

Multi-Mode Buck Converter with LDO Assist for GSM / EDGE, 3G/3.5G and 4G PAs

FAN5910

Description

The FAN5910 is a high-efficiency, low-noise, synchronous, step-down, DC-DC converter optimized for powering Radio Frequency (RF) Power Amplifiers (PAs) in handsets and other mobile applications. Load currents up to 2.5 A are allowed, which enables GSM / EDGE, 3G/3.5G, and 4G platforms under very poor VSWR conditions.

The output voltage may be dynamically adjusted from 0.40 V to 3.60 V, proportional to an analog input voltage V_{CON} ranging from 0.16 V to 1.44 V, optimizing power-added efficiency. Fast transition times are achieved, allowing excellent inter-slot settling.

An integrated LDO is automatically enabled under heavy load conditions or when the battery voltage and voltage drop across the DC-DC PMOS device are within a set range of the desired output voltage. This LDO-assist feature supports heavy load currents under the most stringent battery and V_{SWR} conditions while maintaining high efficiency, low dropout, and superior spectral performance.

The FAN5910 DC-DC operates in PWM Mode with a 2.9 MHz switching frequency and supports a single, small form-factor inductor ranging from 1.0 μ H to 2.2 μ H. In addition, PFM operation is allowed at low load currents for output voltages below 1.5 V to maximize efficiency. PFM operation can be disabled by setting MODE pin to LOW.

When output regulation is not required, the FAN5910 may be placed in Sleep Mode by setting V_{CON} below 100 mV nominally. This ensures a very low I_Q (<50 μ A) while enabling a fast return to output regulation.

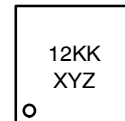
FAN5910 is available in a low profile, small form factor, 16 bump, Wafer-Level Chip-Scale Package (WLCSP) that is 1.615 mm x 1.615 mm. Only three external components are required: two 0402 capacitors and one 2016 inductor.

Features

- Solution Size < 9.52 mm²
- 2.7 V to 5.5 V Input Voltage Range
- V_{OUT} Range from 0.40 V to 3.60 V (or V_{IN})
- Single, Small Form-Factor Inductor
- 29 m Ω Integrated LDO
- 100% Duty Cycle for Low-Dropout Operation
- Input Under-Voltage Lockout / Thermal Shutdown
- 1.615 mm x 1.615 mm, 16-Bump, 0.4 mm Pitch WLCSP
- 2.9 MHz PWM Mode
- Sleep Mode for ~50 μ A Standby Current Consumption



WLCSP
16 BUMP
CASE 567SD



- 12 = Alphanumeric Device Code
(See Ordering Information for specific marking)
- KK = Lot Run Number
- X = Alphabetical Year Code
- Y = 2-weeks Date Code
- Z = Assembly Plant Code

ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

- Forced PWM Mode
 - ◆ Up to 95% Efficient Synchronous Operation in High Power Conditions
 - ◆ 2.9 MHz PWM-Only Mode
- Auto PFM/PWM Mode
 - ◆ 2.9 MHz PWM Operation at High Power and PFM Operation at Low Power and Low Output Voltage for Maximum Low Current Efficiency

Applications

- Dynamic Supply Bias for Polar or Linear GSM / EDGE PAs and 3G/3.5G and 4G PAs
- Dynamic Supply Bias for GSM / EDGE Quad Band Amplifiers for Mobile Handsets and Data Cards

FAN5910

ORDERING INFORMATION

| Part Number | Output Voltage | Temperature Range | Package | Packing† | Device Marking |
|-------------|----------------|-------------------|---|---------------|----------------|
| FAN5910UCX | 0.4 V to PVIN | -40°C to +85°C | 1.615 mm x 1.615 mm, 16-Bump 0.4 mm Pitch, Wafer-Level Chip-Scale Package (WLCSP) | Tape and Reel | LJ |

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, [BRD8011/D](#).

BLOCK DIAGRAMS

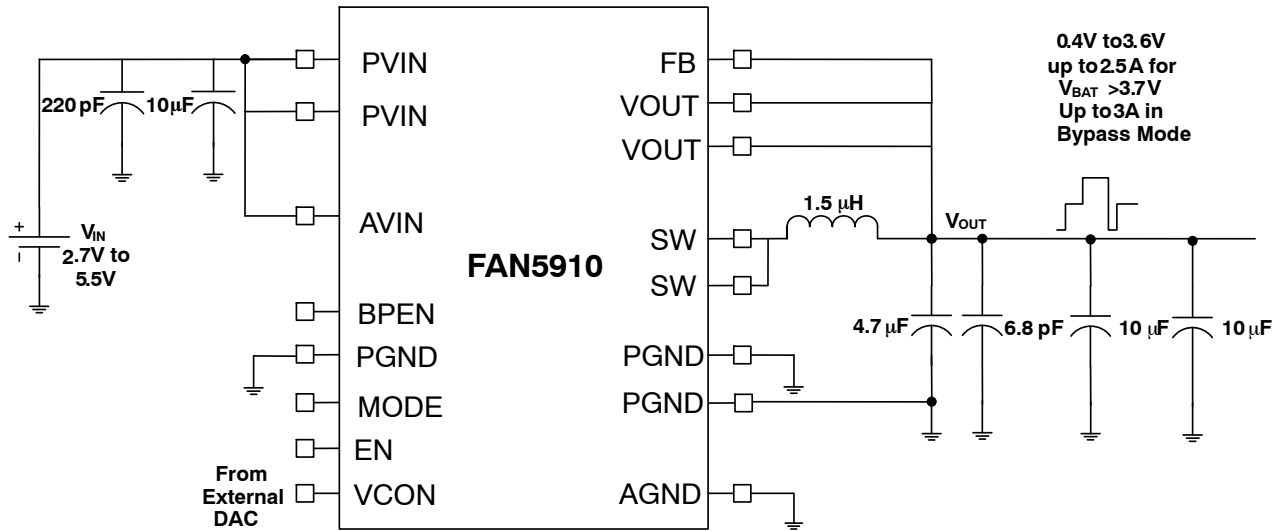


Figure 1. Typical Application

1. The three 4.7 μF capacitors include the FAN5910 output capacitor and PA bypass capacitors.
2. Regulator requires only one 4.7 μF ; the V_{OUT} bus should not exceed 14 μF capacitance over DC bias and temperature.

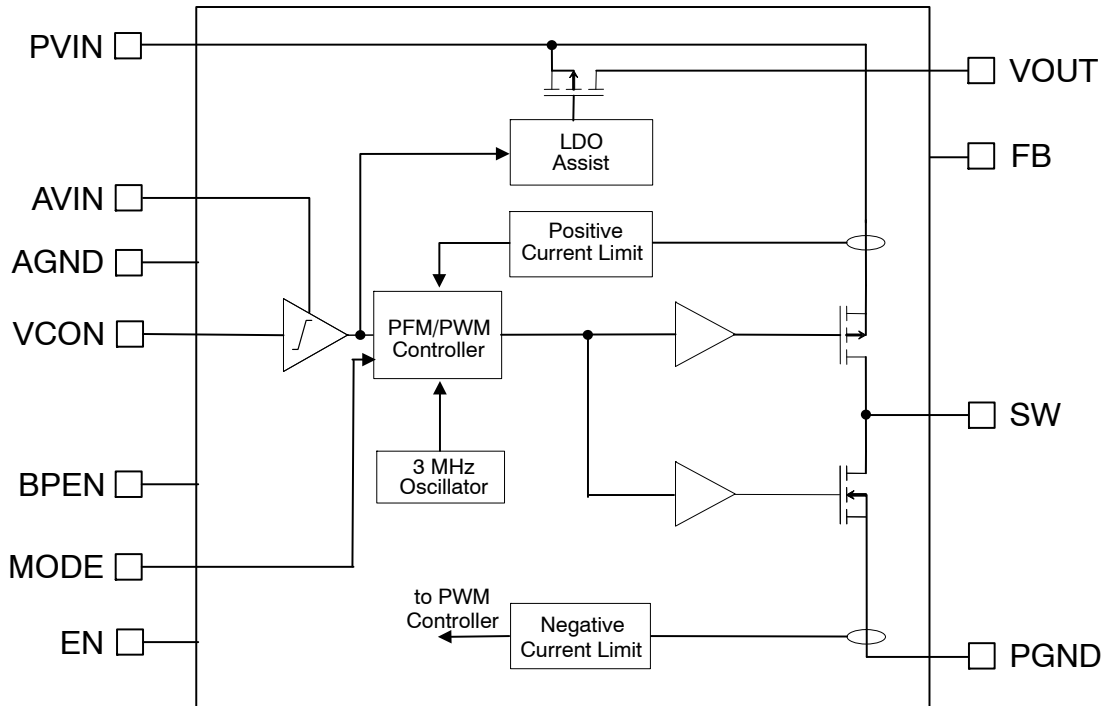


Figure 2. Simplified Block Diagram

FAN5910

PIN CONFIGURATION

| | | | |
|------------|------------|------------|------------|
| PGND A1 | SW A2 | PVIN A3 | VOUT A4 |
| B1 | B2 | B3 | B4 |
| AGND C1 | EN C2 | BPEN C3 | PGND C4 |
| AVIN D1 | VCON D2 | MODE D3 | FB D4 |

Figure 3. Bumps Face Down – Top-Through View

| | | | |
|------------|------------|------------|------------|
| VOUT A4 | PVIN A3 | SW A2 | PGND A1 |
| B4 | B3 | B2 | B1 |
| PGND C4 | BPEN C3 | EN C2 | AGND C1 |
| FB D4 | MODE D3 | VCON D2 | AVIN D1 |

Figure 4. Bumps Face Up

PIN DEFINITIONS

| Pin # | Name | Description |
|------------|------|---|
| C1 | AGND | Analog ground, reference ground for the IC. Follow PCB routing notes for connecting this pin. |
| A4, B4 | VOUT | Output voltage sense pin. Connect to V_{OUT} to establish feedback path for regulation point. Connect together on PCB. |
| D4 | FB | Feedback pin. Connect to positive (+) pad of C_{OUT} on V_{OUT} . |
| C2 | EN | Enables switching when HIGH; Shutdown Mode when LOW. This pin should not be left floating. |
| D2 | VCON | Analog control pin. Shield signal routing against noise. |
| D1 | AVIN | Analog supply voltage input. Connect to PVIN. |
| C3 | BPEN | Force Bypass Mode when HIGH; Auto Bypass Mode when LOW. This pin should not be left floating. |
| D3 | MODE | When MODE is HIGH, the DC-DC permits PFM operation under low load currents and PWM operation under heavy load currents. When MODE pin is set LOW, the DC-DC operates in forced PWM operation. This pin should not be left floating. |
| A3, B3 | PVIN | Supply voltage input to the internal MOSFET switches. Connect to input power source. |
| A2, B2 | SW | Switching node of the internal MOSFET switches. Connect to output inductor. |
| A1, B1, C4 | PGND | Power ground of the internal MOSFET switches. Follow routing notes for connections between PGND and AGND. |

Table 1. ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | | Min | Max | Unit |
|------------------|--|-----------------------------------|----------|------------------------|------|
| V _{IN} | Voltage on AVIN, PVIN | | −0.3 | 6.0 | V |
| | Voltage on Any Other Pin | | −0.3 | AV _{IN} + 0.3 | |
| T _J | Junction Temperature | | −40 | +125 | °C |
| T _{STG} | Storage Temperature | | −65 | +150 | °C |
| T _L | Lead Soldering Temperature (10 Seconds) | | | +260 | °C |
| ESD | Electrostatic Discharge Protection Level | Human Body Model, JESD22−A114 | 2.0 | | kV |
| | | Charged Device Model, JESD22−C101 | 1.0 | | |
| LU | Latch Up | | JESD 78D | | |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

Table 2. RECOMMENDED OPERATING CONDITIONS

| Symbol | Parameter | Min | Typ | Max | Unit |
|-------------------|--------------------------------------|------|-----|-----------|------|
| V_{IN} | Supply Voltage Range | 2.7 | | 5.5 | V |
| V_{OUT} | Output Voltage Range | 0.35 | | $<V_{IN}$ | V |
| I_{OUT_BYPASS} | Output Current in Bypass Mode | | | 4.5 | A |
| I_{OUT} | Output Current | | | 2.5 | A |
| L | Inductor | | 1.5 | | μH |
| C_{IN} | Input Capacitor (Note 3) | | 10 | | μF |
| C_{OUT} | Output Capacitor (Note 4) | | 4.7 | | μF |
| T_A | Operating Ambient Temperature Range | -40 | | +85 | °C |
| T_J | Operating Junction Temperature Range | -40 | | +125 | °C |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

3. The input capacitor must be large enough to limit the input voltage drop during GSM bursts, bypass transitions, and large output voltage transitions.

4. Regulator requires only one 4.7 μF.

Table 3. DISSIPATION RATINGS

| Symbol | Parameter | Min | Typ | Max | Unit |
|---------------|---|-----|-----|-----|------|
| θ_{JA} | Junction-to-Ambient Thermal Resistance (Note 5) | | 40 | | °C/W |

5. Junction-to-ambient thermal resistance is a function of application and board layout. This data is measured with four-layer 2s2p boards with vias in accordance to JEDEC51 – JEDEC standard. Special attention must be paid not to exceed junction temperature $T_{J(MAX)}$ at a given ambient temperature T_A .

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Table 4. ELECTRICAL CHARACTERISTICS, ALL MODES Recommended operating conditions, unless otherwise noted, circuit per Figure 1, minimum and maximum values are at $V_{IN} = 2.7\text{ V}$ to 5.5 V , $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{OUT} = V_{CON} \times 2.5 = 0.4\text{ V}$ to 3.6 V , $V_{IN} \geq V_{OUT} + 0.3\text{ V}$. Typical values are given $V_{IN} = 3.8\text{ V}$ and $V_{OUT} = 2.5\text{ A}$ at $T_A = 25^\circ\text{C}$. $L = 1.5\text{ }\mu\text{H}$, Murata DFE201610C, $C_{IN} = 10\text{ }\mu\text{F}$ 0402 Samsung CL05A106MP5NUNC, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$ 0402 Murata GRM155R60J475ME47D, $2 \times 10\text{ }\mu\text{F}$ 0402 Murata GRM188B30J106ME47D.

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|--------|-----------|-----------|-----|-----|-----|------|
|--------|-----------|-----------|-----|-----|-----|------|

POWER SUPPLIES

| | | | | | | |
|------------|---------------------------------|--------------------------------|------|------|------|---------------|
| V_{IN} | Input Voltage Range | $I_{OUT} \leq 2.5\text{ A}$ | 2.7 | | 5.5 | V |
| I_{SD} | Shutdown Supply Current | $EN = 0\text{ V}$, $MODE = 0$ | | 0.5 | 3.0 | μA |
| V_{UVLO} | Under Voltage Lockout Threshold | V_{IN} Rising | 2.20 | 2.45 | 2.60 | V |
| | | Hysteresis | | 250 | | mV |

LOGIC CONTROL

| | | | | | | |
|------------|---|----------------------|-----|------|------|---------------|
| V_{IH} | Logic Threshold Voltage; EN, BPEN, MODE | Input HIGH Threshold | 1.2 | | | V |
| V_{IL} | | Input LOW Threshold | | | 0.4 | V |
| I_{CTRL} | Logic Control Input Bias Current; EN, BPEN, MODE | V_{IN} or GND | | 0.01 | 1.00 | μA |

ANALOG CONTROL

| | | | | | | |
|---------------------|---|---|-----|--------------|-----|---------------|
| $V_{CON_BYP_EN1}$ | V_{CON} Forced Bypass Entry Threshold | V_{CON} Voltage that Forces Bypass; $V_{IN} \geq 4\text{ V}$ | 1.6 | | | V |
| $V_{CON_BYP_EN2}$ | V_{CON} Forced Bypass Entry Threshold | V_{CON} Voltage that Forces Bypass; $V_{IN} < 4\text{ V}$ | | $V_{IN}/2.5$ | | V |
| $V_{CON_BYP_EX}$ | V_{CON} Forced Bypass Exit Threshold | V_{CON} Voltage that Exits Forced Bypass | | | 1.4 | V |
| $V_{CON_SL_EN}$ | V_{CON} Sleep Enter | V_{CON} Voltage Forcing Low I_Q Sleep Mode | 70 | | | mV |
| $V_{CON_SL_EX}$ | V_{CON} Sleep Exit | V_{CON} Voltage that Exits SLEEP Mode | | | 125 | mV |
| I_Q | DC-DC Quiescent Current in Sleep Mode | $V_{CON} < 70\text{ mV}$ | | 50 | 80 | μA |
| Gain | V_{CON} to V_{OUT} Gain | $V_{CON} = 0.16\text{ V}$ to 1.44 V | | 2.5 | | V/V |
| V_{OUT_ACC} | V_{OUT} Accuracy | Ideal = $2.5 \times V_{CON}$ | -50 | | +50 | mV |

LDO

| | | | | | | |
|-----------------------|----------------------|--------------------------|--|-----|--|------------|
| R_{FET} | LDO FET Resistance | | | 29 | | m Ω |
| ΔV_{OUT_LDO} | LDO Dropout (Note 6) | $I_{OUT} = 2.0\text{ A}$ | | 100 | | mV |

OVER TEMPERATURE PROTECTION

| | | | | | | |
|-----------|-----------------------------|--------------------|--|------|--|------------------|
| T_{OTP} | Over-Temperature Protection | Rising Temperature | | +150 | | $^\circ\text{C}$ |
| | | Hysteresis | | +20 | | $^\circ\text{C}$ |

OSCILLATOR

| | | | | | | |
|----------|------------------------------|--|-----|-----|-----|-----|
| f_{SW} | Average Oscillator Frequency | | 2.6 | 2.9 | 3.2 | MHz |
|----------|------------------------------|--|-----|-----|-----|-----|

DC-DC

| | | | | | | |
|-----------------|-------------------------------------|---------------------------|------|------|------|------------|
| $R_{DS(on)}$ | PMOS On Resistance | | | 80 | | m Ω |
| | NMOS On Resistance | | | 60 | | |
| I_{LIMp} | P-Channel Current Limit (Note 7) | | 1.50 | 1.90 | 2.30 | A |
| I_{LIMn} | N-Channel Current Limit (Note 7) | | 1.50 | 1.90 | 2.30 | A |
| $I_{Discharge}$ | Maximum Transient Discharge Current | | | 3.7 | 4.5 | A |
| V_{OUT_MIN} | Minimum Output Voltage | $V_{CON} = 0.16\text{ V}$ | 0.35 | 0.40 | 0.45 | V |

6. Dropout depends on LDO and DC-DC PFET $R_{DS(on)}$ and inductor DCR.

7. The current limit is the peak (maximum) current.

8. Guaranteed by design. Maximum values are based on simulation results with 50% C_{OUT} derating; not tested in production. Voltage transient only. Assumes $C_{OUT} = 24.7\text{ }\mu\text{F}$ ($1 \times 4.7\text{ }\mu\text{F}$ for regulator and $2 \times 10\text{ }\mu\text{F}$ for PA decoupling capacitors).

9. Protects part under short-circuit conditions

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Table 4. ELECTRICAL CHARACTERISTICS, ALL MODES Recommended operating conditions, unless otherwise noted, circuit per Figure 1, minimum and maximum values are at $V_{IN} = 2.7\text{ V}$ to 5.5 V , $T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$, $V_{OUT} = V_{CON} \times 2.5 = 0.4\text{ V}$ to 3.6 V , $V_{IN} \geq V_{OUT} + 0.3\text{ V}$. Typical values are given $V_{IN} = 3.8\text{ V}$ and $V_{OUT} = 2.5\text{ A}$ at $T_A = 25^\circ\text{C}$. $L = 1.5\text{ }\mu\text{H}$, Murata DFE201610C, $C_{IN} = 10\text{ }\mu\text{F}$ 0402 Samsung CL05A106MP5NUNC, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$ 0402 Murata GRM155R60J475ME47D, $2 \times 10\text{ }\mu\text{F}$ 0402 Murata GRM188B30J106ME47D.

| Symbol | Parameter | Condition | Min | Typ | Max | Unit |
|--------|-----------|-----------|-----|-----|-----|------|
|--------|-----------|-----------|-----|-----|-----|------|

DC-DC

| | | | | | | |
|----------------|------------------------|---|------|------|------|---|
| V_{OUT_MAX} | Maximum Output Voltage | $V_{CON} = 1.44\text{ V}$, $V_{IN} = 3.9\text{ V}$ | 3.55 | 3.60 | 3.65 | V |
|----------------|------------------------|---|------|------|------|---|

DC-DC EFFICIENCY

| | | | | | | |
|----------------|---------------------------------------|---|--|----|--|---|
| η_{Power} | Power Efficiency, Low-Power Auto Mode | $V_{OUT} = 3.1\text{ V}$, $I_{LOAD} = 250\text{ mA}$ | | 95 | | % |
| | | $V_{OUT} = 1.8\text{ V}$, $I_{LOAD} = 250\text{ mA}$ | | 90 | | |
| | | $V_{OUT} = 0.5\text{ V}$, $I_{LOAD} = 10\text{ mA}$ | | 65 | | |

OUTPUT REGULATION

| | | | | | | |
|-------------------|---------------------------|--|--|----------|--|----|
| V_{OUT_RLine} | V_{OUT} Line Regulation | $3.1 \leq V_{IN} \leq 3.8$, 100 mA | | ± 5 | | mV |
| V_{OUT_RLoad} | V_{OUT} Load Regulation | $20\text{ mA} \leq I_{OUT} \leq 800\text{ mA}$ | | ± 25 | | mV |
| V_{OUT_Ripple} | V_{OUT} Ripple | PFM Mode, $I_{OUT} < 100\text{ mA}$ | | 11 | | mV |
| | | PWM Mode | | 4 | | |

TIMING

| | | | | | | |
|-----------------|---|--|--|------|--|---------------|
| t_{SS} | Startup Time | $V_{IN} = 3.8\text{ V}$, V_{OUT} from 0 V to 2.5 V , $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$, 10 V , X5R; $2 \times 10\text{ }\mu\text{F}$, 6.3 V , X5R | | 12 | | μs |
| t_{DC-DC_TR} | V_{CON} Step Response Rise Time | From V_{CON} to $95\% V_{OUT}$, $\Delta V_{OUT} \leq 2.7\text{ V}$ ($0.7\text{ V} - 3.4\text{ V}$), $R_{LOAD} = 5\text{ }\Omega$, $C_{OUT} = 24.7\text{ }\mu\text{F}$ | | 18 | | μs |
| t_{DC-DC_TF} | V_{CON} Step Response Fall Time | From V_{CON} to $5\% V_{OUT}$, $\Delta V_{OUT} \leq 2.7\text{ V}$ ($3.4\text{ V} - 0.7\text{ V}$), $R_{LOAD} = 200\text{ }\Omega$, $C_{OUT} = 24.7\text{ }\mu\text{F}$ | | 12 | | μs |
| t_{DC-DC_CL} | Maximum Allowed Time for Consecutive Current Limit (Note 9) | $V_{OUT} < 1\text{ V}$ | | 1500 | | μs |
| t_{DCDC_CLR} | Consecutive Current Limit Recovery Time (Note 9) | | | 4800 | | μs |

6. Dropout depends on LDO and DC-DC PFET $R_{DS(on)}$ and inductor DCR.

7. The current limit is the peak (maximum) current.

8. Guaranteed by design. Maximum values are based on simulation results with 50% C_{OUT} derating; not tested in production. Voltage transient only. Assumes $C_{OUT} = 24.7\text{ }\mu\text{F}$ ($1 \times 4.7\text{ }\mu\text{F}$ for regulator and $2 \times 10\text{ }\mu\text{F}$ for PA decoupling capacitors).

9. Protects part under short-circuit conditions

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

TYPICAL CHARACTERISTICS

Unless otherwise noted, $V_{IN} = EN = 3.8\text{ V}$, $L = 1.0\text{ }\mu\text{H}$, $C_{IN} = 10\text{ }\mu\text{F}$, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$, $2 \times 10\text{ }\mu\text{F}$, and $T_A = +25^\circ\text{C}$.

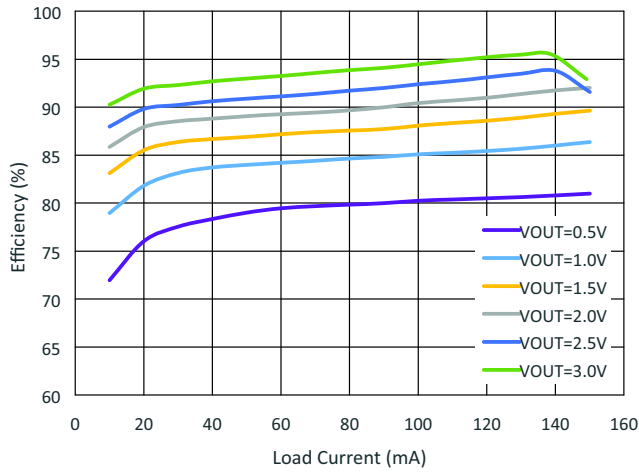


Figure 5. Efficiency vs. Load Current and Output Voltage, $V_{IN} = 3.8\text{ V}$, $I_{OUT} = 10\text{ mA}$ to 150 mA

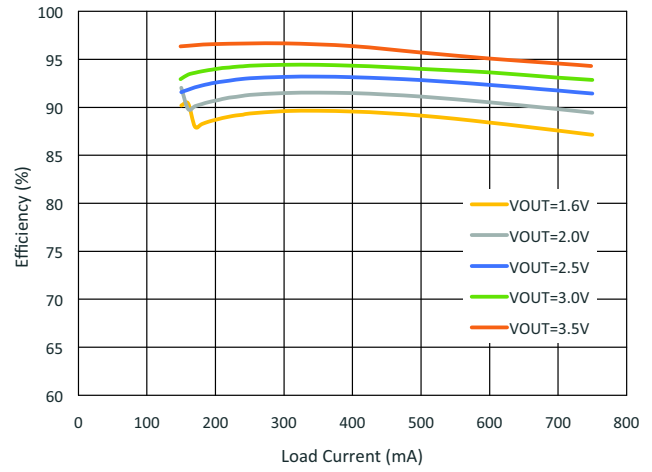


Figure 6. Efficiency vs. Load Current and Output Voltage, $V_{IN} = 3.8\text{ V}$

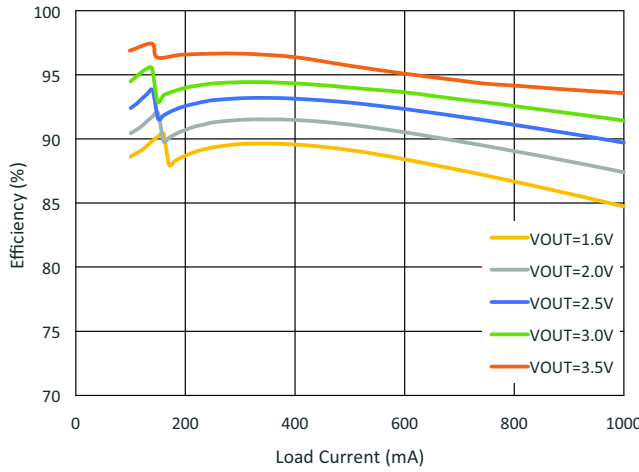


Figure 7. Efficiency vs. Load Current and Output Voltage, $V_{IN} = 3.8\text{ V}$, $I_{OUT} = 100\text{ mA}$ to 1 A

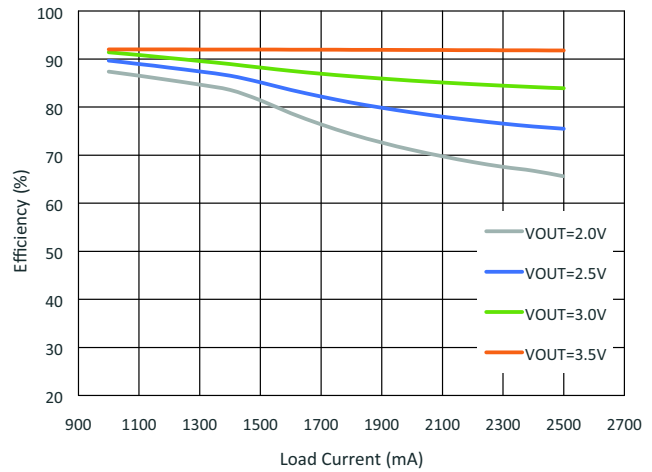


Figure 8. Efficiency vs. Load Current and Output Voltage, $V_{IN} = 3.8\text{ V}$, $I_{OUT} = 1\text{ A}$ to 2.5 A

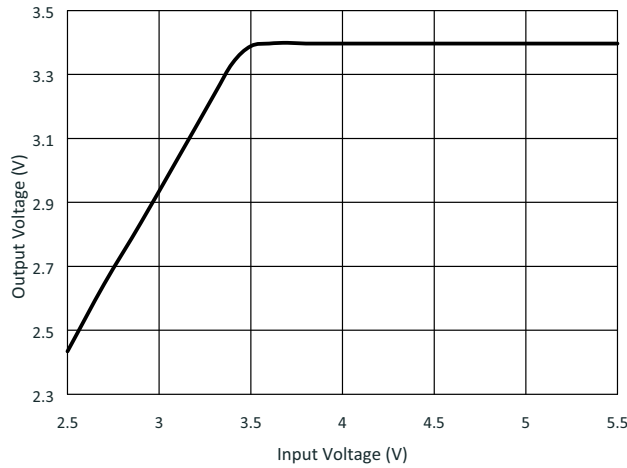


Figure 9. Output Voltage vs. Supply Voltage, $V_{OUT} = 3.4\text{ V}$, $I_{OUT} = 1.5\text{ A}$, $V_{IN} = 4.3\text{ V}$ to Dropout

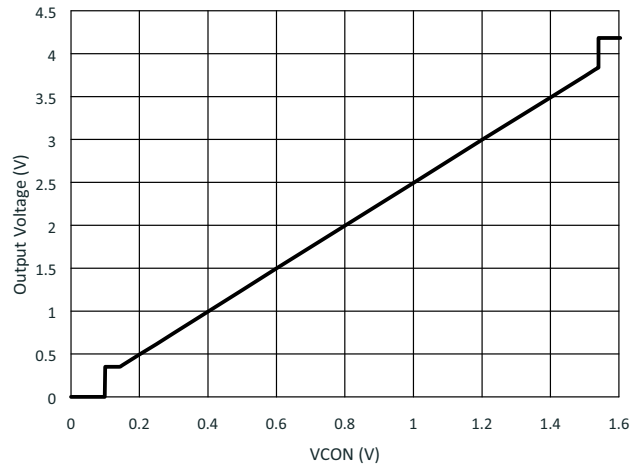


Figure 10. Output Voltage vs. V_{CON} Voltage, $V_{IN} = 4.2\text{ V}$, $R_{LOAD} = 6.8\text{ }\Omega$, $0.1\text{ V} < V_{CON} < 1.6\text{ V}$

TYPICAL CHARACTERISTICS

Unless otherwise noted, $V_{IN} = EN = 3.8\text{ V}$, $L = 1.5\text{ }\mu\text{H}$, $C_{IN} = 10\text{ }\mu\text{F}$, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$, $2 \times 10\text{ }\mu\text{F}$, and $T_A = +25^\circ\text{C}$.

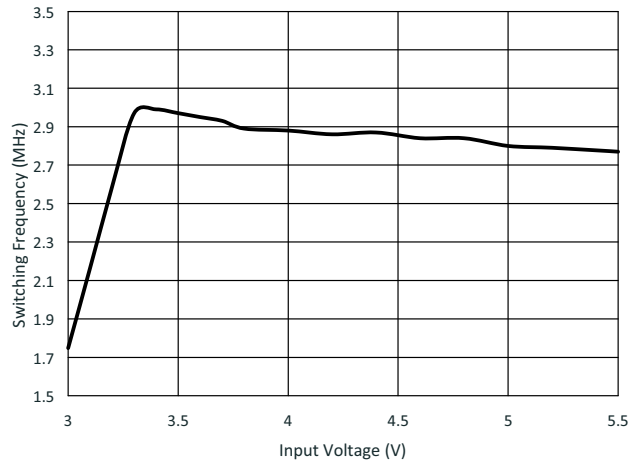


Figure 11. Center-Switching Frequency vs. Supply Voltage, $V_{OUT} = 2.5\text{ V}$, $I_{OUT} = 700\text{ mA}$

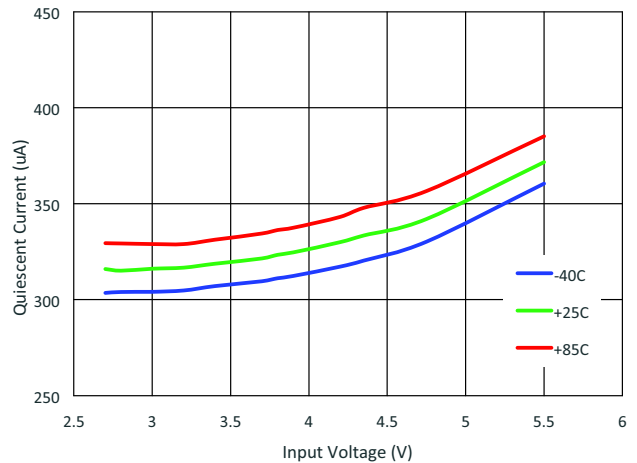


Figure 12. Quiescent Current (PFM) vs. Supply Voltage, $V_{OUT} = 1\text{ V}$, $2.7\text{ V} < V_{IN} < 5.5\text{ V}$ (No Load)

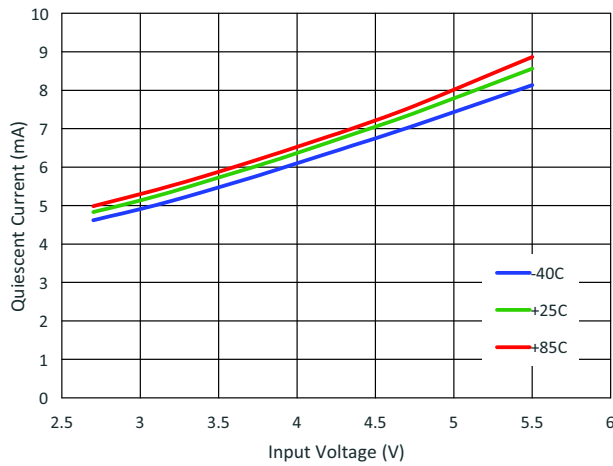


Figure 13. Quiescent Current (PWM) vs. Supply Voltage, $V_{OUT} = 2.5\text{ V}$, $2.7\text{ V} < V_{IN} < 5.5\text{ V}$ (No Load)

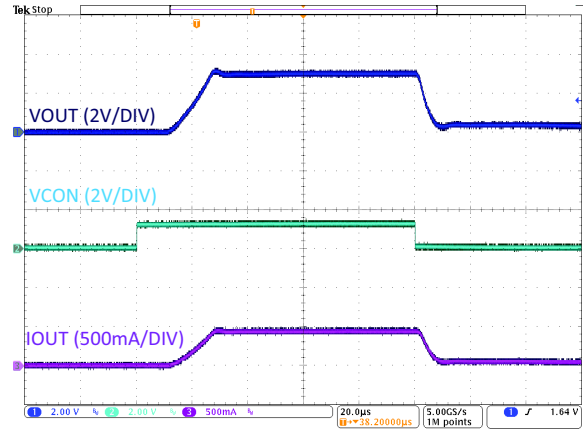


Figure 14. V_{CON} Transient (3 G/G), $V_{OUT} = 0\text{ V}$ to 3 V , $R_{LOAD} = 6.8\text{ }\Omega$, $V_{IN} = 3.8\text{ V}$, 100 ns Edge

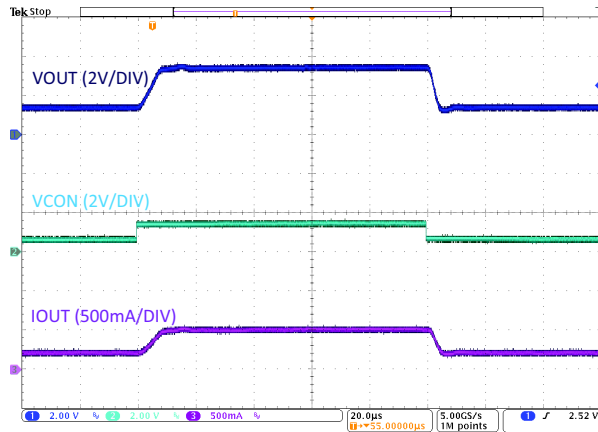


Figure 15. V_{CON} Transient (PFM to PWM), $V_{OUT} = 1.4\text{ V}$ to 3.4 V , $R_{LOAD} = 6.8\text{ }\Omega$, $V_{IN} = 3.8\text{ V}$, 100 ns Edge

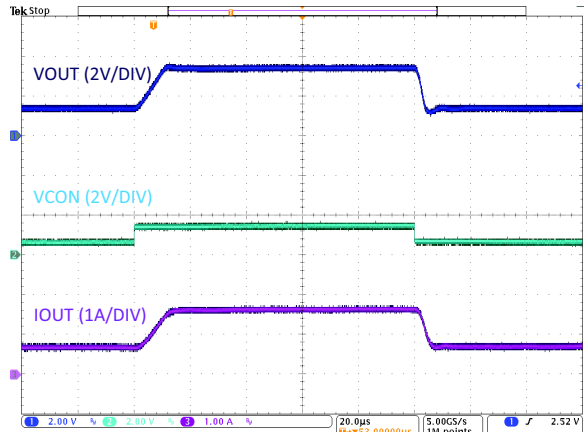


Figure 16. V_{CON} Transient (PWM), $V_{OUT} = 1.4\text{ V}$ to 3.4 V , $R_{LOAD} = 1.9\text{ }\Omega$, $V_{IN} = 4.2\text{ V}$, 100 ns Edge

TYPICAL CHARACTERISTICS

Unless otherwise noted, $V_{IN} = EN = 3.8\text{ V}$, $L = 1.5\text{ }\mu\text{H}$, $C_{IN} = 10\text{ }\mu\text{F}$, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$, $2 \times 10\text{ }\mu\text{F}$, and $T_A = +25^\circ\text{C}$.

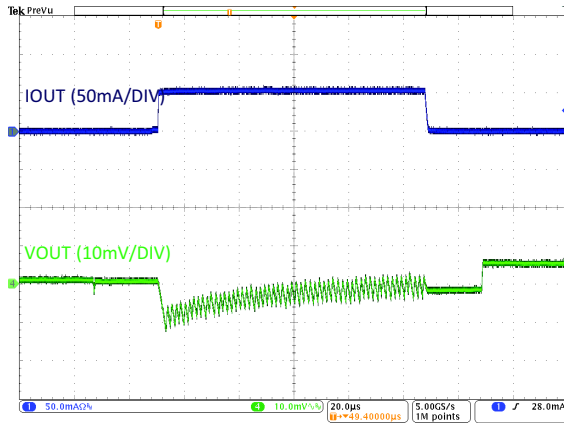


Figure 17. Load Transient in PFM Mode, $V_{IN} = 3.6\text{ V}$, $V_{OUT} = 1\text{ V}$, $I_{OUT} = 0\text{ mA}$ to 60 mA , $1\text{ }\mu\text{s}$ Edge

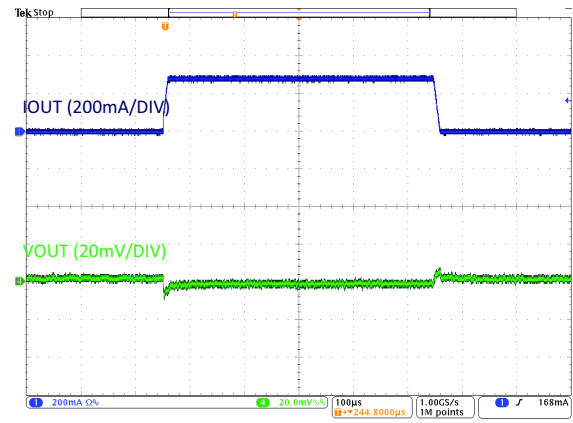


Figure 18. Load Transient in PWM Mode, $V_{IN} = 3.8\text{ V}$, $V_{OUT} = 2.5\text{ V}$, $I_{OUT} = 0\text{ mA}$ to 300 mA , $10\text{ }\mu\text{s}$ Edge

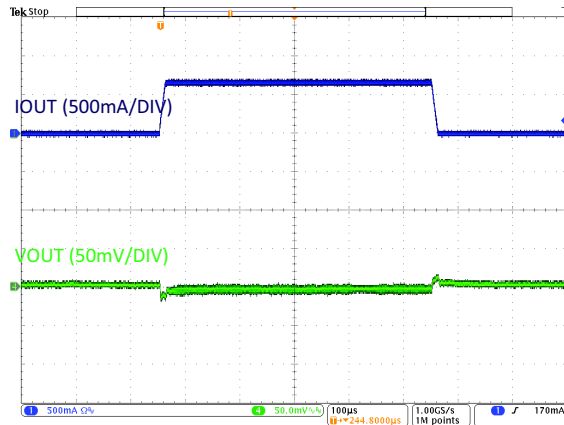


Figure 19. Load Transient in PWM Mode, $V_{IN} = 3.8\text{ V}$, $V_{OUT} = 3.0\text{ V}$, $I_{OUT} = 0\text{ mA}$ to 700 mA , $10\text{ }\mu\text{s}$ Edge

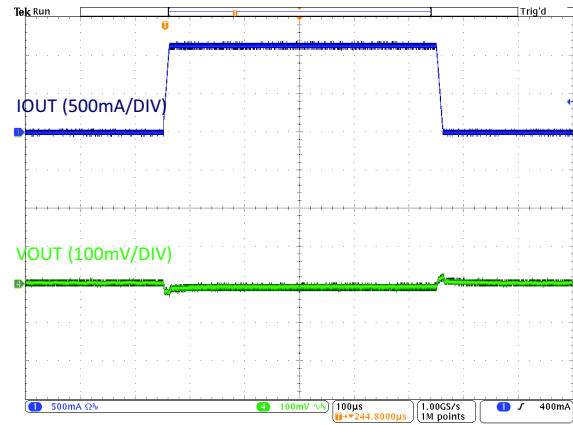


Figure 20. Load Transient in PWM Mode, $V_{IN} = 4.2\text{ V}$, $V_{OUT} = 3.0\text{ V}$, $I_{OUT} = 0\text{ mA}$ to 1.2 A , $10\text{ }\mu\text{s}$ Edge

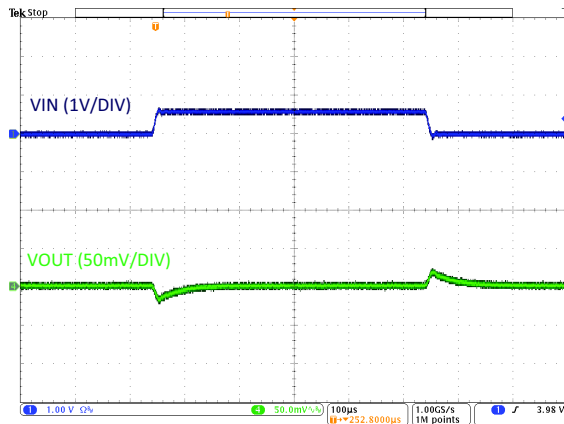


Figure 21. Line Transient, $V_{IN} = 3.6\text{ V}$ to 4.2 V , $V_{OUT} = 1.0\text{ V}$, $6.8\text{ }\Omega$ Load, $10\text{ }\mu\text{s}$ Edge

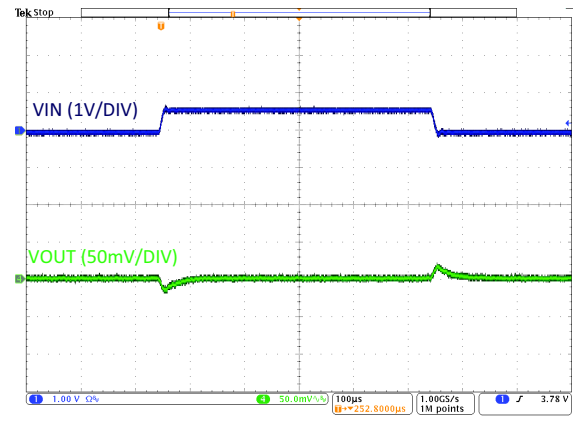


Figure 22. Line Transient, $V_{IN} = 3.6\text{ V}$ to 4.2 V , $V_{OUT} = 2.5\text{ V}$, $6.8\text{ }\Omega$ Load, $10\text{ }\mu\text{s}$ Edge

TYPICAL CHARACTERISTICS

Unless otherwise noted, $V_{IN} = EN = 3.8\text{ V}$, $L = 1.5\text{ }\mu\text{H}$, $C_{IN} = 10\text{ }\mu\text{F}$, $C_{OUT} = 1 \times 4.7\text{ }\mu\text{F}$, $2 \times 10\text{ }\mu\text{F}$, and $T_A = +25^\circ\text{C}$.

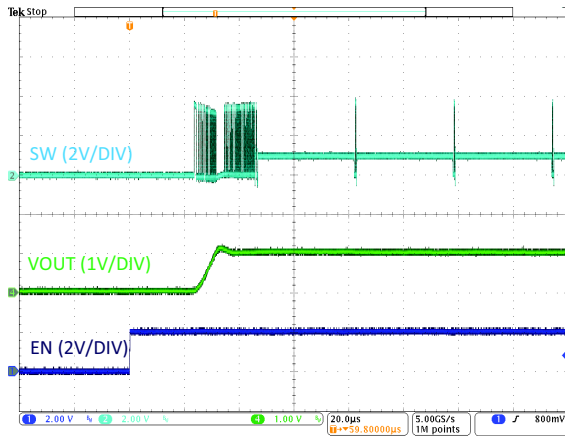


Figure 23. Startup in PFM Mode, $V_{IN} = 3.8\text{ V}$, $V_{OUT} = 1.0\text{ V}$, No Load, EN = Low to High

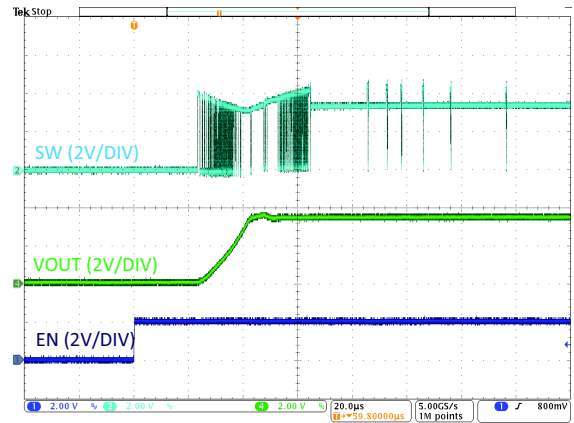


Figure 24. Startup in PWM Mode, $V_{IN} = 4.2\text{ V}$, $V_{OUT} = 3.4\text{ V}$, No Load, EN = Low to High

OPERATING DESCRIPTION

The FAN5910 is a high-efficiency, synchronous, step-down converter (DC-DC) with LDO-assist function.

The DC-DC converter operates with current-mode control and supports a wide range of load currents. High-current applications up to a 2.5 A DC output, such as mandated by GSM/EDGE applications, are allowed. Performance degradation due to spurs is removed by spreading the ripple energy through clock dither. A regulated Bypass Mode continues to regulate the output to the desired voltage as V_{IN} approaches V_{OUT} . The LDO offers a dropout voltage of approximately 100 mV under a 2 A load current.

The output voltage V_{OUT} is regulated to 2.5 times the input control voltage, V_{CON} , set by an external DAC. The FAN5910 operates in either PWM or PFM Mode, depending on the output voltage and load current.

In Pulse Width Modulation (PWM) Mode, regulation begins with on-state. A P-channel transistor is turned on and the inductor current is ramped up until the off-state begins. In the off-state, the P-channel is switched off and an N-channel transistor is turned on. The inductor current decreases to maintain an average value equal to the DC load current. The inductor current is continuously monitored. A current sense flags when the P-channel transistor current exceeds the current limit and the switcher is turned back to off-state to decrease the inductor current and prevent magnetic saturation. The current sense flags when the N-channel transistor current exceeds the current limit and redirects discharging current through the inductor back to the battery.

In Pulse Frequency Modulation (PFM) Mode, the FAN5910 operates in a constant on-time mode at low load currents. During on-state, the P-channel is turned on for a specified time before switching to off-state. In off-state, the N-channel switch is enabled until inductor current decreases to 0 A. The switcher enters three-state until a new regulation cycle starts.

PFM operation is allowed only in Low-Power Mode (MODE=1) for output voltages nominally less than 1.5 V. At low load currents, PFM achieves higher efficiency than PWM. The trade-off for efficiency improvement, however, is larger output ripple. Some applications, such as audio, may not tolerate the higher ripple, especially at high output voltages.

DYNAMIC OUTPUT VOLTAGE TRANSITIONS

FAN5910 has a complex voltage transition controller that realizes fast transition times with a large output capacitor and output voltage ranges.

The transition controller manages five transitions:

- ΔV_{OUT} positive step
- ΔV_{OUT} negative step
- ΔV_{OUT} transition to or from 100% duty cycle
- ΔV_{OUT} transition at startup

In all cases, it is recommended that sharp V_{CON} transitions be applied, letting the transition controller optimize the output voltage slew rate.

ΔV_{OUT} Positive Step

After a V_{CON} positive step, the FAN5910 enters Current-Limit Mode, where V_{OUT} ramps with a constant slew rate dictated by the output capacitor and the current limit.

ΔV_{OUT} Negative Step

After a V_{CON} negative step, the FAN5910 enters Current Limit Mode where V_{OUT} is reduced with a constant slew rate dictated by the output capacitor and the current limit.

V_{OUT} Transition to or from Forced Bypass

The DC-DC is forced into 100% duty cycle for V_{CON} nominally greater than 1.6 V. This allows the output to be connected to the supply through both the low-resistance DC-DC and the LDO PFETs.

V_{OUT} Transition at Startup

At startup, after the EN rising edge is detected, the system requires 25 μ s for all internal voltage references and amplifiers to start before enabling the DC-DC converter function.

MODE PIN

The MODE pin enable Forced PWM Mode or Auto PFM / PWM Mode. When the MODE pin is toggled HIGH (logic 1), the FAN5910 operates in PFM for $V_{OUT} \leq 1.5$ V under light-load conditions and PWM for heavy-load conditions. If the MODE pin is set LOW (logic = 0), it operates in Forced PWM Mode.

Auto PFM / PWM Mode (MODE = 1)

Auto PFM/PWM Mode is appropriate for 3G/3.5G and 4G applications.

Forced PWM Mode (MODE = 0)

Forced PWM Mode is appropriate for applications that demand minimal ripple over the entire output voltage range.

Bypass Mode

Bypass mode is entered based on the voltage difference between the battery voltage and the internal Vref voltage. The threshold when DCDC enters bypass mode is $V_{IN} = V_{OUT} + 200$ mV. In bypass mode, the low R_{DS} on LDO PFET is active and the DCDC is running with 100% duty cycle, which allows very low voltage dropout and load current of up to 2.5 A.

Bypass mode can also be automatically entered when V_{con} exceeds 1.6 V and exits when V_{con} is below 1.4 V. When the BPEN pin is low, the FAN5910 runs in automatic bypass mode where bypass operation depends on V_{CON} . The BPEN pin set high can be used to ignore bypass flags and enable forced bypass mode. Bypass mode is active regardless of V_{CON} including overriding sleep mode when BPEN is high.

DC-DC – LDO-ASSIST

The LDO-assist function maintains output regulation when V_{IN} approaches V_{OUT} , enables fast transition times under heavy loads, and minimizes PCB space by enabling a smaller inductor to be employed by using the LDO to provide a portion of the necessary load current.

The LDO-assist function limits the maximum current that the DC-DC may supply by shunting current away from the DC-DC under heavy loads and high duty cycles. In addition, the LDO-assist enables a seamless transition into 100% duty cycle, ensuring both low output ripple and constant output regulation. Since the LDO-assist function limits the maximum current supplied by the DC-DC, PCB area is minimized by enabling a lower current capable, and thus smaller form factor, inductor to be used.

DC-DC – Sleep Mode

The Sleep Mode minimizes current while enabling rapid return to regulation. Sleep Mode is entered when V_{CON} is held below 70 mV for at least 40 μ s. In this mode, current consumption is reduced to under 50 μ A. Sleep Mode is exited after ~12 μ s when V_{CON} is set above 125 mV.

APPLICATION INFORMATION

Figure 26 illustrates the FAN5910 in a GSM / EDGE / WCDMA transmitter configuration, driving multiple GSM / EDGE and 3G/3.5G and 4G PAs. Figure 27 presents a timing diagram designed to meet GSM specifications.

DC Output Voltage

The output voltage is determined by V_{CON} provided by an external DAC or voltage reference:

$$V_{OUT} = 2.5 \times V_{CON} \quad (\text{eq. 1})$$

The FAN5910 provides regulated V_{OUT} only if V_{CON} falls within the typical range from 0.16 V to 1.44 V. This allows V_{OUT} to be adjusted between 0.4 V and 3.6 V. If V_{CON} is less than 0.16 V, V_{OUT} is clamped to 0.40 V. In Auto PFM/PWM Mode, the FAN5910 automatically switches between PFM and PWM. In Forced PWM Mode (MODE = 0), the FAN5910 automatically switches into PWM Mode.

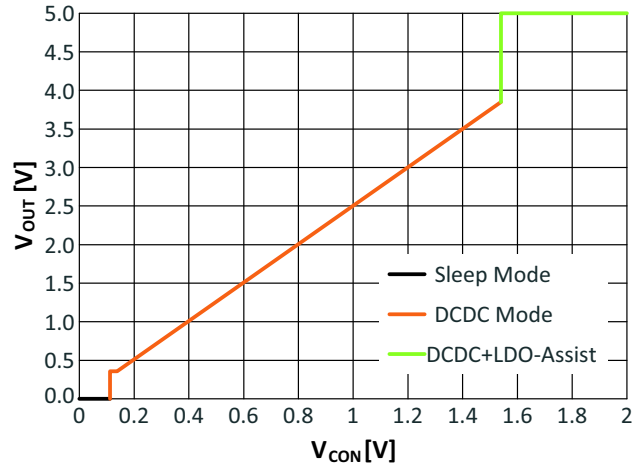


Figure 25. Output Voltage vs. Control Voltage

The FAN5910 is designed to support fast voltage transients when configured for GSM/EDGE applications (MODE=0). Figure 28 shows a timing diagram for WCDMA applications.

FAN5910

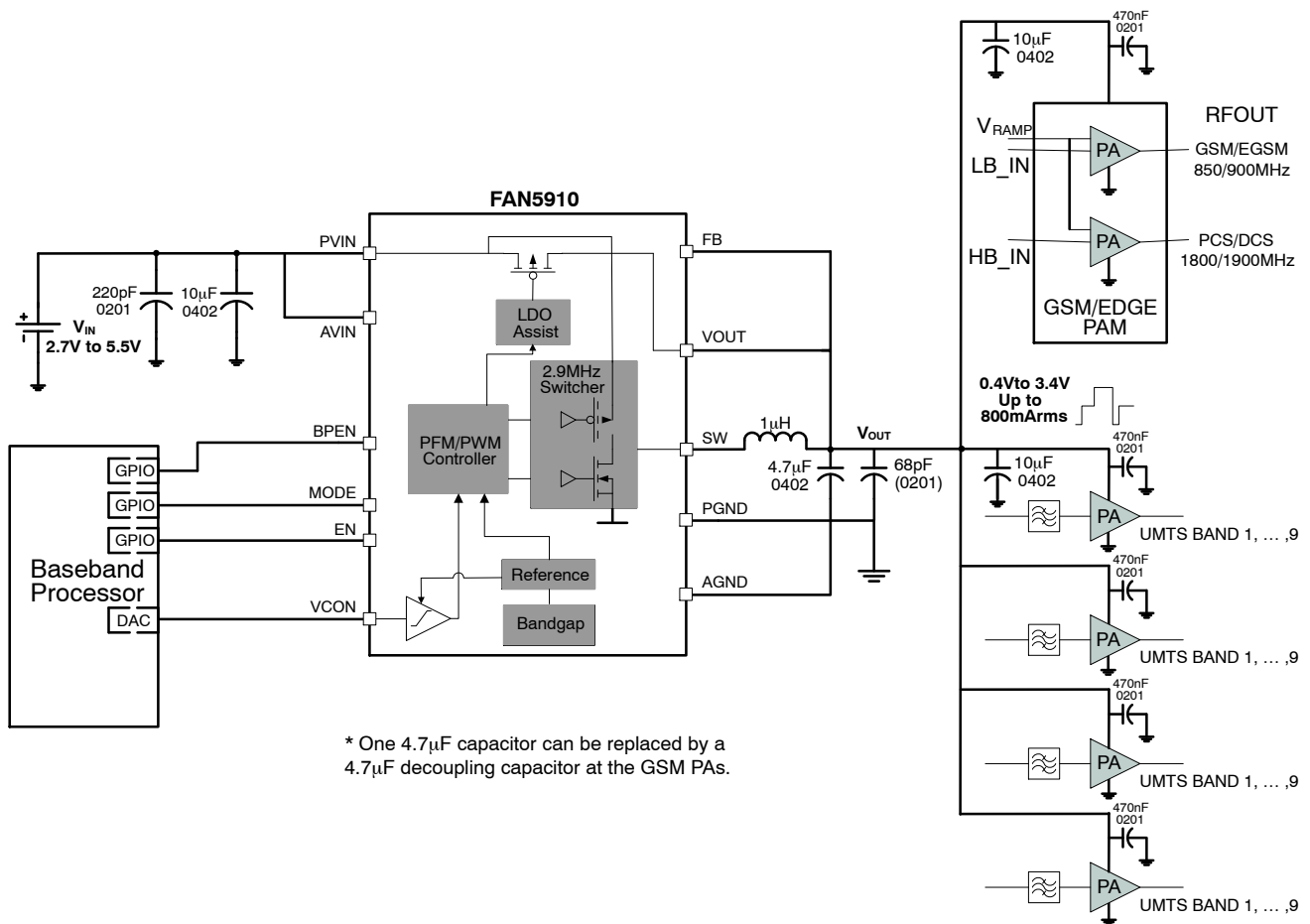


Figure 26. Typical Application Diagram with GSM/EDGE/WCDMA Transmitters

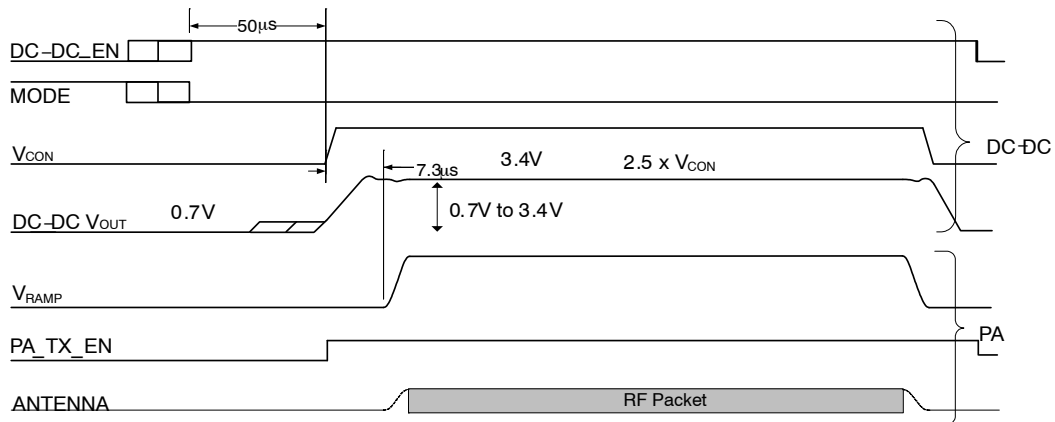


Figure 27. Timing Diagram for GSM/EDGE Transmitters

FAN5910

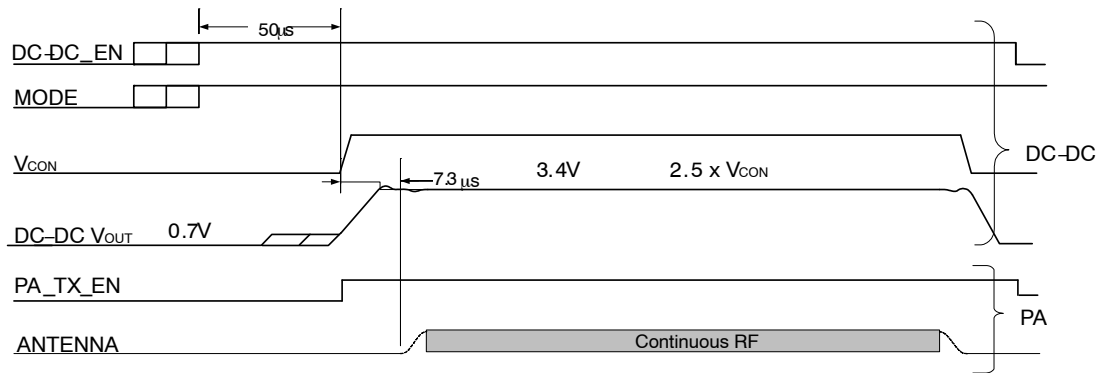


Figure 28. Timing Diagram for WCDMA Transmitters

Inductor Selection

The FAN5910 operates at 2.9 MHz switching frequency, allowing 1.0 µH or 1.5 µH inductors to be used in designs. For applications requiring the smallest possible PCB area, use a 1.0 µH 2012 inductor or a 1.0 µH 2016 inductor for optimum efficiency performance.

Table 5. RECOMMENDED INDUCTORS

| Inductor | Description |
|----------|--|
| L | 1.5 µH ±20%, 2.2 A, 2016 Case Size Murata DFE201610C-1R5M |
| | 1.0 µH ±20%, 2.2 A, 2016 Case Size Tokio: DFE201610R-H-1R0M |

Capacitor Selection

The minimum required output capacitor C_{OUT} should be one (1) 4.7 µF, 6.3 V, X5R with an ESR of 10 mΩ or lower and an ESL of 0.3 nH or lower in parallel after inductor L1. Larger case sizes result in increased loop parasitic inductance and higher noise. One 10 µF capacitor should be used as a decoupling capacitor at the GSM/EDGE PA V_{CC} pin and another 10 µF capacitor should be placed at V_{CC} pin of the 3G/4G PA.

A 6.8 pF capacitor may be added in parallel with C_{OUT} to reduce the capacitor's parasitic inductance.

Table 6. RECOMMENDED CAPACITOR VALUES

| Capacitor | Description |
|------------------|--|
| C _{IN} | 10 µF, 20%, X5R, 10 V, 0402 (1005 metric) Samsung CL05A106MP5NUNC |
| C _{OUT} | 4.7 µF, ±20%, X5R, 10 V, 0402 (1005 metric) Murata GRM155R60J475ME47D |

PCB Layout and Component Placement

- The key point in the placement is the power ground (PGND) connection shared between the FAN5910, C_{IN}, and C_{OUT}. This minimizes the parasitic inductance of the switching loop paths.
- Place the inductor away from the feedback pins to prevent unpredictable loop behavior.
- Ensure the traces are wide enough to handle the maximum current value, especially in Bypass Mode.
- Ensure the vias are able to handle the current density. Use filled vias if available.

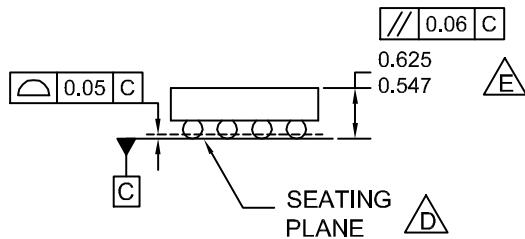
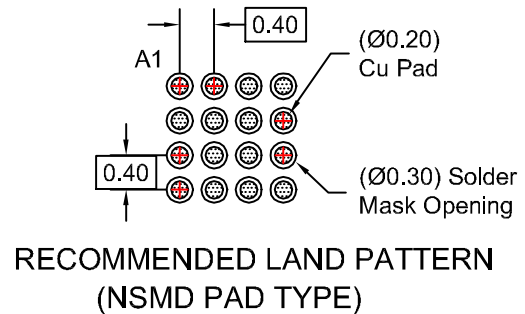
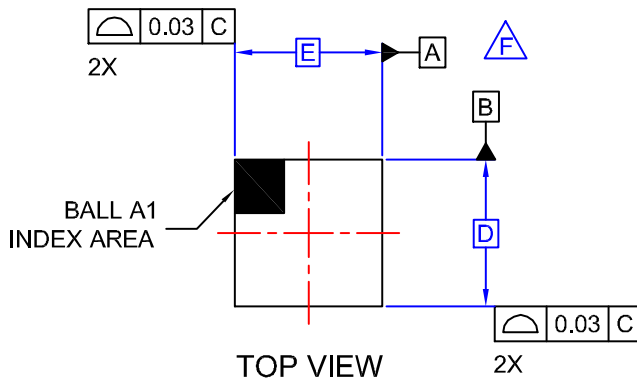
PRODUCT SPECIFIC DIMENSIONS

| D | E | X | Y | Unit |
|---------------|---------------|--------|--------|------|
| 1.615 ± 0.030 | 1.615 ± 0.030 | 0.2075 | 0.2075 | mm |

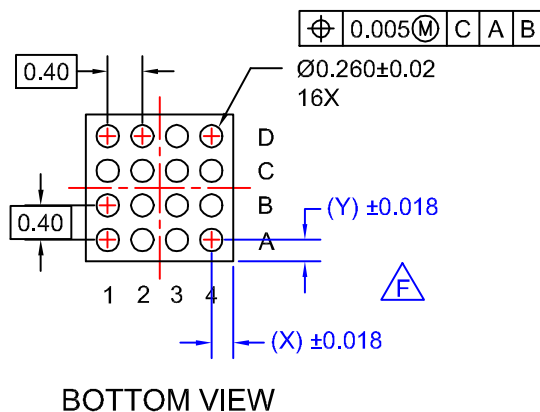
WLCSP16 1.615x1.615x0.586

CASE 567SD
ISSUE O

DATE 30 NOV 2016






SIDE VIEWS



BOTTOM VIEW

NOTES:

- A. NO JEDEC REGISTRATION APPLIES.
- B. DIMENSIONS ARE IN MILLIMETERS.
- C. DIMENSIONS AND TOLERANCE PER ASME Y14.5M, 1994.
-  DATUM C IS DEFINED BY THE SPHERICAL CROWNS OF THE BALLS.
-  PACKAGE NOMINAL HEIGHT IS 586 MICRONS ± 39 MICRONS (547-625 MICRONS).
-  FOR DIMENSIONS D, E, X, AND Y SEE PRODUCT DATASHEET.

| | | |
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