

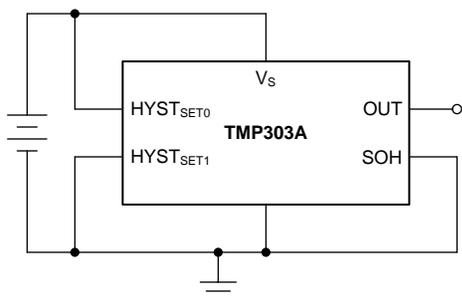
# Low-Power Battery Temperature Monitoring

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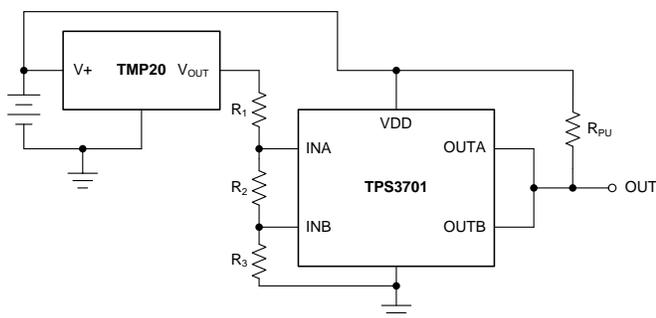
Charging a battery cannot be independent of temperature. In fact, most batteries specify a range of temperatures where charging is permitted. Charging outside these bounds risks damage, failure or worse.

To prevent charging when the temperature is too hot or too cold, a temperature sensor and corresponding circuitry are required to disable the charging circuit accordingly. Some temperature sensors like **TMP303** already incorporate this functionality. **TMP303** monitors the local temperature and asserts its output when the temperature rises above or falls below factory-programmed trip points. This output signal is used to disable the charging circuit, as shown in [Figure 1](#):



**Figure 1. TMP303 monitoring battery temperature and driving OUT accordingly**

However, it can be advantageous to be able to adjust these trip points according to new design requirements or circumstances. Although **TMP303** is capable of additional factory-programmed trip points, simply changing a resistor is a quick method for adjusting a trip point in the lab. [Figure 2](#) shows one such adjustable solution.



**Figure 2. Pairing TMP20 with TPS3701 to detect high and low temperatures**

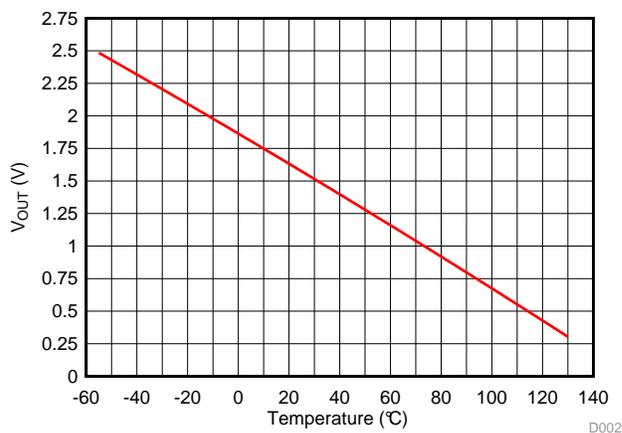
This solution pairs an analog output temperature sensor (**TMP20**) and a window comparator with an integrated reference voltage (**TPS3701**). **TMP20** senses the local temperature and outputs a corresponding voltage. This is then sensed by **TPS3701** which will assert the reset output if the sensed voltage falls outside the range set by the resistor divider ( $R_1$ ,  $R_2$  and  $R_3$ ).

Setting the overvoltage (OV) and undervoltage (UV) limit for this range requires first determining the voltage outputs ( $V_{T_{HIGH}}$  and  $V_{T_{LOW}}$ ) that correlate with the desired trip points ( $T_{HIGH}$  and  $T_{LOW}$ ). This is yielded by **TMP20**'s parabolic transfer function:

$$V_{OUT} = (-3.88 \times 10^{-6} \times T^2) + (-1.15 \times 10^{-2} \times T) + 1.8639 \quad (1)$$

where  $T$  is the temperature in degrees °C

[Equation 1](#) is visualized in [Figure 3](#):



**Figure 3. V<sub>OUT</sub> vs. Temperature for TMP20 over the entire temperature range**

After the voltage limits are established, the resistor divider values are determined by the following equations:

$$V_{T_{HIGH}} = V_{IT-(INA)} \left(1 + \frac{R_1}{R_2 + R_3}\right) \quad (2)$$

$$V_{T_{LOW}} = V_{IT+(INB)} \left(1 + \frac{R_1 + R_2}{R_3}\right) \quad (3)$$

$$R_1 + R_2 + R_3 \leq \frac{V_{T_{HIGH}}}{100 \times I_{IN}} \quad (4)$$

where:

- $V_{IT-(INA)}$  is the INA pin negative input threshold voltage (400 mV)
- $V_{IT+(INB)}$  is the INB pin positive input threshold voltage (400 mV)
- $I_{IN}$  is the maximum total input current into the INA and INB pins (50 nA)

The total resistance of the resistor divider ( $R_1 + R_2 + R_3$ ) should be low enough so that the accuracy of the voltage detection should not be affected but also high enough to avoid excess current consumption. This is reflected in Equation 4.

As an example, consider a designer who wants charging to occur when the temperature is between 0°C and 45°C. Since TMP20 has some inaccuracy associated with output voltage, the bounds are set at 2°C and 43°C for derating purposes. Solving for  $V_{T_{HIGH}}$  and  $V_{T_{LOW}}$  via Equation 1 yields:

$$V_{T_{HIGH}} = 1.3622 \text{ V}$$

$$V_{T_{LOW}} = 1.8409 \text{ V}$$

Equations 2, 3 and 4 can then be solved via a matrix:

$$\begin{bmatrix} 1 & -2.405 & -3.405 \\ 1 & 1 & -3.602 \\ 1 & 1 & 1 \end{bmatrix} \begin{bmatrix} R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 272k \end{bmatrix}$$

$$\begin{bmatrix} R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{bmatrix} 192k \\ 20.8k \\ 59.2k \end{bmatrix}$$

The closest standard 1% resistor values are then chosen:

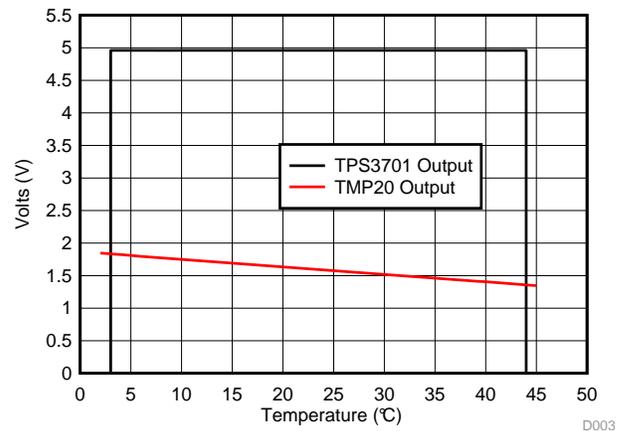
$$\begin{bmatrix} R_1 \\ R_2 \\ R_3 \end{bmatrix} = \begin{bmatrix} 191k \\ 21k \\ 59k \end{bmatrix}$$

Solving Equations 2 and 3 in reverse yields the following nominal voltage limits:

$$\text{UV (Over-temperature) limit} = 1.3550 \text{ V}$$

$$\text{OV (Under-temperature) limit} = 1.8373 \text{ V}$$

These voltage limits do not include the tolerance that spurs from the inaccuracy associated with the internal reference ( $\pm 0.75\%$ ) and the resistor network ( $\pm 1\%$ ). Nonetheless, when tested over this temperature range, the circuit asserts its reset output before reaching 0°C or 45°C, as shown in Figure 4.



**Figure 4. Using TMP20 and TPS3701 to detect for under- and over-temperature**

Additionally, since this circuit is being supplied by the battery, it is important to gauge its current consumption. This is detailed in Table 1.

**Table 1. Current consumption by device**  
( $T_A = 25^\circ\text{C}$ ,  $V_{BAT} = 3.8 \text{ V}$ )

Device	Parameter	Current ( $\mu\text{A}$ )	Condition
TPS3701	Supply current	7	OUT high
		6.8	OUT low
	Open-drain current	39	OUT high; $R_{PU} = 100 \text{ k}\Omega$
	Resistor divider current	6.8	$V_{OUT} = 1.84 \text{ V}$
5		$V_{OUT} = 1.36 \text{ V}$	
TMP20	Supply current	2.4	No load

As shown, until OUT is asserted low, the circuit only consumes around 16  $\mu\text{A}$ . Such low consumption helps preserve battery life especially for applications with extended times between charging.

Although not covered in this report, attention must also be paid to the hysteresis of the high and low trip points. The hysteresis release points are calculated by substituting  $V_{IT+(INA)}$  for  $V_{IT-(INA)}$  in Equation 2 and  $V_{IT-(INB)}$  for  $V_{IT+(INB)}$  in Equation 3 and solving Equation 1 for both values.

Pairing an analog output temperature sensor and a window comparator with an integrated voltage reference is a simple, accurate, flexible and low-power method for ensuring charging occurs within a specified temperature range.

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