

# GreenFET

## Product Selection Guide



# GreenFET

## ULTRA-LOW RDS<sub>ON</sub> LOAD SWITCH SELECTION GUIDE

Renesas' GreenFET family of high-performance load switches are designed and optimized for all high-side power rail control applications from 0.25 V to 5.5 V where the load currents range from 1 A to 9 A. Using Renesas' proprietary MOSFET design, all GreenFET load switches achieve ultra-stable RDS<sub>ON</sub> across wide input and supply voltage ranges. Combining Renesas' proprietary MOSFET IP and advanced assembly techniques, these advanced state-of-the-art products are available in ultra-small pcb footprints from 0.56 mm<sup>2</sup> to 4 mm<sup>2</sup> and exhibit low thermal resistances for high-current operation.

Compared to discrete GreenFET circuit implementations, Renesas' GreenFET products combine high-performance nFET or pFET structures, high-current handling capability, charge pumps, as well as multiple protection and control circuits into space-efficient single and dual channel products. The combination of all these advanced features directly results in BOM (bill-of-material) component and cost reductions as well as increasing system reliability and reduced board size.

All of Renesas' GreenFET low-voltage load switches are designed and fully characterized over the commercial (0 °C to 70 °C), extended commercial (-20 °C to 70 °C), industrial (-40 °C to 85 °C), or extended industrial (-40 °C to 125 °C) temperature range. Consistent with generating very low thermal gradients, Renesas integrated power control switches are available in low thermal resistance, STDFN/STQFN RoHS-compliant packaging or wafer-level chip scale packaging (WLCSP).

### Key features in the GreenFET family of high-performance load switches products include:

- High-performance Low RDS<sub>ON</sub> nFET & pFET MOSFETs
- From as low as 4 mΩ
- Internal protection features:
  - Built-in supply undervoltage lockout protection
  - Fixed and capacitor/resistor-adjustable inrush current control
  - Fixed and resistor-adjustable current limit protection
  - Built-in short-circuit current protection
  - Built-in thermal shutdown protection with auto restart
  - Reverse-current blocking using bulk wwitch or back-to-back FETs
  - Reverse-voltage detection (selected part numbers)
  - Fast V<sub>OUT</sub> discharge (V<sub>OUT</sub> discharge delete options available)
- Active HIGH ON-OFF control (Active-LOW ON-OFF control available)
- Open-drain signaling (selected part numbers)
- Open-drain power good signaling (selected part numbers)
- Wafer-level chip-scale packaging (selected part numbers)
- UL2367 certified (selected part numbers)

### Applications:

- Smartphones and fitness bands
- Notebook and tablet PCs
- Enterprise networking
- Enterprise multifunction copiers/printers
- Enterprise computing
- Set-top boxes
- HDDs and SSDs
- PCIe/PCI adapter cards
- Portable consumer electronics
- General-purpose, high-side power-rail switching/control

### Single N-Channel Load Switches

| Part Number | Description                                                                                                              | Max I <sub>DS</sub> (A) | RDS <sub>ON</sub> (mΩ) | VD/VIN Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*   | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)    |
|-------------|--------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|----------------|-----------------------------------------|---------------------------------------------------|---------------------------------|------------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|----------------------|
| SLG59M1717V | 4 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, protection, and PG signal output         | 5                       | 4                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | UVLO, ACL(R), SCL, TSD | No                     | PG                          | Yes                      | -40 to +85                        | STQFN-16 (1.6 x 2.5) |
| SLG59M1709V | 4 mm <sup>2</sup> load switch with charge pump, ramp control, and protection                                             | 4                       | 4                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | UVLO, ACL, SCL, TSD    | No                     | No                          | No                       | -40 to +85                        | STQFN-16 (1.6 x 2.5) |
| SLG59M1713V | 4 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                           | 2                       | 4                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | UVLO, ACL, SCL, TSD    | No                     | No                          | Yes                      | -40 to +85                        | STQFN-16 (1.6 x 2.5) |
| SLG59M1568V | 3 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                           | 9                       | 7                      | 1              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD          | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1456V | 3 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                           | 5                       | 8                      | 1              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD          | No                     | No                          | Yes                      | -20 to +70                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M1457V | 3 mm <sup>2</sup> load switch with charge pump, output discharge, and protection                                         | 6                       | 8                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD          | No                     | No                          | Yes                      | -40 to +85                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M1496V | 3 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                           | 5                       | 8                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD          | No                     | No                          | Yes                      | -40 to +85                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M1600V | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection | 9                       | 8                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB               | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1655V | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control and protection                    | 9                       | 8                      | 0              | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB               | No                     | No                          | No                       | -40 to +85                        | STDFN-14 (1.0 x 3.0) |

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## ULTRA-LOW $R_{DS(ON)}$ LOAD SWITCH SELECTION GUIDE

### Single N-Channel Load Switches (continued)

| Part Number | Description                                                                                                                                 | Max $I_{DS}$ (A) | $R_{DS(ON)}$ (m $\Omega$ ) | $V_D/V_{IN}$ Min (V) | $V_D/V_{IN}$ Max (V) | Power Supply ( $V_{DD}$ ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*        | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, ( $^{\circ}$ C) | Package Size (mm)      |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|----------------------|----------------------|---------------------------------------------|---------------------------------|-----------------------------|------------------------|-----------------------------|--------------------------|----------------------------------------------|------------------------|
| SLG59M301V  | 3 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                              | 4                | 9                          | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-14 (1.0 x 3.0)   |
| SLG59M307V  | 3 mm <sup>2</sup> load switch with charge pump, ramp control, and output discharge                                                          | 4                | 8                          | 0                    | VDD                  | 1.5 – 5.5                                   | Capacitor                       | No                          | No                     | No                          | Yes                      | -20 to +85                                   | TDFN-8 (1.5 x 2.0)     |
| SLG59M308V  | 3 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                              | 3                | 8                          | 1                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | Yes                      | -40 to +70                                   | TDFN-8 (1.5 x 2.0)     |
| SLG59M309V  | 3 mm <sup>2</sup> load switch with charge pump, ramp control, and protection                                                                | 4                | 8                          | 1                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | No                       | -40 to +85                                   | TDFN-8 (1.5 x 2.0)     |
| SLG59M1657V | 3 mm <sup>2</sup> load switch with charge pump, ramp control, and protection                                                                | 4                | 8                          | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | No                       | -40 to +125                                  | TDFN-8 (1.5 x 2.0)     |
| SLG59M1614V | 3 mm <sup>2</sup> load switch with charge pump, ramp control, and output discharge                                                          | 4                | 9                          | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | Yes                      | -40 to +85                                   | TDFN-8 (1.5 x 2.0)     |
| SLG59M1470V | 3 mm <sup>2</sup> fast turn on, nano-power current consumption load switch                                                                  | 6                | 10                         | 0                    | VDD – 1.5 V          | 3.0 – 5.25                                  | No                              | No                          | No                     | No                          | Yes                      | -40 to +85                                   | TDFN-9 (1.5 x 2.0)     |
| SLG59M1685C | 0.82 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                           | 2                | 10                         | 1                    | 4                    | –                                           | Internally Fixed                | UVLO, ACL, SCL, TSD         | No                     | No                          | Yes                      | -40 to +85                                   | WLCSP-6L (0.71 x 1.16) |
| SLG59M1707V | 4 mm <sup>2</sup> load switch with charge pump, $I_{DS}$ current monitor output, output discharge, and protection                           | 4                | 13                         | 0                    | VDD                  | 2.5 – 5.5                                   | Internally Fixed                | UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +125                                  | STQFN-16 (1.6 x 2.5)   |
| SLG59M1571V | 1 mm <sup>2</sup> low-voltage load switch with reverse-current blocking, charge pump, output discharge, protection, and 4-pin package       | 1                | 15                         | 0                    | 2                    | –                                           | No                              | TSD, RCB                    | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-4 (1.0 x 1.0)    |
| SLG59M1714V | 4 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, $I_{DS}$ current monitor output, output discharge, and protection | 4                | 15                         | 0                    | VDD                  | 2.5 – 5.5                                   | Internally Fixed                | UVLO, ACL(R), SCL, TSD, RCB | Yes                    | FAULT                       | Yes                      | -40 to +85                                   | STQFN-16 (1.6 x 2.5)   |
| SLG59M1551V | 1 mm <sup>2</sup> low voltage load switch with charge pump, output discharge, protection, and 4-pin package                                 | 2                | 16                         | 0                    | 2                    | –                                           | No                              | TSD                         | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-4 (1.0 x 1.0)    |
| SLG59M1556V | 1 mm <sup>2</sup> low voltage load switch with charge pump, protection, and 4-pin package                                                   | 2                | 16                         | 0                    | 2                    | –                                           | No                              | TSD                         | No                     | No                          | No                       | -40 to +85                                   | STDFN-4 (1.0 x 1.0)    |
| SLG59M1658V | 1.6 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                            | 3                | 17                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | UVLO, ACL, SCL, TSD         | No                     | No                          | Yes                      | -40 to +125                                  | STDFN-8 (1.0 x 1.6)    |
| SLG59M1448V | 1.6 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                            | 3                | 17                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-8 (1.0 x 1.6)    |
| SLG59M1545V | 1.6 mm <sup>2</sup> load switch with charge pump, ramp control, and protection                                                              | 3                | 17                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | No                       | -20 to +70                                   | STDFN-8 (1.0 x 1.6)    |
| SLG59M1598V | 1.6 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                                            | 3                | 17                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD               | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-8 (1.0 x 1.6)    |
| SLG59M1746C | 0.82 mm <sup>2</sup> load switch with output discharge                                                                                      | 1                | 18                         | 0                    | 2                    | 2.7 – 3.6                                   | Internally Fixed                | No                          | No                     | No                          | Yes                      | -40 to +85                                   | WLCSP-6L (0.71 x 1.16) |
| SLG59M1515V | 1.6 mm <sup>2</sup> fast turn on load switch with ramp control, and output discharge                                                        | 2                | 20                         | 0                    | VDD – 1.5 V          | 2.5 – 5.5                                   | Capacitor                       | TSD                         | No                     | No                          | Yes                      | -40 to +85                                   | STDFN-8 (1.0 x 1.6)    |
| SLG59M610V  | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection                    | 4                | 22                         | 1                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD, RCB          | No                     | No                          | Yes                      | -40 to +85                                   | TDFN-8 (1.5 x 2.0)     |

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## ULTRA-LOW RDS<sub>ON</sub> LOAD SWITCH SELECTION GUIDE

### Single N-Channel Load Switches (continued)

| Part Number | Description                                                                                                   | Max I <sub>DS</sub> (A) | RDS <sub>ON</sub> (mΩ) | V <sub>D</sub> /V <sub>IN</sub> Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features* | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)    |
|-------------|---------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------|---------------------------------|----------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|----------------------|
| SLG59M611V  | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, and protection        | 4                       | 22                     | 1                                       | V <sub>DD</sub>                         | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD, RCB   | No                     | No                          | No                       | -40 to +85                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M1563V | 1.6 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, and PG signal output              | 3                       | 23                     | 1                                       | V <sub>DD</sub>                         | 1.5 – 5.5                                         | Internally Fixed                | TSD, RCB             | No                     | PG                          | No                       | -40 to +85                        | STDFN-8 (1.0 x 1.6)  |
| SLG59M1460V | 1.6 mm <sup>2</sup> fast turn on and nano-power current consumption load switch                               | 2                       | 30                     | 0                                       | V <sub>DD</sub> - 1.5 V                 | 2.5 – 5.25                                        | No                              | No                   | No                     | No                          | Yes                      | -20 to +70                        | STDFN-8 (1.0 x 1.6)  |
| SLG59M1440V | 1 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, protection, and 4-pin package | 1                       | 40                     | 3                                       | 6                                       | –                                                 | Resistor                        | TSD                  | No                     | No                          | Yes                      | -40 to +85                        | STDFN-4 (1.0 x 1.0)  |
| SLG59M1495V | 1 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, protection, and 4-pin package | 1                       | 80                     | 3                                       | 6                                       | –                                                 | Resistor                        | TSD                  | No                     | No                          | Yes                      | -20 to +70                        | STDFN-4 (1.0 x 1.0)  |
| SLG59M1780V | 4 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and protection                | 4                       | 4                      | 0                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | UVLO, ACL, SCL, TSD  | No                     | No                          | Yes                      | -40 to +85                        | STQFN-16 (1.6 x 2.5) |

### Single P-Channel Load Switches

| Part Number | Description                                                                                                    | Max I <sub>DS</sub> (A) | RDS <sub>ON</sub> (mΩ) | V <sub>D</sub> /V <sub>IN</sub> Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features* | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)   |
|-------------|----------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------|---------------------------------|----------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|---------------------|
| SLG59M1649V | 1.6 mm <sup>2</sup> load switch with reverse-current blocking, reverse-voltage detection, and output discharge | 4                       | 23                     | 2                                       | 6                                       | –                                                 | No                              | UVLO, RCB, RVD       | No                     | FAULT                       | Yes                      | -40 to +85                        | STDFN 8 (1.0 x 1.6) |
| SLG59M1557V | 1 mm <sup>2</sup> load switch with output discharge                                                            | 1                       | 29                     | 2                                       | 6                                       | –                                                 | Internally Fixed                | No                   | No                     | No                          | Yes                      | -40 to +85                        | STDFN-4 (1.0 x 1.0) |
| SLG59M1558V | 1 mm <sup>2</sup> load switch without output discharge                                                         | 1                       | 29                     | 2                                       | 6                                       | –                                                 | Internally Fixed                | No                   | No                     | No                          | No                       | -40 to +85                        | STDFN-4 (1.0 x 1.0) |
| SLG59M1736C | 0.64 mm <sup>2</sup> load switch with controlled inrush current, and output discharge                          | 2                       | 33                     | 3                                       | 6                                       | –                                                 | No                              | Fixed ICL            | No                     | No                          | Yes                      | -40 to +85                        | WLCSP-4 (0.8 x 0.8) |
| SLG59M1730C | 0.64 mm <sup>2</sup> load switch with controlled inrush current, and output discharge                          | 1                       | 33                     | 3                                       | 6                                       | –                                                 | No                              | Fixed ICL            | No                     | No                          | Yes                      | -40 to +85                        | WLCSP-4 (0.8 x 0.8) |
| SLG59M1748C | 0.64 mm <sup>2</sup> load switch with reverse-current blocking, reverse-voltage detection, and ramp control    | 2                       | 36                     | 2                                       | 5                                       | –                                                 | Internally Fixed                | RCB, RVD             | No                     | No                          | No                       | -40 to +85                        | WLCSP-4 (0.8 x 0.8) |

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## ULTRA-LOW $R_{DS(on)}$ LOAD SWITCH SELECTION GUIDE

### Dual N-Channel Load Switches

| Part Number | Description                                                                                                                           | Max $I_{DS}$ (A) | $R_{DS(on)}$ (m $\Omega$ ) | $V_D/V_{IN}$ Min (V) | $V_D/V_{IN}$ Max (V) | Power Supply ( $V_{DD}$ ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features* | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)    |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|----------------------|----------------------|---------------------------------------------|---------------------------------|----------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|----------------------|
| SLG59M1804V | 3 mm <sup>2</sup> UL2367-certified, dual-channel load switch with charge pump, ramp control, output discharge, and protection         | 5                | 15                         | 0                    | VDD                  | 2.5 – 5.0                                   | Capacitor                       | ACL, SCL, TSD        | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1527V | 3 mm <sup>2</sup> dual-channel load switch with charge pump, ramp control, output discharge, and protection                           | 5                | 15                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | ACL, SCL, TSD        | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1603V | 3 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection | 5                | 16                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | TSD, RCB             | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1606V | 3 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, charge pump, ramp control, and protection                   | 5                | 16                         | 0                    | VDD                  | 2.5 – 5.5                                   | Capacitor                       | TSD, RCB             | No                     | No                          | No                       | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1446V | 1 mm <sup>2</sup> load switch with charge pump, ramp control, output discharge, and 4-pin package                                     | 1                | 40                         | 0                    | VDD                  | 2.5 – 5.5                                   | Resistor                        | TSD                  | No                     | No                          | Yes                      | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |
| SLG59M1599V | 1.6 mm <sup>2</sup> dual-channel load switch with charge pump, ramp control, and protection                                           | 1                | 40                         | 0                    | VDD                  | 2.5 – 5.5                                   | Resistor                        | TSD                  | No                     | No                          | No                       | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |
| SLG59M1512V | 1.6 mm <sup>2</sup> dual-channel load switch with charge pump, ramp control, output discharge, and protection                         | 1                | 80                         | 0                    | VDD                  | 2.5 – 5.5                                   | Resistor                        | TSD                  | No                     | No                          | Yes                      | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |

### Dual P-Channel Load Switches

| Part Number | Description                                                                                                                           | Max $I_{DS}$ (A) | $R_{DS(on)}$ (m $\Omega$ ) | $V_D/V_{IN}$ Min (V) | $V_D/V_{IN}$ Max (V) | Power Supply ( $V_{DD}$ ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features* | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)   |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|----------------------|----------------------|---------------------------------------------|---------------------------------|----------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|---------------------|
| SLG59M1639V | 1.6 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, reverse-voltage detection, and active high ON-OFF control | 2                | 45                         | 2                    | 6                    | –                                           | No                              | UVLO, RCB, RVD       | No                     | No                          | No                       | -40 to +85                        | STDFN 8 (1.0 x 1.6) |
| SLG59M1641V | 1.6 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, reverse-voltage detection, and active low ON-OFF control  | 2                | 45                         | 2                    | 6                    | –                                           | No                              | UVLO, RCB, RVD       | No                     | No                          | No                       | -40 to +85                        | STDFN 8 (1.0 x 1.6) |

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## ULTRA-LOW RDS<sub>ON</sub> LOAD SWITCH SELECTION GUIDE

### Reverse-Current Blocking Load Switches

| Part Number | Description                                                                                                                                        | Max I <sub>DS</sub> (A) | RDS <sub>ON</sub> (mΩ) | V <sub>D</sub> /V <sub>IN</sub> Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*        | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)    |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------|---------------------------------|-----------------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|----------------------|
| SLG59M1600V | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection                           | 9                       | 8                      | 0                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB                    | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1655V | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control and protection                                              | 9                       | 8                      | 0                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB                    | No                     | No                          | No                       | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1571V | 1 mm <sup>2</sup> low-voltage load switch with reverse-current blocking, charge pump, output discharge, protection, and 4-pin package              | 1                       | 15                     | 0                                       | 2                                       | –                                                 | No                              | TSD, RCB                    | No                     | No                          | Yes                      | -40 to +85                        | STDFN-4 (1.0 x 1.0)  |
| SLG59M1714V | 4 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, I <sub>DS</sub> current monitor output, output discharge, and protection | 4                       | 15                     | 0                                       | VDD                                     | 2.5 – 5.5                                         | Internally Fixed                | UVLO, ACL(R), SCL, TSD, RCB | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-16 (1.6 x 2.5) |
| SLG59M1603V | 3 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection              | 5                       | 16                     | 0                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB                    | No                     | No                          | Yes                      | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M1606V | 3 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, charge pump, ramp control, and protection                                | 5                       | 16                     | 0                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | TSD, RCB                    | No                     | No                          | No                       | -40 to +85                        | STDFN-14 (1.0 x 3.0) |
| SLG59M610V  | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, output discharge, and protection                           | 4                       | 22                     | 1                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD, RCB          | No                     | No                          | Yes                      | -40 to +85                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M611V  | 3 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, ramp control, and protection                                             | 4                       | 22                     | 1                                       | VDD                                     | 2.5 – 5.5                                         | Capacitor                       | ACL, SCL, TSD, RCB          | No                     | No                          | No                       | -40 to +85                        | TDFN-8 (1.5 x 2.0)   |
| SLG59M1563V | 1.6 mm <sup>2</sup> load switch with reverse-current blocking, charge pump, and PG signal output                                                   | 3                       | 23                     | 1                                       | VDD                                     | 1.5 – 5.5                                         | Internally Fixed                | TSD, RCB                    | No                     | PG                          | No                       | -40 to +85                        | STDFN-8 (1.0 x 1.6)  |
| SLG59M1649V | 1.6 mm <sup>2</sup> load switch with reverse-current blocking, reverse-voltage detection, and output discharge                                     | 4                       | 23                     | 2                                       | 6                                       | –                                                 | No                              | UVLO, RCB, RVD              | No                     | FAULT                       | Yes                      | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |
| SLG59M1748C | 0.64 mm <sup>2</sup> load switch with reverse-current blocking, reverse-voltage detection, and ramp control                                        | 2                       | 36                     | 2                                       | 5                                       | –                                                 | Internally Fixed                | RCB, RVD                    | No                     | No                          | No                       | -40 to +85                        | WLCSP-4 (0.8 x 0.8)  |
| SLG59M1639V | 1.6 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, reverse-voltage detection, and active high ON-OFF control              | 2                       | 45                     | 2                                       | 6                                       | –                                                 | No                              | UVLO, RCB, RVD              | No                     | No                          | No                       | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |
| SLG59M1641V | 1.6 mm <sup>2</sup> dual-channel load switch with reverse-current blocking, reverse-voltage detection, and active low ON-OFF control               | 2                       | 45                     | 2                                       | 6                                       | –                                                 | No                              | UVLO, RCB, RVD              | No                     | No                          | No                       | -40 to +85                        | STDFN 8 (1.0 x 1.6)  |

\* Notes (Please consult product specifications for additional information):

1. ACL - Internally Fixed Active Current Limit
2. ACL(R) - External resistor-adjustable Active Current Limit
3. SCL - Internally Fixed Short-circuit Current Limit
4. Fixed ICL – Internally Fixed Inrush Current Limit
5. RVD – Reverse-voltage Detection

6. RCB – Reverse-current Blocking
7. TSD – Overtemperature protection (Thermal Shutdown)
8. UVLO – Undervoltage Protection
9. OVLO – Overvoltage protection
10. TVS – Internal Transient Voltage Suppressor

# HIGH VOLTAGE GreenFET

## HIGH VOLTAGE, HIGH CURRENT, ULTRA LOW RDS<sub>ON</sub> LOAD SWITCHES SELECTION GUIDE

Renesas' family of high-performance load switches include high-voltage capability for all high-side, 4.5 V to 25.2 V power rail applications up to 6 A. Using Renesas' proprietary MOSFET design, this new family of power control switches achieves ultra-stable and low RDS<sub>ON</sub> across a wide input voltage range. Combining Renesas' proprietary MOSFET IP and advanced assembly techniques, these products are available in very pcb space-efficient footprints and exhibit low thermal resistance for high-current operation. Compared to discrete FETs currently used in high-voltage applications, Renesas' High Voltage GreenFET products combine high-performance nFET structures, charge pumps, multiple protection, and control circuits into feature-rich products. For products rated to operate over the industrial (-40 °C to 85 °C) or extended industrial temperature (-40 °C to 125 °C) range, these high-voltage load switches are available in low thermal resistance, RoHS-compliant packaging or wafer level chip scale packaging (WLCSP).

### Featured Products

| Part Number | Description                                                                                                                                                                                        | Max I <sub>DS</sub> (A)         | RDS <sub>ON</sub> (mΩ)         | V <sub>D</sub> /V <sub>IN</sub> Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*                   | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)           |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|--------------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------|---------------------------------|----------------------------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|-----------------------------|
| SLG59H1302C | 5.04 mm <sup>2</sup> surge-protected, 28V tolerant USB Type C Power Splitter/Switch with charge pump, LDO and PG signal output                                                                     | OUT: 6<br>SYS: 6                | OUT: 12<br>SYS: 24             | 3                                       | 13                                      | –                                                 | No                              | OVLO, UVLO, TVS, SYS: RCB              | No                     | OUT: no<br>SYS: PG          | No                       | -40 to +85                        | WLCSP-28<br>(2.98 x 1.69)   |
| SLG59H1313C | 2.34 mm <sup>2</sup> surge-protected, 29V tolerant nFET load switch with Internal 100V TVS and Adjustable OVP in WLCSP                                                                             | 5                               | 23                             | 3                                       | 20                                      | –                                                 | No                              | OVLO, ACL, SCL, TSD, TVS               | No                     | PG                          | No                       | -40 to +85                        | WLCSP-12<br>(1.3 x 1.8)     |
| SLG59H1341C | 1.46 mm <sup>2</sup> load switch with V <sub>IN</sub> undervoltage protection, V <sub>OUT</sub> overvoltage protection, reverse-current blocking, reverse-voltage detection, and FLT Output        | 1.3                             | 70                             | 2.5                                     | 5.5                                     | –                                                 | No                              | OVLO, UVLO, RCB, RVD, ACL(R), TSD      | No                     | FLT                         | No                       | -40 to +85                        | WLCSP-9<br>(1.21 x 1.21)    |
| SLG59H1342C | 1.46 mm <sup>2</sup> load switch with V <sub>IN</sub> undervoltage and overvoltage protection, reverse-current blocking, reverse-voltage detection, and FLT Output                                 | 1.5                             | 70                             | 2.7                                     | 5.5                                     | –                                                 | No                              | OVLO, UVLO, RCB, RVD, ACL(R), TSD      | No                     | FLT                         | No                       | -40 to +85                        | WLCSP-9<br>(1.21 x 1.21)    |
| SLG59H1401C | 3.15 mm <sup>2</sup> power multiplexer with V <sub>IN(1,2)</sub> undervoltage protection, resistor-adjustable overvoltage protection, true reverse-current blocking, and channel status indication | 3                               | 52                             | 3                                       | 6                                       | –                                                 | Capacitor                       | OVLO, UVLO, RCB, RVD, ACL(R), SCL, TSD | No                     | No                          | No                       | -40 to +85                        | WLCSP-20<br>(1.585 x 1.985) |
| SLG59H1403C | 3.15 mm <sup>2</sup> power multiplexer with V <sub>IN(1,2)</sub> undervoltage protection, resistor-adjustable overvoltage protection, true reverse-current blocking, and channel status indication | 3                               | 52                             | 3                                       | 22                                      | –                                                 | Capacitor                       | OVLO, UVLO, RCB, RVD, ACL(R), SCL, TSD | No                     | No                          | No                       | -40 to +85                        | WLCSP-20<br>(1.585 x 1.985) |
| SLG59H1405V | 5 mm <sup>2</sup> power multiplexer with V <sub>IN(1,2)</sub> undervoltage and overvoltage protection, Channel 1 true reverse-current blocking, and FLAG Output                                    | Channel 1: 3<br>Channel 2: 1.25 | Channel 1: 40<br>Channel 2: 67 | 4                                       | Channel 1: 5.5<br>Channel 2: 13.2       | –                                                 | Internally Fixed                | OVLO, UVLO, RCB, RVD, ACL(R), SCL, TSD | No                     | FLAG                        | Yes                      | -20 to +85                        | FC-QFN-12<br>(2.0 x 2.5)    |

\* Notes (Please consult product specifications for additional information):

1. ACL - Internally Fixed Active Current Limit
2. ACL(R) - External resistor-adjustable Active Current Limit
3. SCL - Internally Fixed Short-circuit Current Limit
4. Fixed ICL - Internally Fixed Inrush Current Limit
5. RVD - Reverse-voltage Detection
6. RCB - Reverse-current Blocking
7. TSD - Overtemperature protection (Thermal Shutdown)
8. UVLO - Undervoltage Protection
9. OVLO - Overvoltage protection
10. TVS - Internal Transient Voltage Suppressor

### For Applications up to 13.2 V

| Part Number | Description                                                                                                                                                 | Max I <sub>DS</sub> (A) | RDS <sub>ON</sub> (mΩ) | V <sub>D</sub> /V <sub>IN</sub> Min (V) | V <sub>D</sub> /V <sub>IN</sub> Max (V) | Power Supply (V <sub>DD</sub> ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*         | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)       |
|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------|-----------------------------------------|-----------------------------------------|---------------------------------------------------|---------------------------------|------------------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|-------------------------|
| SLG59H1127V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and Power Good Output                      | 4                       | 15                     | 5                                       | 13                                      | –                                                 | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD | No                     | PG, FAULT                   | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1120V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and DS current monitor output              | 5                       | 18                     | 5                                       | 13                                      | –                                                 | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1126V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and I <sub>DS</sub> current monitor output | 6                       | 18                     | 5                                       | 13                                      | –                                                 | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |

# HIGH VOLTAGE GreenFET

## HIGH VOLTAGE, HIGH CURRENT, ULTRA LOW $R_{DS(on)}$ LOAD SWITCHES SELECTION GUIDE

### For Applications up to 25.2 V

| Part Number | Description                                                                                                                                                                                  | Max $I_{DS}$ (A) | $R_{DS(on)}$ (m $\Omega$ ) | $V_D/V_{IN}$ Min (V) | $V_D/V_{IN}$ Max (V) | Power Supply ( $V_{DD}$ ) Voltage Range (V) | Output Voltage Slew Rate set by | Protection Features*              | Current Monitor Output | Power Good, FAULT indicator | Output Discharge Circuit | Operating Temperature Range, (°C) | Package Size (mm)       |
|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|----------------------|----------------------|---------------------------------------------|---------------------------------|-----------------------------------|------------------------|-----------------------------|--------------------------|-----------------------------------|-------------------------|
| SLG59H1013V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN lockout protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output for enterprise printer/copier applications  | 4                | 13                         | 11                   | 25                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +125                       | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1017V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN lockout protection, internal 10W nFET SOA protection, and $I_{DS}$ current monitor output for enterprise printer/copier applications | 4                | 13                         | 11                   | 25                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1008V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN lockout protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output for enterprise printer/copier applications  | 4                | 13                         | 11                   | 25                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1010V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN lockout protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output for enterprise printer/copier applications  | 5                | 13                         | 11                   | 25                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1019V | 4.8 mm <sup>2</sup> load switch with VIN OVLO disabled, internal 10W nFET SOA protection, and $I_{DS}$ current monitor output                                                                | 5                | 13                         | 5                    | 25                   | –                                           | Capacitor                       | UVLO, ACL(R), SCL, TSD            | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1016V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output                                         | 4                | 13                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +125                       | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1009V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output                                         | 4                | 13                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1128V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 10W nFET SOA protection, and $I_{DS}$ current monitor output                                        | 5                | 13                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1006V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output                                         | 5                | 13                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1012V | 4.8 mm <sup>2</sup> load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output                                         | 6                | 13                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD      | Yes                    | FAULT                       | Yes                      | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1005V | 4.8 mm <sup>2</sup> back-to-back reverse-current blocking load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output   | 3                | 50                         | 5                    | 22                   | –                                           | Capacitor                       | OVLO, UVLO, ACL(R), SCL, TSD, RCB | Yes                    | FAULT                       | No                       | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |
| SLG59H1020V | 4.8 mm <sup>2</sup> back-to-back reverse-current blocking load switch with pin-selectable VIN overvoltage protection, internal 5W nFET SOA protection, and $I_{DS}$ current monitor output   | 3                | 50                         | 5                    | 20                   | –                                           | Capacitor                       | OVLO, ACL(R), SCL, TSD, RCB       | Yes                    | FAULT                       | No                       | -40 to +85                        | STQFN-18<br>(1.6 x 3.0) |

\* Notes (Please consult product specifications for additional information):

1. ACL - Internally Fixed Active Current Limit
2. ACL(R) - External resistor-adjustable Active Current Limit
3. SCL - Internally Fixed Short-circuit Current Limit
4. Fixed ICL – Internally Fixed Inrush Current Limit
5. RVD – Reverse-voltage Detection

6. RCB – Reverse-current Blocking
7. TSD – Overtemperature protection (Thermal Shutdown)
8. UVLO – Undervoltage Protection
9. OVLO – Overvoltage protection
10. TVS – Internal Transient Voltage Suppressor



# GreenFET SELECTION GUIDE

Visit [renesas.com/load-switches](https://renesas.com/load-switches) for more details on the complete portfolio of products, including the product guide, eval boards and samples.



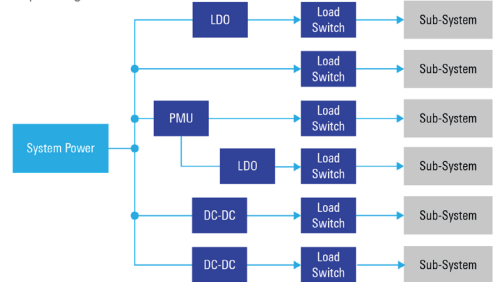
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## GreenFET LOAD SWITCH USAGE EXAMPLES

04-05

### Power Distribution Application

Load Switch Example Usage



### Power Control Application

02-03

## GreenFET Load Switch Portfolio

### GreenFET

- Single-channel nFET & pFET in STDFN & STDFN (1 mm<sup>2</sup> to 4 mm<sup>2</sup>)
- Single-channel in WLCSF (1 A to 4 A, 0.66 mm<sup>2</sup> to 1.5 mm<sup>2</sup>)
- Dual-channel nFET and pFET in STDFNs (3 mm<sup>2</sup>)

### Operating input voltage range

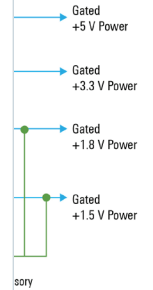
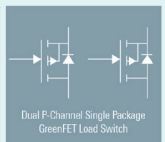
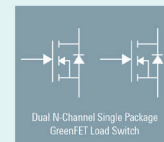
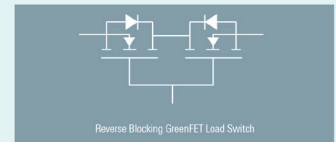
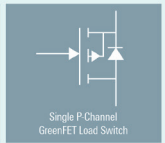
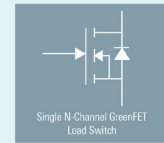
- Maximum  $V_{in}$  Voltage Ranges: 2 V, 3.6 V & 5.5 V
- FET  $V_{th}$  Range: 0.25 V to  $V_{DD}$
- $R_{DS(on)}$  Range: 4 m $\Omega$  to 45 m $\Omega$
- $I_{OS}$  Current Range: 1 A to 9 A
- UL2367 Current-Limiter Certified (select parts)

### High voltage GreenFET

- Single-channel (2.3 mm<sup>2</sup> to 5 mm<sup>2</sup>)
- Power-supply/FET Input Voltage Ranges: 4.5 V to 25.2 V
- $R_{DS(on)}$  Range: 13.3 m $\Omega$  to 50 m $\Omega$
- IDS Current Range: 3 A to 6 A
- WLCSF for Space-Constrained Applications
- UL2367 Current-Limiter Certified (select parts)

### High Side Gate Drivers

- N-Channel MOSFET Drivers



GreenFET products combine high-performance nFET or pFET structures, high current handling capability, charge pumps, as well as multiple protection and control circuits into space-efficient single- and dual-channel products.

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