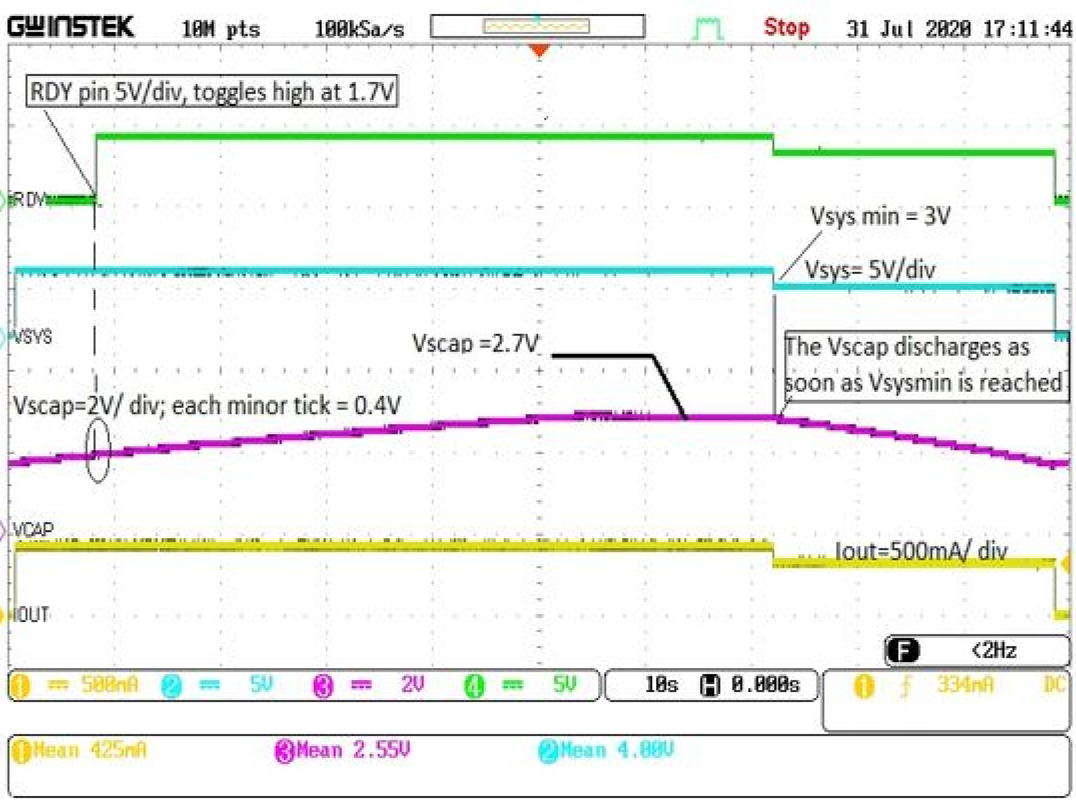


Figure 5: The MAX38888 is ready for discharge from V_{SCAP} = 1.7V. Since FET (M1) is on, charges all way to 2.7V.

Table 1: Modified Circuit Bill of Materials

Item	REF_DES	QTY	MFG Part#	Manufacturer	Description
1	R1	1	CRCW0603910KFKEA	Vishay Dale	SMD Resistor, 1%, 0.1W, 910kΩ, 0603, Thick film.
2	R25	1	CRCW06031M10FKEA	Vishay Dale	SMD Resistor, 1%, 0.1W, 1.1MΩ, 0603, Thick film.
3	M1	1	FDV301N	On Semi	SMD Logic Level nMOS, 25VDS, 0.22A, SOT23.

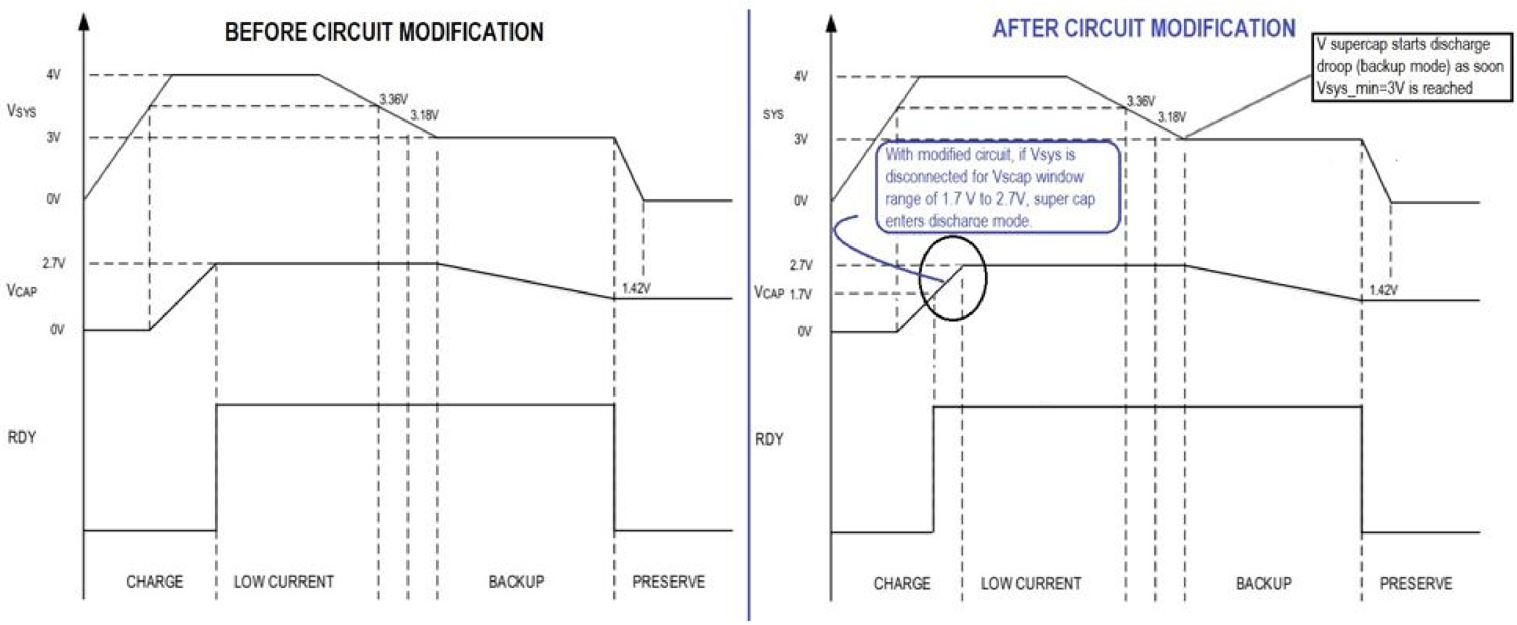


Figure 6. MAX38888 circuit operation waveforms before and after modification.

Programmable resistors R1, R2, R3, and R25 values can be chosen vs the desired supercap minimum and maximum voltages from 0.8V to 4.5V. In this application note, R1, R2, R3, and R25 are chosen for maximum supercap voltage of 2.7V, while allowing the supercap to be discharge-ready from 1.7V.

Conclusion

In this application note, a supercap-based backup regulator with programmable voltage discharge threshold with a choice of resistors and MOSFET switch is suggested. The discharge readiness of the super capacitor is indicated through the toggled-status change of the RDY pin. These application enhancements reduce production run time and usability across products and expands the MAX38888 design opportunities.

Reference

MAX38888EVKIT Data Sheet

Related Parts

Related Parts		
MAX38888	2.5V–5.0V, 0.5A/2.5A Reversible Buck/Boost Regulator for Backup Power Applications	Free Sample

Next Steps	
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