



Keywords: ideal diode, MAX40200, power path controlling, diode ORing

APPLICATION NOTE 6486

# PARALLELING IDEAL DIODES: USING THE MAX40200 AS A SCALABLE BUILDING BLOCK

*Abstract: This application note investigates using multiple MAX40200 ICs in parallel and their combined performance. The multiple ideal-diode solution should provide the same characteristics of a single, larger device with a factor based on the number of MAX40200 ICs being used.*

## Introduction

The [MAX40200](#) is an ideal diode current switch that drops so little voltage that it approaches an order of magnitude better than Schottky diodes. The device thermally protects itself, and any downstream circuitry, from overtemperature conditions. When disabled (EN = low), it blocks voltages up to 6V in either direction, making it suitable for most low-voltage, portable electronic devices. When reversed-biased, it leaks less than many comparable Schottky diodes. The MAX40200 operates from a 1.5V to 5.5V supply voltage.

The MAX40200 ideal diode has many benefits including the following:

1. Low 7 $\mu$ A quiescent supply current
2. Low power dissipation at 1A, just 125 $\mu$ W
3. Tiny voltage-drop of approximately 18mV for  $I_F$  up to 100mA
4. Less than 100 $\mu$ s reverse/turn-off times
5. 4-bump WLP space-saving package
6. Enable/disable control and thermal shutdown

In many circuits, the functionality of an ideal diode is required but at much higher currents. One useful aspect of ideal diodes such as the MAX40200 is that because they are implemented with MOSFETs and not diodes, they inherently share any load current. This application note investigates using multiple MAX40200 devices in parallel and their combined performance.

The multiple ideal-diode solution should provide the same characteristics of a single, larger device with a factor based on the number of MAX40200 devices being used. This allows us to use two in parallel for a 2A system and, by extension, four in parallel for a 4A system.

## Experimental Results

**Figure 1** shows four MAX40200 devices paralleled to up to 4A of current. If the devices are placed closer to each other, the temperature of each device is close to one another. Since the devices are at same temperature, they are expected to have similar characteristics. **Figure 1a** shows the DC characteristics of forward drop vs. forward current. **Figure 1b** shows a comparison of one MAX40200 device and four MAX40200 devices, confirming that the characteristics of one MAX40200 device and four MAX40200 devices are very similar.

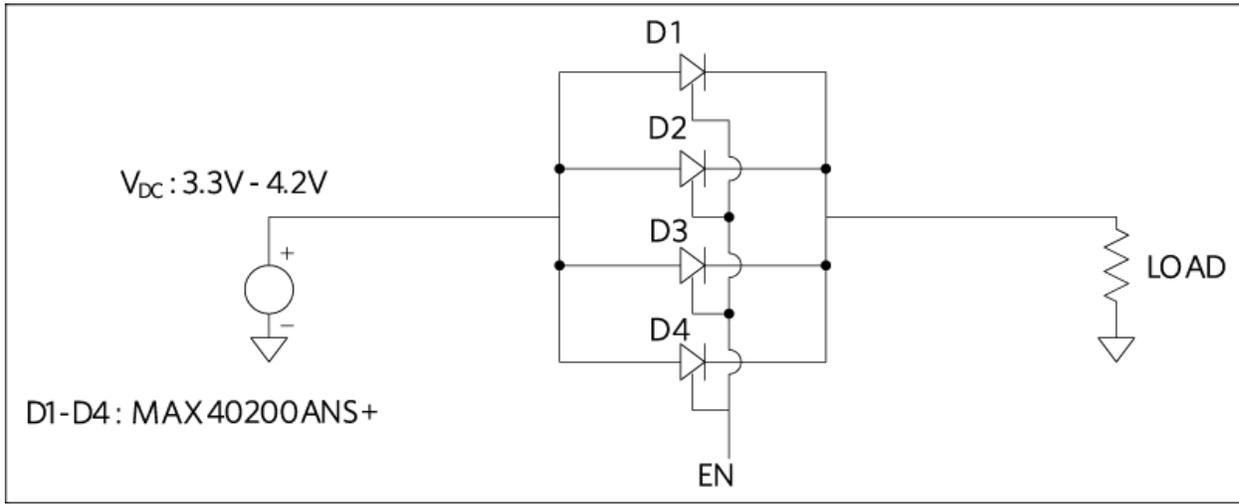


Figure 1. Typical application circuit to increase current sharing to carry high currents.

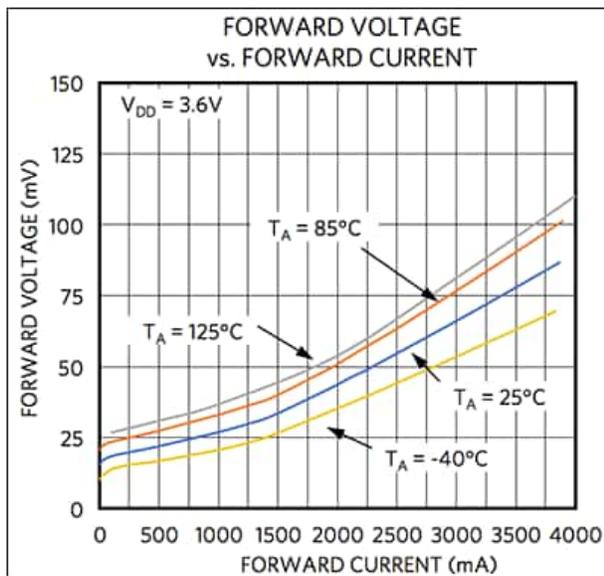
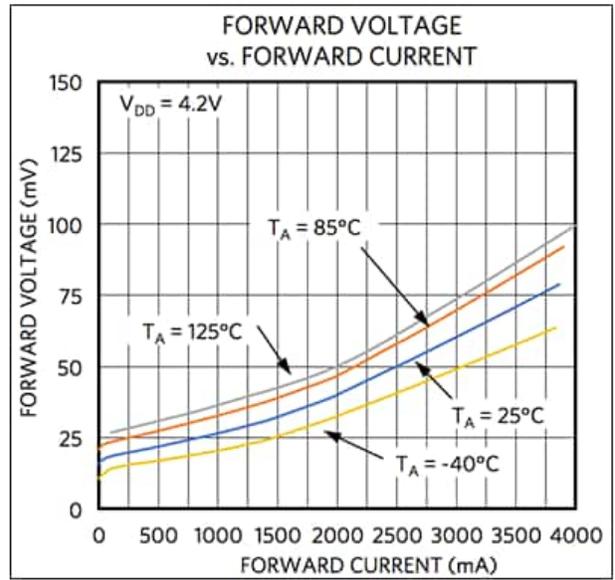
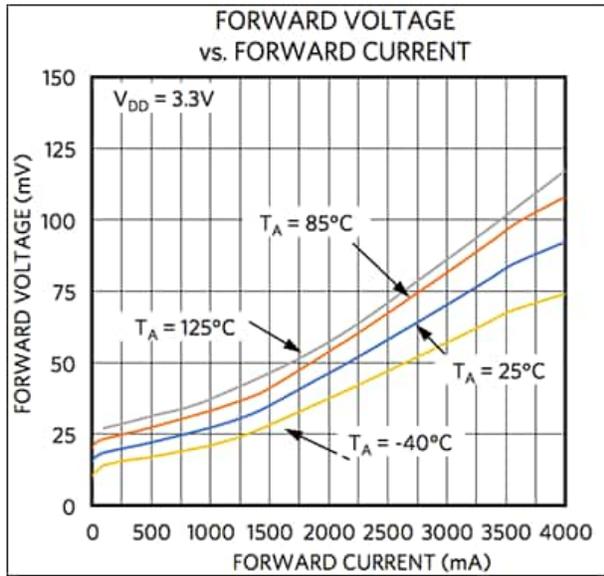


Figure 1a. Curves a, b, and c are DC characteristics showing the forward drop across the devices vs. forward current through them.

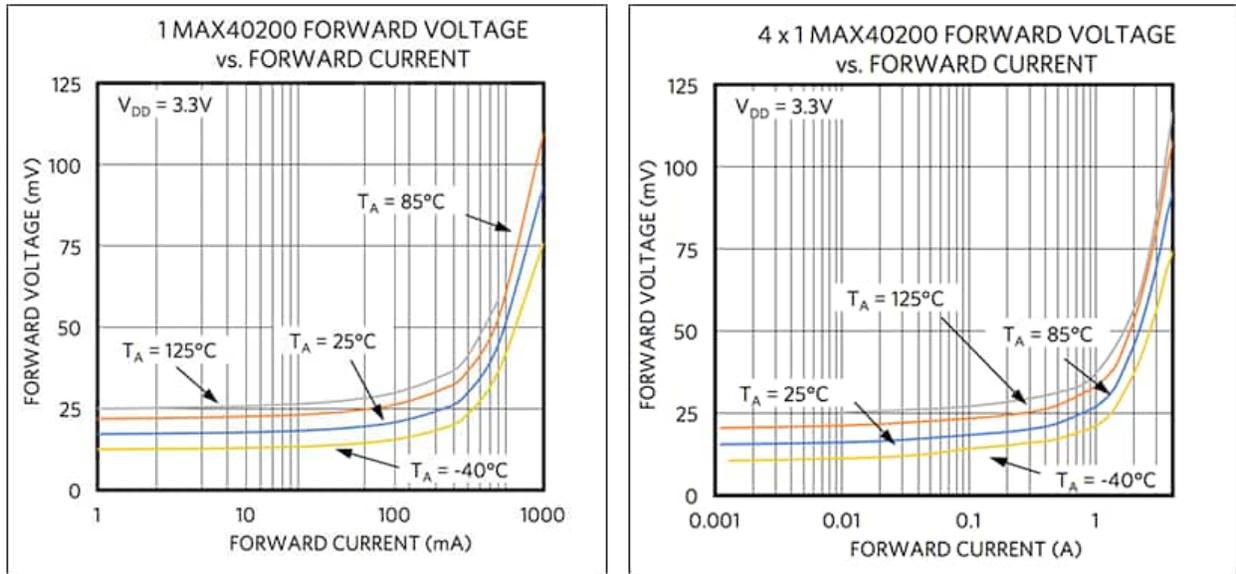


Figure 1b. Comparison of one MAX40200 device and four MAX40200 devices.

Figure 2 shows the schematic setup for enable and disable response of the application circuit. Curves 2a and 2b shows the observed results.

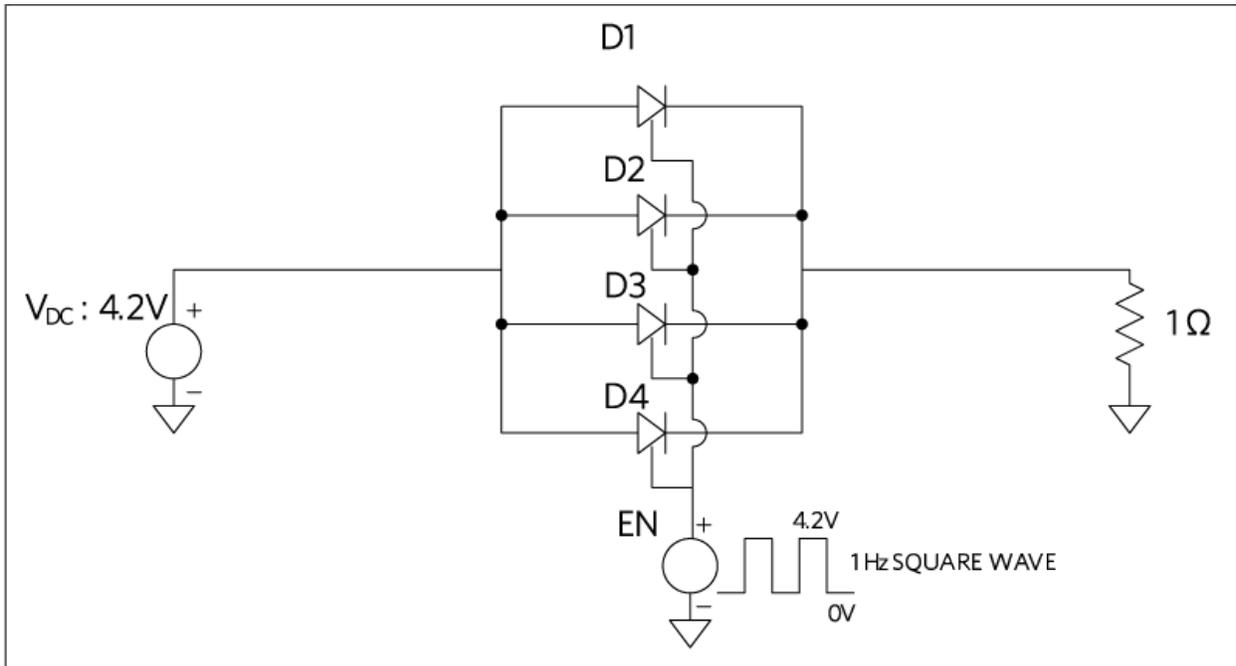
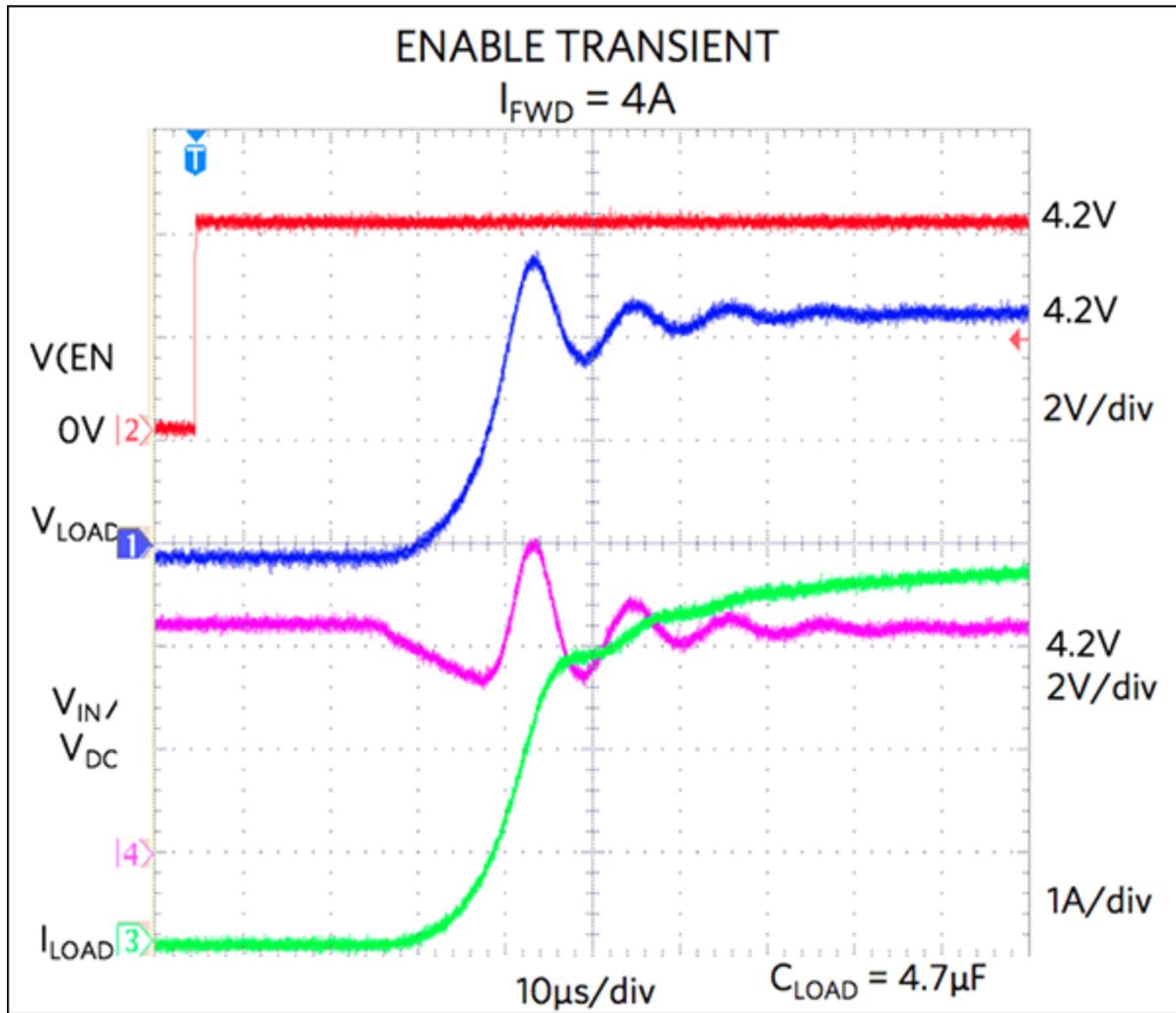


Figure 2. Setup for enable/disable response.



Curve 2a. Enable transient ( $I_{FWD} = 4A$ ).

Note that the  $V_{IN}$  exhibits a significant transient in the above figure. This is due to the load regulation response of the power supply used when sourcing from 0 to 4A. This transient effect is also seen at the  $V_{LOAD}$ .



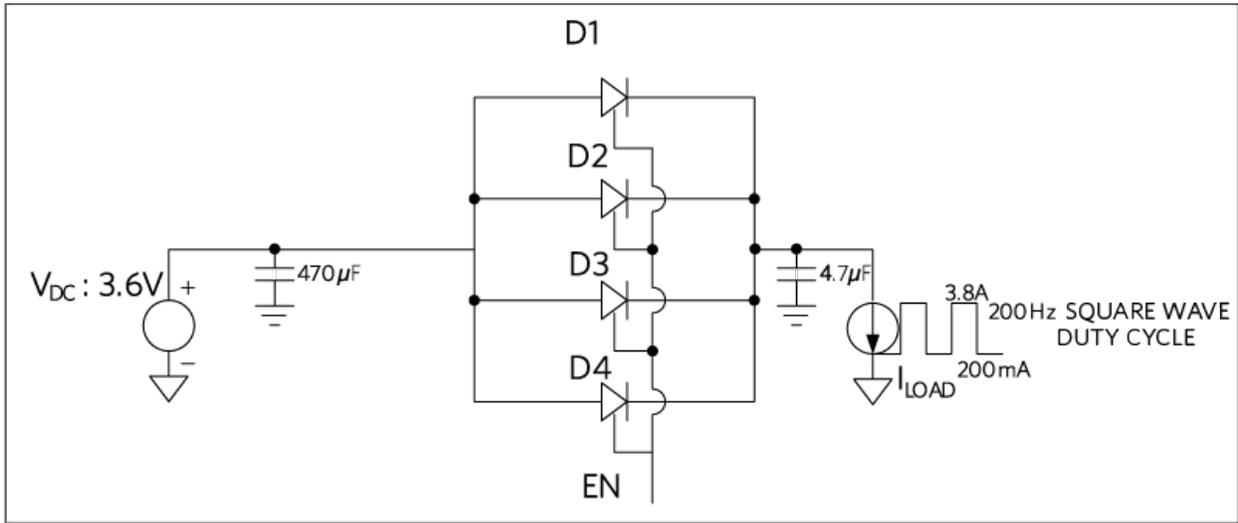
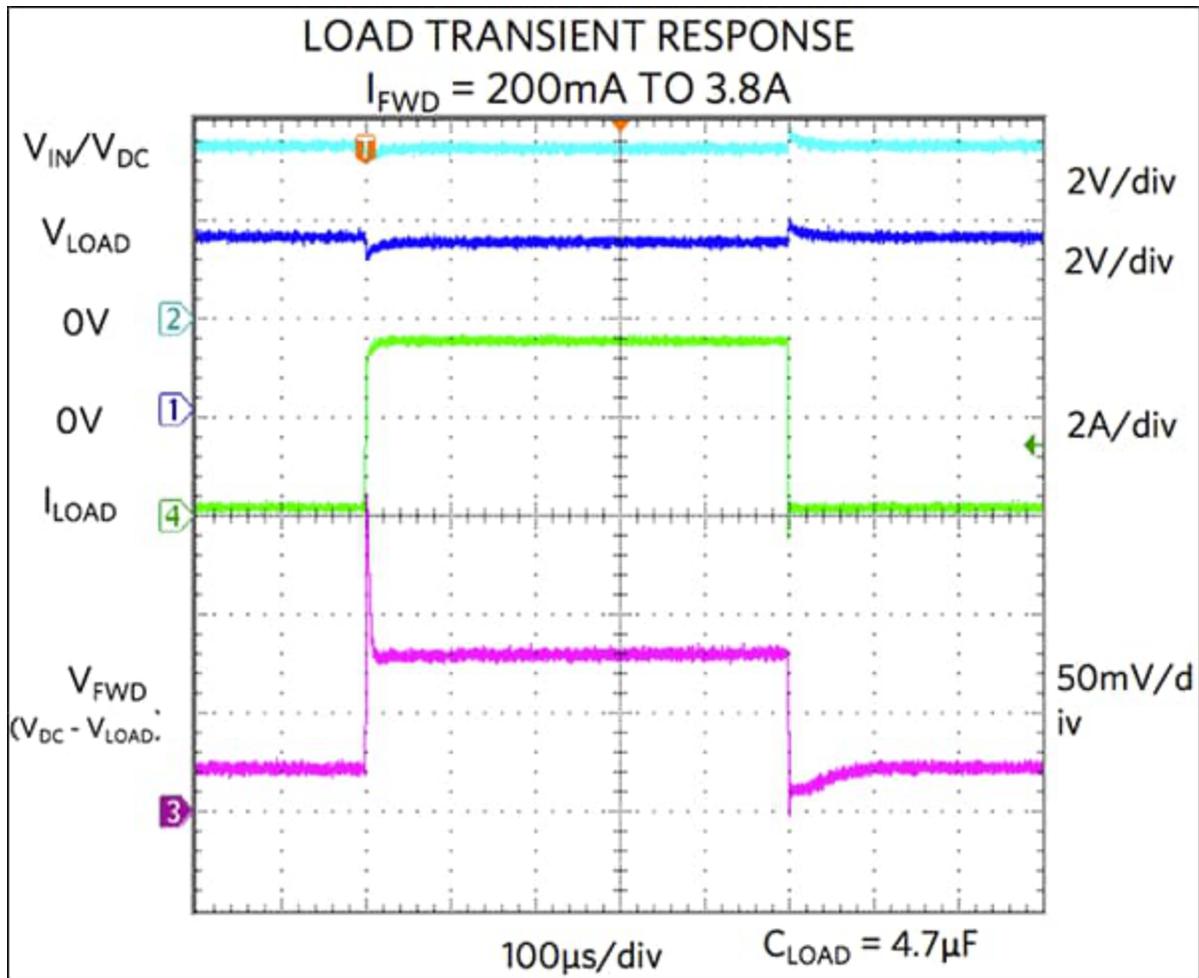


Figure 3. Setup for load transient response.



Curve 3a. Load transient response ( $I_{FWD} = 200\text{mA to } 3.8\text{A}$ ).

The below setup schematic shown in Figure 4 uses a standard Schottky diode (CMSH5-20: 20V, 5A Schottky) in conjunction with four MAX40200 devices. A transient is created at  $V_{IN2}$  to simulate a diode ORing/power-path-select scenario.

When  $V_{IN2}$  (3.3V) is less than  $V_{IN1}$  (3.6V),  $V_{IN1}$  is selected and diode D1 is reverse-biased. When  $V_{IN2}$  is greater than 3.6V, D1 starts conducting and U1 to U4 turns off. **Curve 4a** shows the transient response of the **Figure 4** circuit.

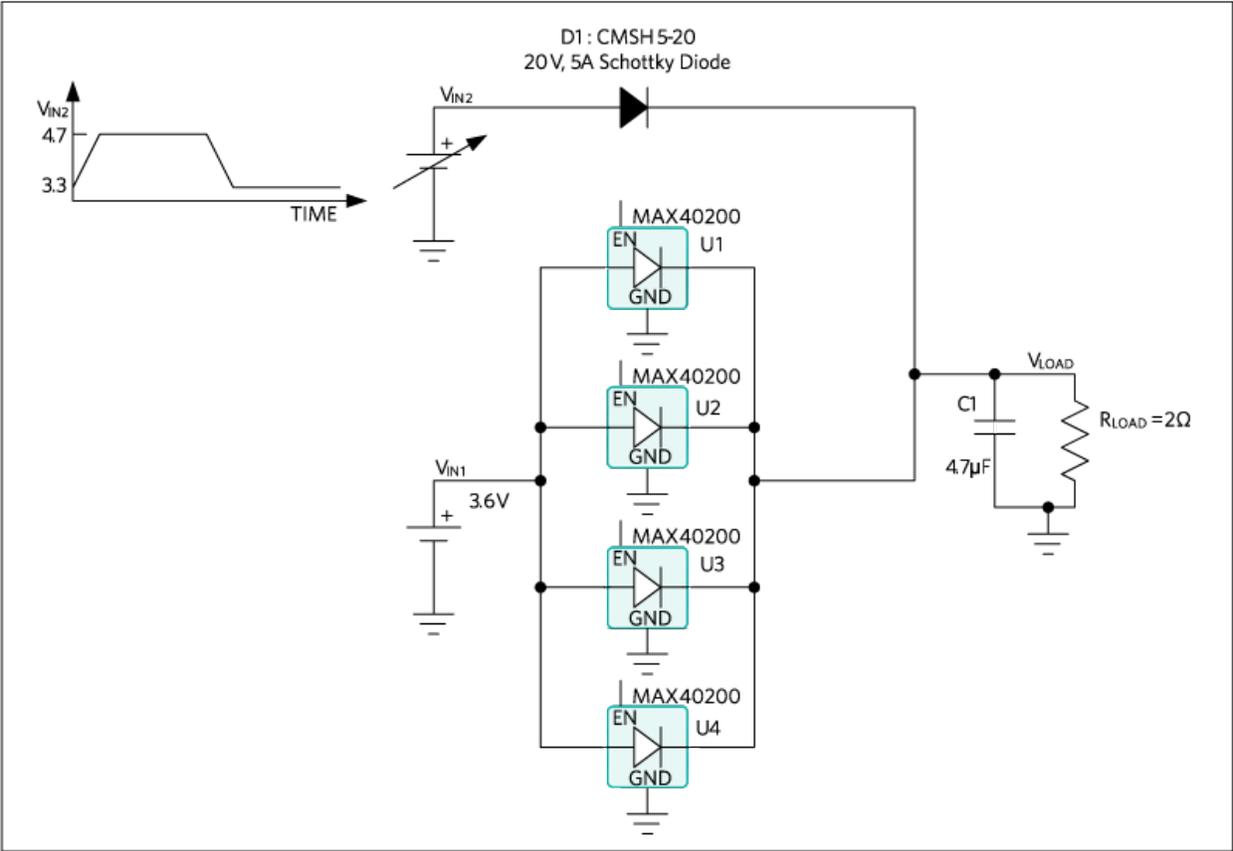
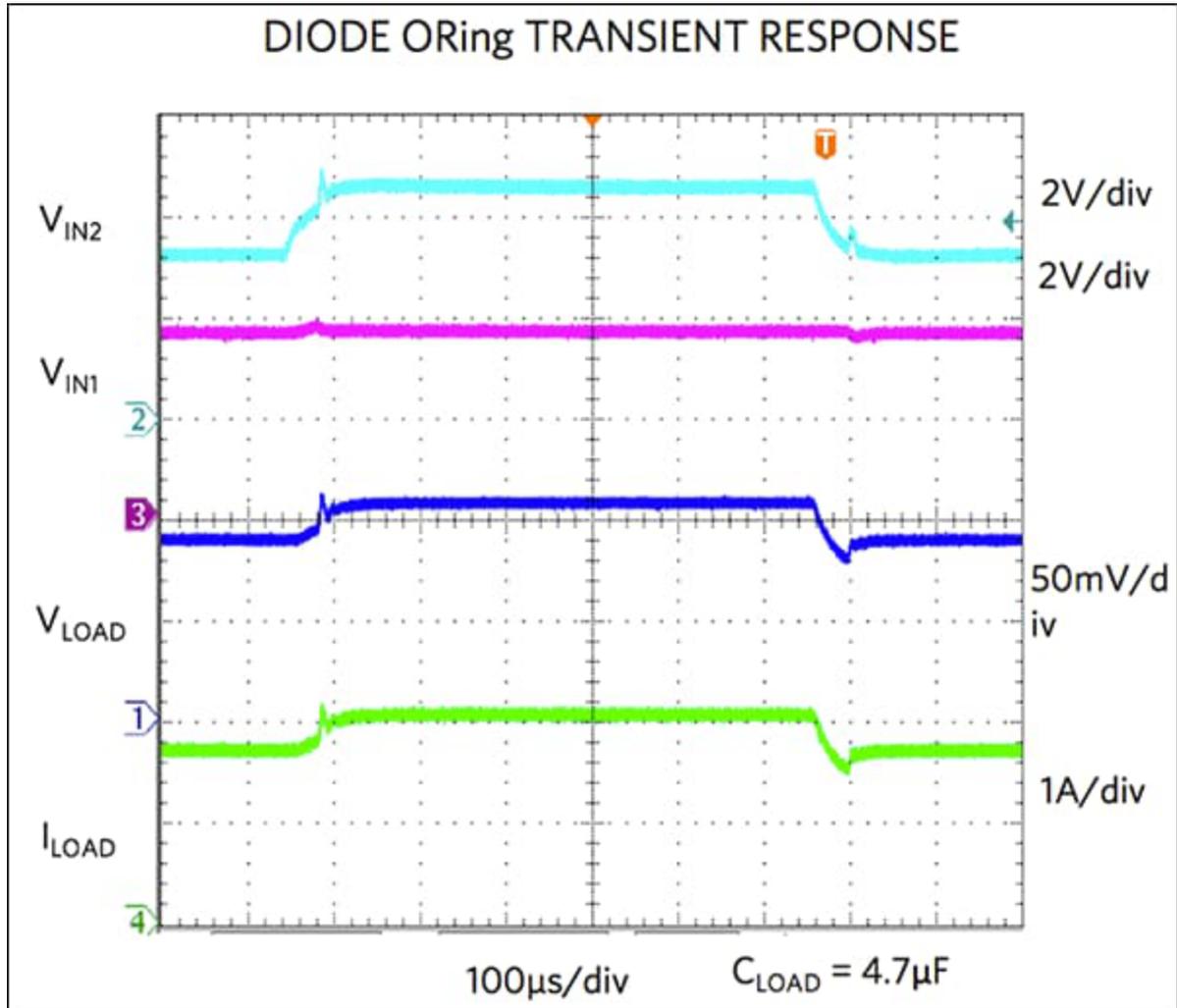
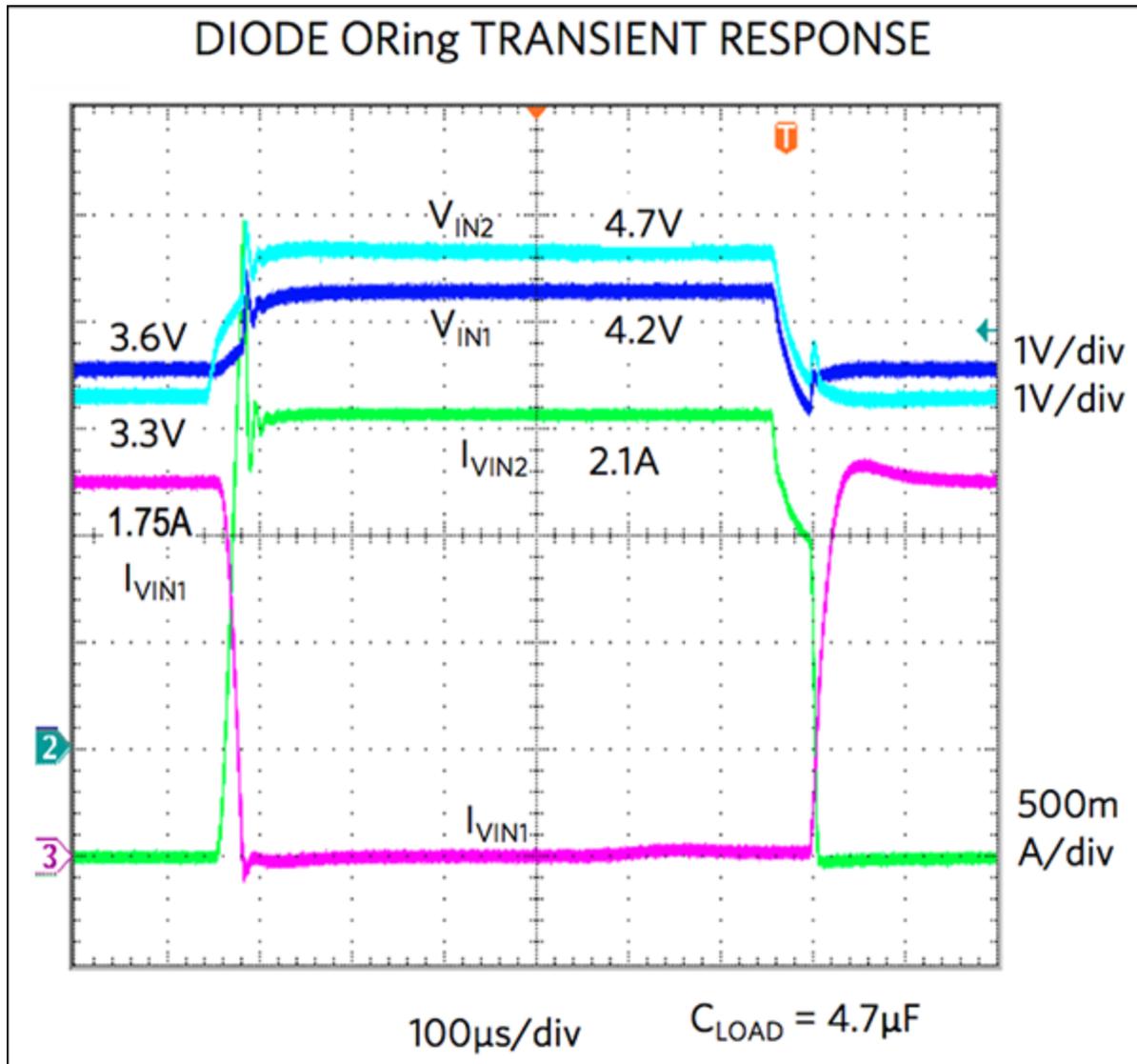


Figure 4. Diode ORing application using a standard diode and four MAX40200 devices.

# DIODE ORing TRANSIENT RESPONSE



Curve 4a. Diode ORing transient response.



Curve 4b. Diode ORing transient response.

### PCB Layout Considerations

Figure 5 shows a typical example of board layout using four MAX40200 paralleled devices. As shown, the  $V_{DD}$  and OUT traces on the board have considerable island space of copper pour to decrease the trace resistance and decreasing the current density. Both the  $V_{DD}$  and OUT traces are present on the top layer and no vias are used. Since the physical mechanism that ensures load-current sharing is thermal, the paralleled ideal diodes should be located as close as practical to each other. Given that currents are presumably quite large, or one would not need to parallel the parts, the PCB should use the thickest copper available. Doing so helps spread the heat and reduces voltage drops at high currents. Note that the WLP package is optimal for paralleling multiple units because the small size and good thermal conductivity allow sufficient thermal coupling to make this approach practical.

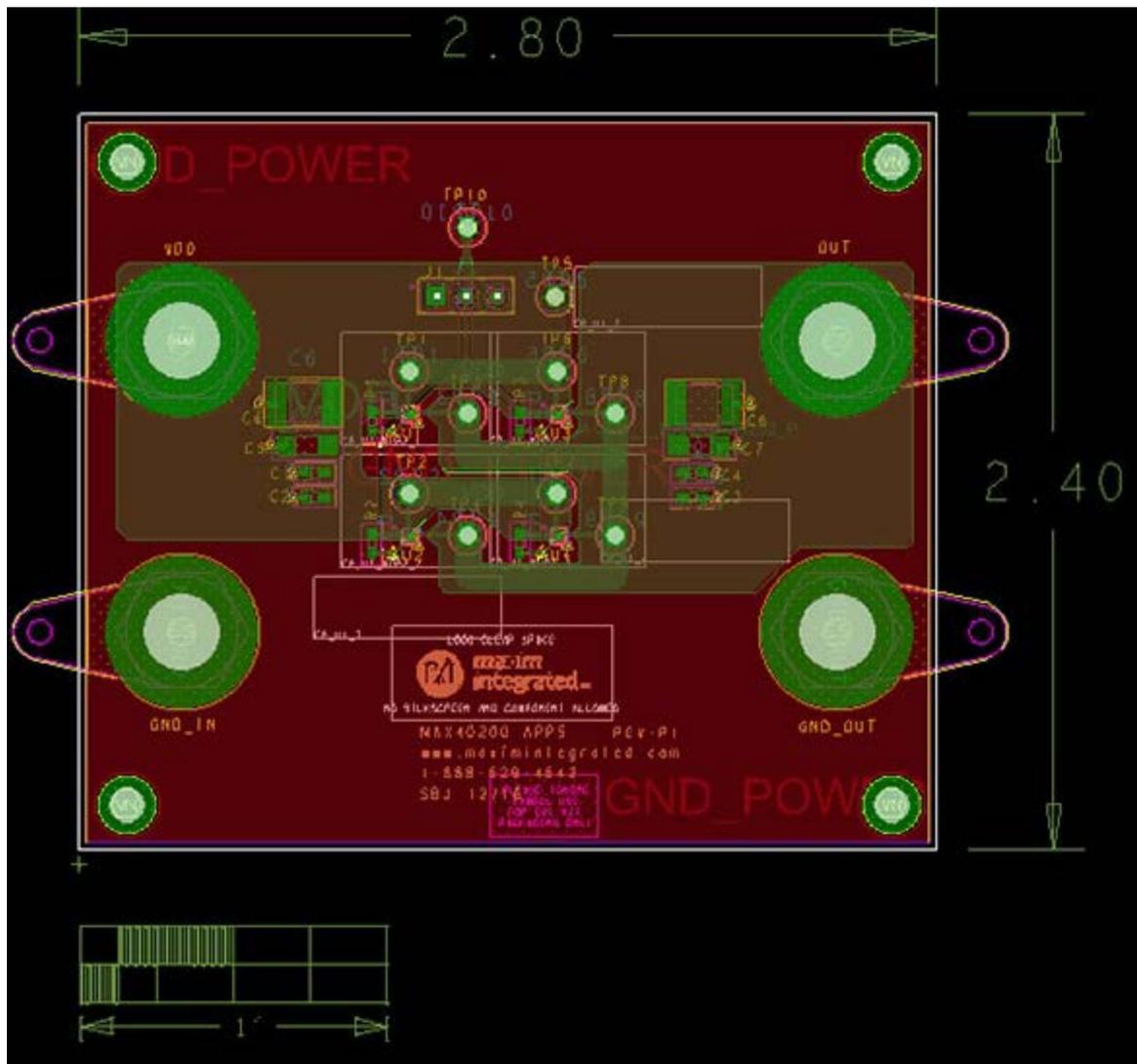


Figure 5. Example of layout technique.

As shown in **Figure 6**, the parts are placed 12mm (484 mils) apart from each other, which ensure all the MAX40200 devices are thermally equivalent. Keep the paralleled devices away from significant external heat sources. Failure to do so would have all the devices operating at higher temperatures, thereby increasing the internal  $R_{ON}$ . Unequal board temperature on each of the devices results in unequal current sharing. Vias on the main path ( $V_{DD}$  or OUT) are not recommended as they add parasitic inductances and increase the effective  $R_{ON}$  on the forward path, thereby increasing the voltage drop ( $V_{FWD}$ ).

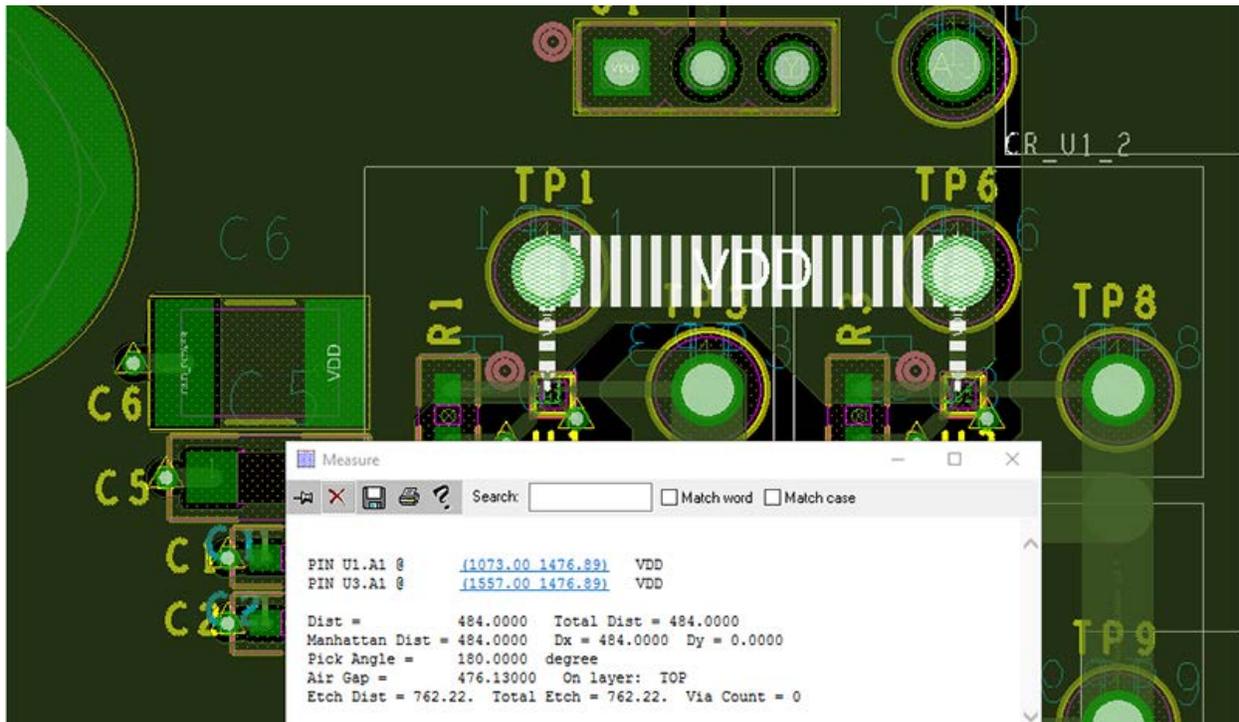


Figure 6. Distance between adjacently placed MAX40200 device.

**Figure 7** shows the temperature difference between the ambient and the board containing paralleled MAX40200 devices. You can observe that the temperature difference is directly proportional to the forward load current passed through the devices. This result was obtained using the board from **Figure 5**.

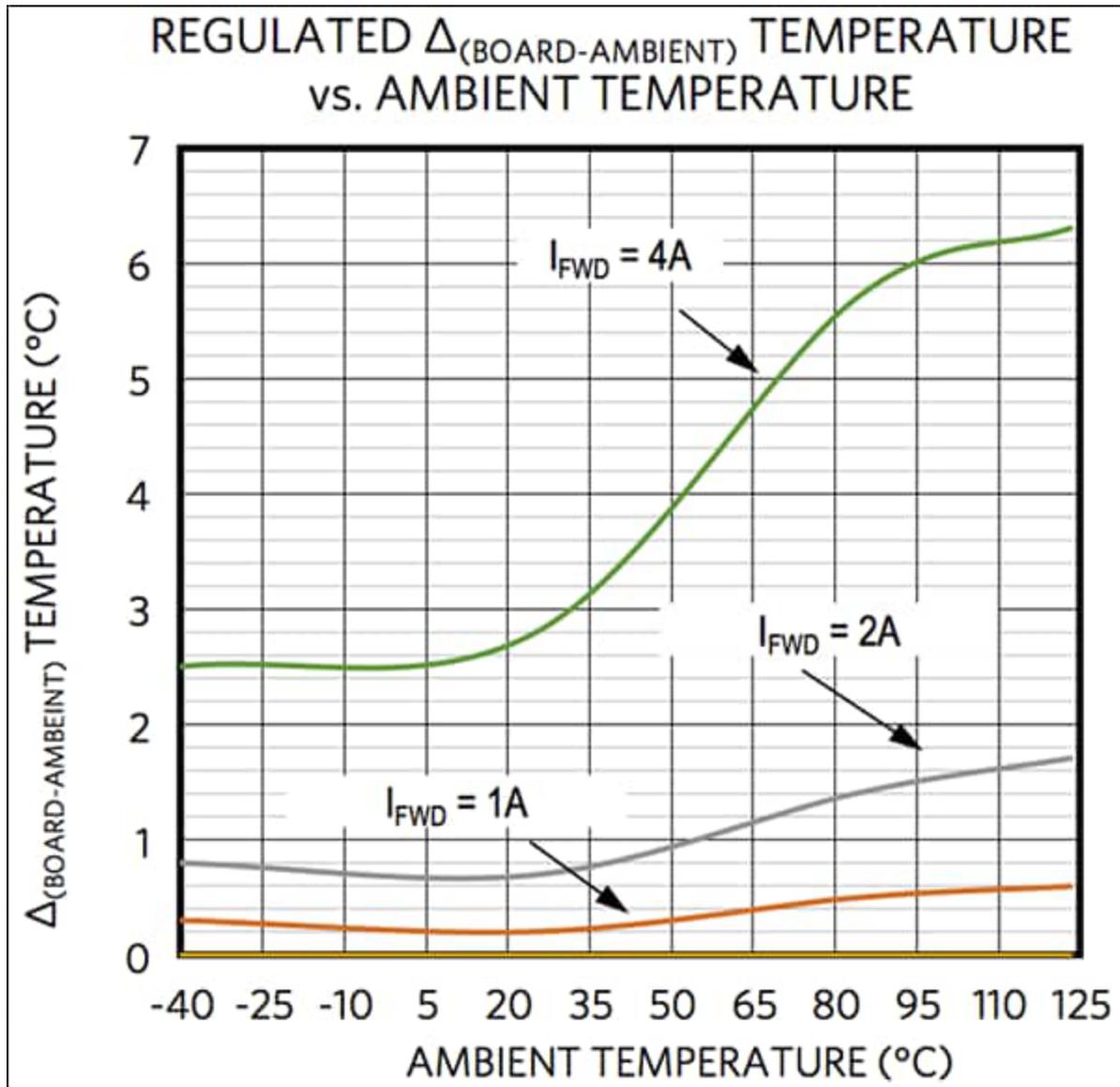


Figure 7. Regulated ambient board temperature vs. ambient temperature.

### Why Using Multiple Parallel Devices Works So Well

The MOSFET's on-resistance has a strong, positive temperature coefficient, which ensures that the hotter MOSFET has more resistance than the cooler MOSFET, forcing the cooler MOSFET to take a little more current. The two MOSFETs, therefore, establish a thermal equilibrium matching the current balance. Good PCB layout ensures this thermal equilibrium. In general, placing the parts close together is sufficient, but if there is another device on the PCB that dissipates a lot of heat, the thermal gradient set up by such a device alters the current-sharing balance of the paralleled ideal diodes.

### Wafer Level Package and Packaged Device Differences

The above investigation was carried out for the WLP (wafer level package) and is optimal for paralleling multiple units because the very small size, its package characteristics, and good thermal conductivity allow

sufficient thermal coupling to make this approach practical.

Due to the higher thermal resistance of the SOT23 package (internal bond wire resistance), the current sharing the forward-voltage drop ( $V_{FWD}$ ) is not as good as with the WLP counterpart. Also, any additional thermal gradients have a significant effect even when the SOT packages are very closely spaced. It is recommended to derate the ideal diodes in this package to 75% of full specification.

## Summary

The MAX40200 has been shown to scale well when connecting two in parallel as well as four in parallel. Both DC characteristics and transient responses show that current sharing is close to ideal and the transient performance is not degraded. The MAX40200 is scalable, allowing it to be used in many applications requiring higher currents, or for lower voltage drops than a single part could handle.

### Related Parts

[MAX40200](#)

Ultra-Tiny Micropower, 1A Ideal Diode with Ultra-Low Voltage Drop

[Free Samples](#)

---

### More Information

For Technical Support: <https://www.maximintegrated.com/en/support>

For Samples: <https://www.maximintegrated.com/en/samples>

Other Questions and Comments: <https://www.maximintegrated.com/en/contact>

---

Application Note 6486: <https://www.maximintegrated.com/en/an6486>

APPLICATION NOTE 6486, AN6486, AN 6486, APP6486, Appnote6486, Appnote 6486

© 2014 Maxim Integrated Products, Inc.

The content on this webpage is protected by copyright laws of the United States and of foreign countries.

For requests to copy this content, [contact us](#).

Additional Legal Notices: <https://www.maximintegrated.com/en/legal>