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# AN-9759

## Fairchild GreenBridge™ Solution to Replace Conventional Diode Bridge in Power Over Ethernet Applications

### Summary

A Power Device (PD) in a Power over Ethernet (PoE) application requires a bridge circuit to regulate the polarity of the input power when the Power Source Equipment (PSE) supplying power to the PD is equipped with an Uninterruptible Power Supply (UPS). The simple diode bridge design has been used without major concerns at low cost. However, as PD gets hungrier for power, the conduction loss of the diode bridge caused by the forward-voltage drop becomes one of the main issues to be solved efficiently. Fairchild's GreenBridge™ solution reduces power losses in the bridge circuit and leads to an efficient and cost-effective PoE system. In this application note, the GreenBridge drive circuit is examined and test results with a typical diode bridge are presented.

### Power Over Ethernet

Power over Ethernet (PoE) introduces a new facet to Ethernet networking, delivering DC power through a CAT5 network cable. Figure 1 shows a typical PoE system. It is convenient to install PDs; such as IP telephones, wireless LAN access points, and security cameras; without any wall power lines because the CAT5 cable delivers data as well as power required by those PDs. In addition, the PoE system is energy efficient because the PSE communicates to the PD first and provides regulated power PD for demands. The power management block of PD must be designed carefully to operate efficiently at limited input power from the PSE.

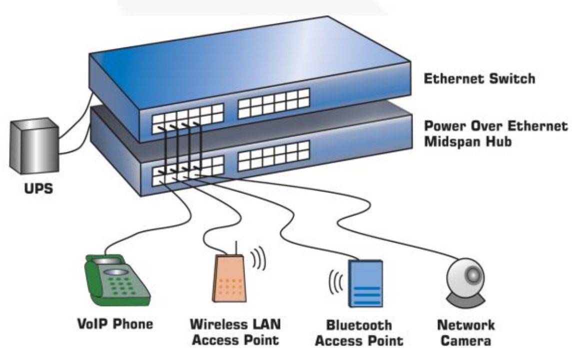



**Figure 1. Typical PoE System**

The IEEE802.3af/3at standard defines the power class for PD as described in Table 1.

**Table 1. IEEE802.3af/3at PoE Classification**

| PD Class | Maximum PD Power |
|---|---|
| 0 | 0.5 to 13 W |
| 1 | 0.5 to 3.84 W |
| 2 | 3.84 to 6.49 W |
| 3 | 6.49 to 13 W |
| 4 | 13 to 25 W |

### GreenBridge™ Solution

To improve the conduction loss and efficiency of the conventional diode bridge, Fairchild Semiconductor integrates dual P-channel and dual N-channel MOSFETs in a compact and thermally enhanced package. Table 2 the GreenBridge FDMQ8203 electrical parameters.

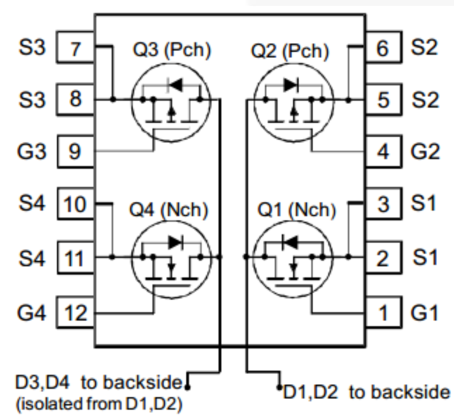



**Figure 2. Configuration and Pin Map**

**Table 2. GreenBridge™ FDMQ8203 Parameters**

| Part No. | MOSFET | $BV_{DSS}$ (V) | $R_{DS(ON)}$ [mΩ] Max. | $Q_g$ [nC] Typ. | $\Theta_{JA}$ [°C/W] |
|---|---|---|---|---|---|
| FSMQ8203 | Q1, Q4 | 100 | 110 | 2.9 | 50 |
| | Q2, Q3 | -80 | 190 | 13 | |

The package plays a critical role in power supply performance. The thermally enhanced MLP 4.5 x 5 mm package shown in Figure 3 is able to increase power density and save PCB space.

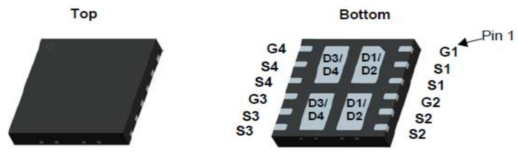



**Figure 3. MLP 4.5 x 5 mm Package**

A bridge circuit in the PD regulates power polarity from the PSE so all power loss is conduction loss. Replacing the diode bridge with the GreenBridge™ device, shown in Figure 4, reduces conduction loss to improve PD efficiency.

As current flow is turned on, the current flows through the corresponding P- or N-channel MOSFET of the GreenBridge device. As a result, the $R_{DS(on)}$ of GreenBridge solution reduces the conduction loss when compared to a diode bridge from the forward voltage, $V_F$.

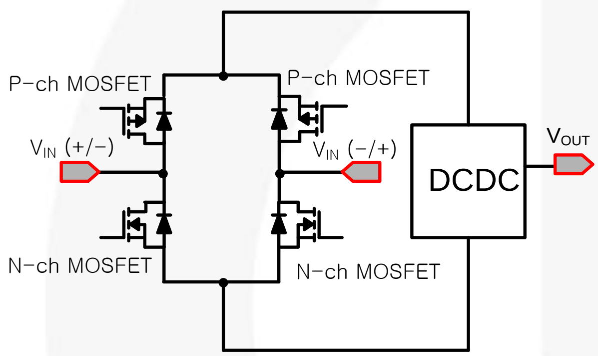



**Figure 4. GreenBridge™ Solution**

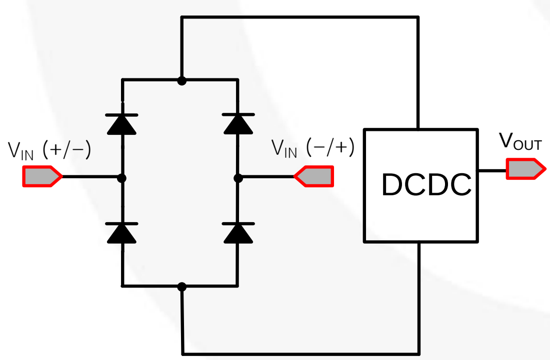



**Figure 5. Conventional Diode Bridge in PD**

GreenBridge power loss is calculated by:

$$=I^2 \times R_{DS(ON)} – Pch + I^2 \times R_{DS(ON)} - Nch \quad (1)$$

Diode bridge power loss is calculated by:

$$=2 \times V_F \times I \quad (2)$$

The self-driven gate circuit for GreenBridge FDMQ8203 is configured as illustrated in Figure 6, which consists of transistors, diodes, Zener diodes, and resistors.

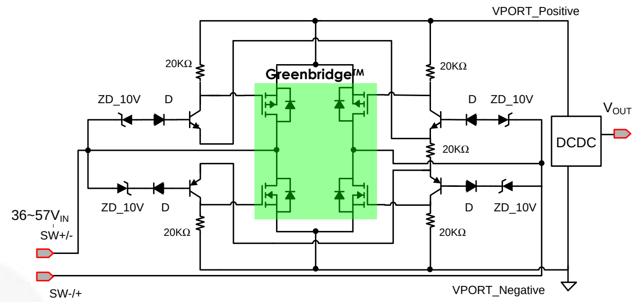



**Figure 6. Self-Driven Gate Drive Circuit**

Figure 6 shows the current flow from SW+ to SW-. Q1 and Q4 in the GreenBridge device turn on, while Q2 and Q3 are off. Red lines indicate the power flow path and green lines express the bias current of the self-driven gate circuit. Zener diodes limit the gate-to-source voltage of the GreenBridge device, not to exceed $BV_{GSS}$. The gate voltage of Q1 and Q4 are defined as:

$$V_{gs\_Q1} = \text{Zener Voltage\_10V} + V_{F\_D} \quad (3)$$

$$V_{gs\_Q4} = \text{Zener Voltage\_10V} + V_{F\_D} \quad (4)$$

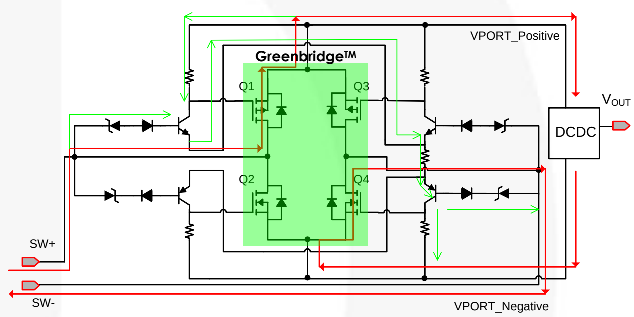



**Figure 7. Current Flows of GreenBridge Device at SW+ and SW-**

When PD is plugged into the PSE, the PSE recognizes the presence of the PD by checking the current through a 25 kΩ (±1.3 kΩ) resistor on the PD. It is the resistance detection process of the PoE standard. The PSE provides two consecutive voltages, V1=2.7 V and V2=10.1 V, shown in Figure 7, to the PD for the resistance detection mode and records measured current values, I1 and I2 by V1 and V2, respectively. The computed $\Delta V/\Delta I$ by the PSE ensures the presence of a PD and the PSE moves on to identify the PD power class. During this step, the GreenBridge device should not compromise the resistance detection procedure by bypassing the current through the body diode. The recommended gate drive circuit in Figure 6 helps the GreenBridge device stay turned off and bypasses the current via body diode at 2.7 V and 10.1V from the PSE. Without the safe gate drive circuit, the GreenBridge device can turn on at the 10.1 V input given by the PSE during the resistance detection because the MOSFETs of the GreenBridge device have a 4 V maximum threshold voltage. This could cause resistance detection to fail.

Below is how the PSE calculates in this scenario:

- I1 = (2.7 V – 1.4 V) / 25 kΩ = 0.052 mA GreenBridge device turns off at 2.7 V. Current flows through body diode, causing body diode voltage drop (2 x 0.7 V).
- I2=10.1 V / 25 kΩ =0.404 mA
- GreenBridge device turns on at 10.1 V. Current flows through the channel of GreenBridge device.
- Measured ∆V/ ∆I = (10.1 V-2.7 V) / (0.404 mA – 0.052 mA) = 21.02 kΩ
- The measured ∆V/ ∆I does not meet the 25 kΩ (±1.3 kΩ) standard.

After the resistance detection process, the input voltage from the PSE increases more than twice (Zener voltage _10 V+ $V_{F\_D}$) and the GreenBridge device turns on completely. The current begins flowing through the conduction channel of the GreenBridge device.

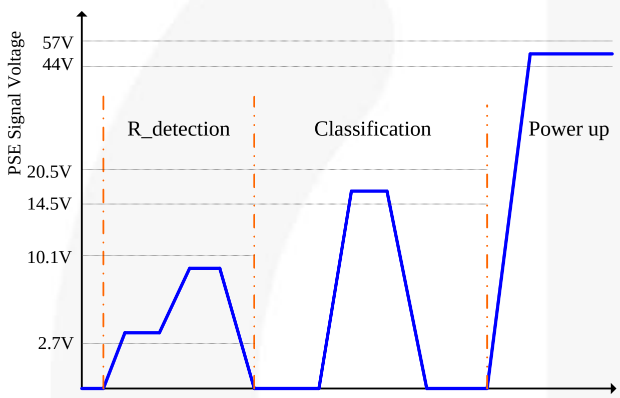



**Figure 8. Signal at Initial Operation**

## GreenBridge™ Performance

The 25 W PD power block is designed as listed in Table 3 for the test between the GreenBridge FDMQ8203 and the conventional Schottky diode bridge with S210 (100 V/2 A).

**Table 3. PD Power Design Specification**

| | |
|---|---|
| **PoE Class** | Class 4 |
| **IEEE Standard** | IEEE802.3at |
| **DCDC Topology** | Flyback |
| **Input Voltage** | 36V ~ 57V |
| **Output Voltage** | 5V |
| **Maximum Output Current** | 5A |
| **Output Power** | 25W |
| **Switching Frequency** | 250KHz |

At 25 W maximum output power and 36 V minimum input voltage, the estimated input current is 0.7 A through the GreenBridge solution or diode bridge. Based on equations [1] and [2], the computed power loss gap between the GreenBridge solution and the diode bridge is 0.83 W. ($R_{DS(on)}$_Pch = 190 mΩ, $R_{DS(on)}$_Nch=110 mΩ, typical diode $V_F$ = 0.7 V):

- GreenBridge power loss is calculated by:
  = 0.7 A x 0.7 A x 110 mΩ+0.7 A x 0.7 Ax190 mΩ = 0.147 W
- Diode bridge power loss is calculated by:
  = 0.7 V x 0.7 A x 2 = 0.98 W

Figure 9 shows that the GreenBridge™ FDMQ8203 improves the efficiency by 2.41% and saves the total power loss by 0.82 W compared to diode bridge at 25 W maximum output power and 36 V minimum input voltage conditions.

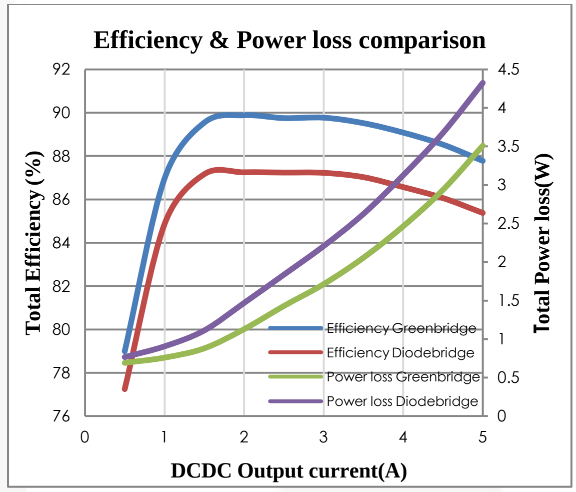
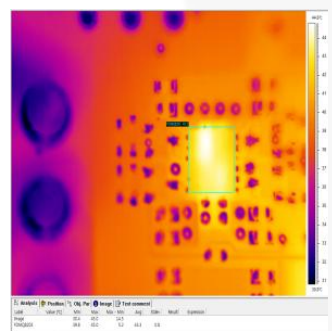
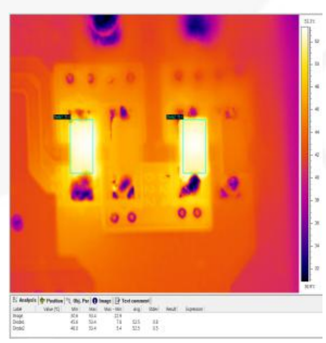



**Figure 9. Efficiency & Power Loss Comparison of GreenBridge™ Solution and Diode Bridge at $V_{IN}$=36 V, $V_{OUT}$=5 V, $f_{SW}$=250 kHz, $T_A$=25°C**



Top View, Temperature: 45°C

**Figure 10. Thermal Performance Comparison of GreenBridge™ Solution and Diode Bridge at $V_{IN}$=36 V, $V_{OUT}$=5 V, $f_{SW}$=250 kHz, $T_A$=25°C**



Diode Bridge Top View, Temperature: 53.4°C

**Figure 11. Thermal Performance Comparison of GreenBridge™ Solution and Diode Bridge at $V_{IN}$=36 V, $V_{OUT}$=5 V, $f_{SW}$=250 kHz, $T_A$=25°C**

Figure 10 and Figure 11 show the thermal performance of the GreenBridge solution at lower temperature because of the lower thermal impedance of the MLP 4x4.5 mm package and lower power loss even thought the GreenBridge package size is 45% smaller.

**Table 4. Comparison Summary**

| | GreenBridge™ | Diode Bridge |
|---|---|---|
| Power Loss | Good (0.82 W ↓) | Bad |
| Thermal | Good (8.4°C ↓) | Bad |
| Solution Size | Good<br>(45% ↓)<br>48.74 mm$^2$<br>(FDMQ8203: 22.5 mm$^2$<br>Gate circuits: 26.24 mm$^2$) | Bad<br>88.48 mm$^2$ |
| Complexity | Complex | Simple |

Finally, Table 4 shows that the GreenBridge™ solution saves power loss and PCB area.

## Conclusion

In a PoE application, the PSE delivers the limited power defined by PoE power class. The PD should be designed carefully to maximize the efficiency. Using Fairchild's GreenBridge™ solution instead of the conventional diode bridge reduces power loss and increases the power density. This results in lower PD class rating and saved PCB area. An efficient and cost-effective PoE system can be achieved with Fairchild's innovative GreenBridge solution.

## Authors

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Edgar Kim – LV Applications Engineer

## References

*[1] GreenBridge™ Evaluation Kit for Power over Ethernet 25 W Flyback DC-DC User Guide*

## Related Resources

*FDMQ8203 — GreenBridge™ Series of High-Efficiency Bridge Rectifiers Dual N-Channel and Dual P-Channel PowerTrench® MOSFET N-Channel: 100 V, 6 A, 110mΩ P-Channel: -80V, -6 A, 190mΩ*

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