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LT6658

Precision Dual Output, High Current, Low Noise, Voltage Reference

FEATURES

- **Dual Output Tracking Reference**
  - Each Output Configurable to 6V
  - Output 1: 150mA Source/20mA Sink
  - Output 2: 50mA Source/20mA Sink
- **Low Drift:**
  - **A-Grade: 10ppm/°C Max**
  - **B-Grade: 20ppm/°C Max**
- **High Accuracy:**
  - **A-Grade: ±0.05% Max**
  - **B-Grade: ±0.1% Max**
- **Low Noise: 1.5ppm$_{P-P}$ (0.1Hz to 10Hz)**
- **Wide Operating Voltage Range to 36V**
- **Load Regulation: 0.25μV/mA**
- AC PSRR: 96dB at 10kHz
- Kelvin Sense Connection on Outputs
- Thermal Shutdown
- Separate Supply Pins for Each Output
- Available Output Voltage Options: 1.2V, 1.8V, 2.5V, 3V, 3.3V, 5V. All Options are Adjustable
- Available in Exposed Pad Package MSE16

APPLICATIONS

- Microcontroller or FPGA with ADC/DAC Applications
- Data Acquisition Systems
- Automotive Control and Monitoring
- Precision Low Noise Regulators
- Instrumentation and Process Control

DESCRIPTION

The LT®6658 is a family of precision dual output references combining the performance of a precision voltage reference and a linear regulator that we call the Refulator™. Both outputs are ideal for driving the reference inputs of high resolution ADCs and DACs, even with heavy loading, while simultaneously powering microcontrollers and other circuitry. Both outputs have the same precision specifications and track each other over temperature and load. Each output can be configured with external resistors to give an output voltage up to 6V.

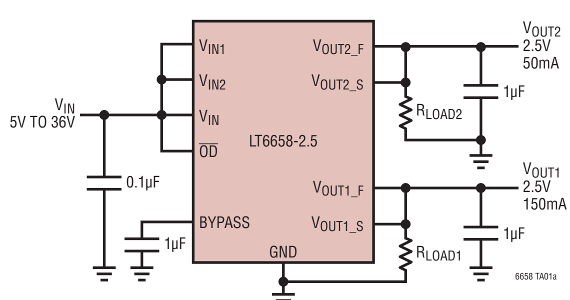
Using Kelvin connections, the LT6658 typically has 0.1ppm/mA load regulation with up to 150mA load current. A noise reduction pin is available to band-limit and lower the total integrated noise.

Separate supply pins are provided for each output, providing an option to reduce power consumption and isolate the buffer amplifiers. The outputs have excellent supply rejection and are stable with 1μF to 50μF capacitors.

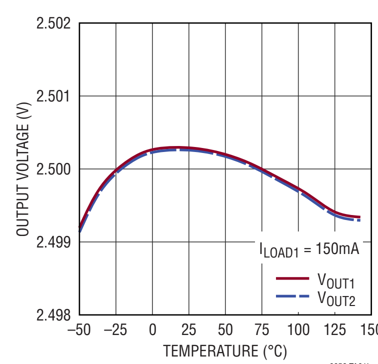
The LT6658 is available in a 16-lead MSOP with an exposed pad for thermal management. Short circuit and thermal protection help to prevent thermal overstress.

TYPICAL APPLICATION

Precision Dual Output 2.5V Reference and Supply



Output Voltage Temperature Drift Both Outputs



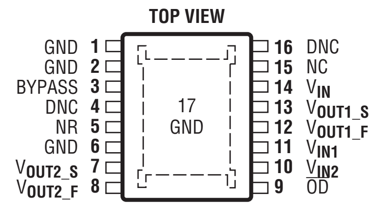
Rev B

ABSOLUTE MAXIMUM RATINGS

(Note 1)

Supply Voltages
 V_{IN}, V_{IN1}, V_{IN2} to GND............................–0.3V to 38V
Input Voltages
 $\overline{OD}$ to GND ....–0.3V to 38V
 V_{OUT1_S}, V_{OUT2_S}, NR, BYPASS to GND..–0.3V to 6V
Output Voltages
 V_{OUT1_F}, V_{OUT2_F} to GND........................–0.3V to 6V
Input Current
 BYPASS ....±10mA
Output Short-Circuit Duration .... Indefinite
Specified Temperature Range
 I-Grade..–40°C to 85°C
 H-Grade ....–40°C to 125°C
Operating Junction Temperature Range. –55°C to 150°C
Storage Temperature Range (Note 2)..... –65°C to 150°C
Lead Temperature (Soldering, 10 sec)
 (Note 3) ....300°C

PIN CONFIGURATION



MSE PACKAGE
16-LEAD PLASTIC MSOP
T_{JMAX} = 150°C, θ_{JC} = 10°C/W, θ_{JA} = 35°C/W
DNC: CONNECTED INTERNALLY
DO NOT CONNECT EXTERNAL CIRCUITRY TO THESE PINS
EXPOSED PAD (PIN 17) IS GND, MUST BE SOLDERED TO PCB

ORDER INFORMATION

TUBE	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	SPECIFIED JUNCTION TEMPERATURE RANGE
LT6658AIMSE-1.2#PBF	LT6658AIMSE-1.2#TRPBF	665812	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-1.2#PBF	LT6658BIMSE-1.2#TRPBF	665812	16-Lead Plastic MSOP	–40°C to 85°C
LT6658AHMSE-1.2#PBF	LT6658AHMSE-1.2#TRPBF	665812	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-1.2#PBF	LT6658BHMSE-1.2#TRPBF	665812	16-Lead Plastic MSOP	–40°C to 125°C
LT6658AIMSE-1.8#PBF	LT6658AIMSE-1.8#TRPBF	665818	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-1.8#PBF	LT6658BIMSE-1.8#TRPBF	665818	16-Lead Plastic MSOP	–40°C to 85°C
LT6658AHMSE-1.8#PBF	LT6658AHMSE-1.8#TRPBF	665818	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-1.8#PBF	LT6658BHMSE-1.8#TRPBF	665818	16-Lead Plastic MSOP	–40°C to 125°C
LT6658AIMSE-2.5#PBF	LT6658AIMSE-2.5#TRPBF	665825	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-2.5#PBF	LT6658BIMSE-2.5#TRPBF	665825	16-Lead Plastic MSOP	–40°C to 85°C
LT6658AHMSE-2.5#PBF	LT6658AHMSE-2.5#TRPBF	665825	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-2.5#PBF	LT6658BHMSE-2.5#TRPBF	665825	16-Lead Plastic MSOP	–40°C to 125°C
LT6658AIMSE-3#PBF	LT6658AIMSE-3#TRPBF	66583	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-3#PBF	LT6658BIMSE-3#TRPBF	66583	16-Lead Plastic MSOP	–40°C to 85°C
LT6658AHMSE-3#PBF	LT6658AHMSE-3#TRPBF	66583	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-3#PBF	LT6658BHMSE-3#TRPBF	66583	16-Lead Plastic MSOP	–40°C to 125°C
LT6658AIMSE-3.3#PBF	LT6658AIMSE-3.3#TRPBF	665833	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-3.3#PBF	LT6658BIMSE-3.3#TRPBF	665833	16-Lead Plastic MSOP	–40°C to 85°C

ORDER INFORMATION

TUBE	TAPE AND REEL	PART MARKING*	PACKAGE DESCRIPTION	SPECIFIED JUNCTION TEMPERATURE RANGE
LT6658AHMSE-3.3#PBF	LT6658AHMSE-3.3#TRPBF	665833	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-3.3#PBF	LT6658BHMSE-3.3#TRPBF	665833	16-Lead Plastic MSOP	–40°C to 125°C
LT6658AIMSE-5#PBF	LT6658AIMSE-5#TRPBF	66585	16-Lead Plastic MSOP	–40°C to 85°C
LT6658BIMSE-5#PBF	LT6658BIMSE-5#TRPBF	66585	16-Lead Plastic MSOP	–40°C to 85°C
LT6658AHMSE-5#PBF	LT6658AHMSE-5#TRPBF	66585	16-Lead Plastic MSOP	–40°C to 125°C
LT6658BHMSE-5#PBF	LT6658BHMSE-5#TRPBF	66585	16-Lead Plastic MSOP	–40°C to 125°C

*The temperature grade is identified by a label on the shipping container.

Consult ADI Marketing for parts specified with wider operating temperature ranges. Parts ending with PBF are RoHS and WEEE compliant.

Tape and reel specifications. Some packages are available in 500 unit reels through designated sales channels with #TRMPBF suffix.

AVAILABLE OPTIONS

OUTPUT VOLTAGE	INITIAL ACCURACY	TEMPERATURE COEFFICIENT	ORDER PART NUMBER **	SPECIFIED JUNCTION TEMPERATURE RANGE
1.200V	0.05%	10ppm/°C	LT6658AIMSE-1.2	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-1.2	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-1.2	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-1.2	–40°C to 125°C
1.800V	0.05%	10ppm/°C	LT6658AIMSE-1.8	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-1.8	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-1.8	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-1.8	–40°C to 125°C
2.500V	0.05%	10ppm/°C	LT6658AIMSE-2.5	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-2.5	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-2.5	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-2.5	–40°C to 125°C
3.000V	0.05%	10ppm/°C	LT6658AIMSE-3	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-3	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-3	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-3	–40°C to 125°C
3.300V	0.05%	10ppm/°C	LT6658AIMSE-3.3	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-3.3	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-3.3	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-3.3	–40°C to 125°C
5.000V	0.05%	10ppm/°C	LT6658AIMSE-5	–40°C to 85°C
	0.1%	20ppm/°C	LT6658BIMSE-5	–40°C to 85°C
	0.05%	10ppm/°C	LT6658AHMSE-5	–40°C to 125°C
	0.1%	20ppm/°C	LT6658BHMSE-5	–40°C to 125°C

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full specified temperature range, otherwise specifications are at $T_A = 25°C$. $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1,2\_F} + 2.5V$, $C_{OUT1,2} = 1.3µF$, $I_{LOAD} = 0$, unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Voltage Accuracy	LT6658A		–0.05		0.05	%
	LT6658B		–0.1		0.1	%
	LT6658AI	●	–0.175		0.175	%
	LT6658BI	●	–0.35		0.35	%
	LT6658AH	●	–0.215		0.215	%
	LT6658BH	●	–0.43		0.43	%
Output Voltage Temperature Coefficient (Note 4)	LT6658A	●		3	10	ppm/°C
	LT6658B	●		10	20	ppm/°C
Line Regulation (Note 5)	LT6658-1.2, LT6658-1.8			2.0	5.0	ppm/V
	$4.5V \le V_{IN} \le 36V$, $V_{IN} = V_{IN1} = V_{IN2}$	●			6.0	ppm/V
	LT6658-2.5, LT6658-3.3, LT6658-5			1.4	4.5	ppm/V
	$V_{OUT} + 2.5V \le V_{IN} \le 36V$, $V_{IN} = V_{IN1} = V_{IN2}$	●			5	ppm/V
Load Regulation (Note 5)	Output 1 Sourcing, ΔI_{LOAD} = 0mA to 150mA			0.25	1.25	µV/mA
		●			2.0	µV/mA
	Output 2 Sourcing, ΔI_{LOAD} = 0mA to 50mA (Note 6)			0.25	3.25	µV/mA
		●			3.75	µV/mA
	Output 1 Sinking, ΔI_{LOAD} = 0mA to 20mA			0.25	3.2	µV/mA
		●			3.75	µV/mA
	Output 2 Sinking, ΔI_{LOAD} = 0mA to 20mA			0.25	3.2	µV/mA
		●			3.75	µV/mA
V_{IN} Minimum Voltage	LT6658-1.2, LT6658-1.8, LT6658-2.5			3.5	4.0	V
	ΔV_{OUT} = 0.1%, I_{OUT} = 0mA, $V_{IN1} = V_{IN2}$ = 4.5V	●			4.5	V
	LT6658-3			4.2	4.5	V
	ΔV_{OUT} = 0.1%, I_{OUT} = 0mA, $V_{IN1} = V_{IN2}$ = 5.5V	●			5.0	V
	LT6658-3.3			4.5	4.8	V
	ΔV_{OUT} = 0.1%, I_{OUT} = 0mA, $V_{IN1} = V_{IN2}$ = 5.8V	●			5.3	V
	LT6658-5			5.2	7.0	V
	ΔV_{OUT} = 0.1%, I_{OUT} = 0mA, $V_{IN1} = V_{IN2}$ = 7.5V	●			7.5	V
V_{IN1} Dropout Voltage	LT6658-1.2, LT6658-1.8					
	ΔV_{OUT1} = 0.1%, I_{OUT1} = 0mA, $V_{IN} = V_{IN2} = V_{OUT}$ + 4.5V			2.0	2.3	V
	ΔV_{OUT1} = 0.1%, I_{OUT1} = 150mA, $V_{IN} = V_{IN2} = V_{OUT}$ + 4.5V	●		2.3	2.5	V
	LT6658-2.5, LT6658-3, LT6658-3.3, LT6658-5					
	ΔV_{OUT1} = 0.1%, I_{OUT1} = 0mA, $V_{IN} = V_{IN2} = V_{OUT}$ + 2.5V			2.0	2.3	V
	ΔV_{OUT1} = 0.1%, I_{OUT1} = 150mA, $V_{IN} = V_{IN2} = V_{OUT}$ + 2.5V	●		2.2	2.5	V
V_{IN2} Dropout Voltage	LT6658-1.2, LT6658-1.8					
	ΔV_{OUT2} = 0.1%, I_{OUT2} = 0mA, $V_{IN} = V_{IN1} = V_{OUT}$ + 4.5V			1.8	2.2	V
	ΔV_{OUT2} = 0.1%, I_{OUT2} = 50mA, $V_{IN} = V_{IN1} = V_{OUT}$ + 4.5V	●		2.0	2.5	V
	LT6658-2.5, LT6658-3, LT6658-3.3, LT6658-5					
	ΔV_{OUT2} = 0.1%, I_{OUT2} = 0mA, $V_{IN} = V_{IN1} = V_{OUT}$ + 2.5V			1.8	2.2	V
	ΔV_{OUT2} = 0.1%, I_{OUT2} = 50mA, $V_{IN} = V_{IN1} = V_{OUT}$ + 2.5V	●		2.0	2.5	V
Supply Current	LT6658-1.2, $V_{\overline{OD}}$ = 2.0V, No Load	●		2.0	3.2	mA
	LT6658-1.8, $V_{\overline{OD}}$ = 2.0V, No Load	●		2.5	3.6	mA
	LT6658-2.5, LT6658-3, LT6658-3.3, LT6658-5, $V_{\overline{OD}}$ = 2.0V, No Load	●		1.9	3.0	mA
	$V_{\overline{OD}}$ = 0.8V, No Load					
	LT6658-1.2	●		0.7	1.1	mA
	LT6658-1.8	●		1.3	1.8	mA
	LT6658-2.5	●		1.0	1.5	mA
	LT6658-3	●		1.2	1.8	mA
	LT6658-3.3	●		1.3	2	mA
	LT6658-5	●		1.7	2.5	mA

Rev B

ELECTRICAL CHARACTERISTICS

The ● denotes the specifications which apply over the full operating temperature range, otherwise specifications are at T_A = 25°C. $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1,2\_F}$ + 2.5V, $C_{OUT1,2}$ = 1.3µF, I_{LOAD} = 0, unless otherwise noted.

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
Output Short-Circuit Current	Short V_{OUT1_F} to 400mV (Note 11) Short V_{OUT2_F} to 400mV (Note 11)	● ●	170 65	270 120		mA mA
Output Noise Voltage (Note 7)	0.1Hz ≤ f ≤ 10Hz LT6658-1.2 LT6658-1.8 LT6658-2.5 LT6658-3 LT6658-3.3 LT6658-5			 0.8 1.0 1.5 1.6 1.7 2.2		 ppm_{P-P} ppm_{P-P} ppm_{P-P} ppm_{P-P} ppm_{P-P} ppm_{P-P}
	10Hz ≤ f ≤ 1kHz, C_{OUT} = 1µF, C_{NR} = 10µF, I_{LOAD} = Full Current (Note 10) 10Hz ≤ f ≤ 1kHz, C_{OUT} = 1µF, C_{NR} = OPEN, I_{LOAD} = Full Current (Note 10) Frequency = 10kHz, C_{OUT1} = 1µF, C_{NR} = 10µF, I_{LOAD} = Full Current (Note 10)			0.5 2 8		ppm_{RMS} ppm_{RMS} $nV/\sqrt{Hz}$
Output Voltage Tracking	Tracking = Output 1 – Output 2			0.9		µV/°C
V_{OUT1_S}, V_{OUT2_S} Pin Current	Unity Gain			135		nA
$\overline{OD}$ Threshold Voltage	Logic High Input Voltage Logic Low Input Voltage	● ●	2 		 0.8	V V
$\overline{OD}$ Pin Current	$V_{\overline{OD}}$ = 0V $V_{\overline{OD}}$ = 36V	● ●		30 0.3	45 1.5	µA µA
Ripple Rejection	$V_{IN1} = V_{OUT1}$ + 3V, V_{RIPPLE} = 0.5V_{P-P}, f_{RIPPLE} = 120Hz, I_{LOAD} = 150mA, C_{OUT1} = 1µF, C_{NR} = 10µF $V_{IN2} = V_{OUT2}$ + 3V, V_{RIPPLE} = 0.5V_{P-P}, f_{RIPPLE} = 120Hz, I_{LOAD} = 50mA, C_{OUT2} = 1µF, C_{NR} = 10µF			107 107		dB dB
Turn-On Time	0.1% Settling, C_{LOAD} = 1µF			160		µs
Long Term Drift (Note 8)				120		$ppm/\sqrt{kHr}$
Thermal Hysteresis (Note 9)	ΔT = –40°C to 85°C ΔT = –40°C to 125°C			30 45		ppm ppm

Note 1: Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. Exposure to any Absolute Maximum Rating condition for extended periods may affect device reliability and lifetime.

Note 2: Thermal hysteresis can occur during storage at extreme temperatures.

Note 3: The stated temperature is typical for soldering of the leads during manual rework. For detailed IR reflow recommendations, refer to the Applications Information section.

Note 4: Temperature coefficient is measured by dividing the maximum change in output voltage by the specified temperature range.

Note 5: Line and load regulation are measured on a pulse basis for specified input voltage or load current ranges. Output changes due to die temperature change must be taken into account separately.

Note 6: V_{OUT2} load regulation specification is limited by practical automated test resolution. Please refer to the Typical Performance Characteristics section for more information regarding actual typical performance.

Note 7: Peak-to-peak noise is measured with a 1-pole highpass filter at 0.1Hz and 2-pole lowpass filter at 10Hz. The unit is enclosed in a still-air environment to eliminate thermocouple effects on the leads. The test time is 10 seconds. RMS noise is measured on a spectrum analyzer in a shielded environment where the intrinsic noise of the instrument is removed to determine the actual noise of the device.

Note 8: Long-term stability typically has a logarithmic characteristic and therefore, changes after 1000 hours tend to be much smaller than before that time. Total drift in the second thousand hours is normally less than one third that of the first thousand hours with a continuing trend toward reduced drift with time. Long-term stability will also be affected by differential stresses between the IC and the board material created during board assembly.

Note 9: Hysteresis in output voltage is created by package stress that differs depending on whether the IC was previously at a higher or lower temperature. Output voltage is always measured at 25°C, but the IC is cycled to the hot or cold temperature limit before successive measurements. Hysteresis measures the maximum output change for the averages of three hot or cold temperature cycles. For instruments that are stored at well controlled temperatures (within 20 or 30 degrees of operational temperature), it's usually not a dominant error source. Typical hysteresis is the worst-case of 25°C to cold to 25°C or 25°C to hot to 25°C, preconditioned by one thermal cycle.

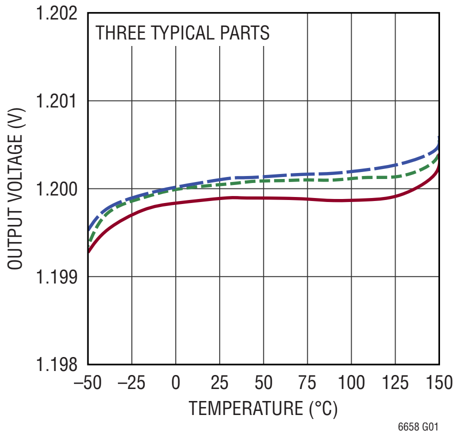
Note 10: The full current for I_{LOAD} is 150mA and 50mA for Output 1 and Output 2, respectively.

Note 11: When the output voltage is less than 400mV, the output current may foldback to less than the rated output current. Once the output is released, the rated output current will be available.

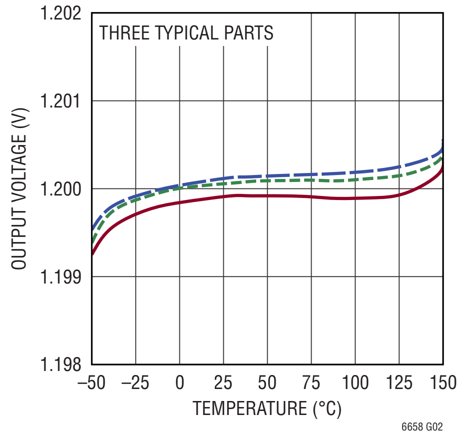
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

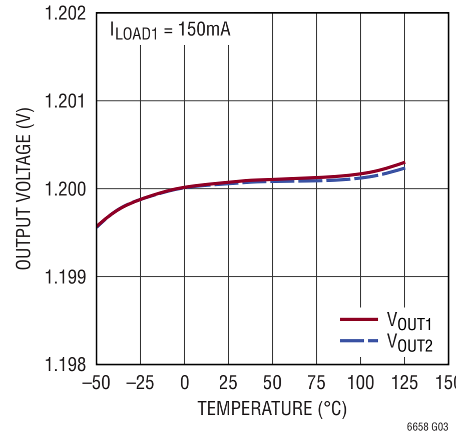
1.2V V_{OUT1} Output Voltage Temperature Drift



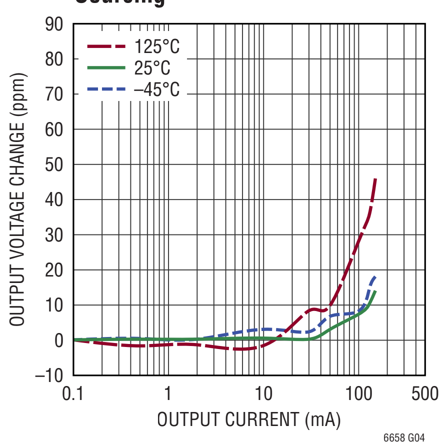
1.2V V_{OUT2} Output Voltage Temperature Drift



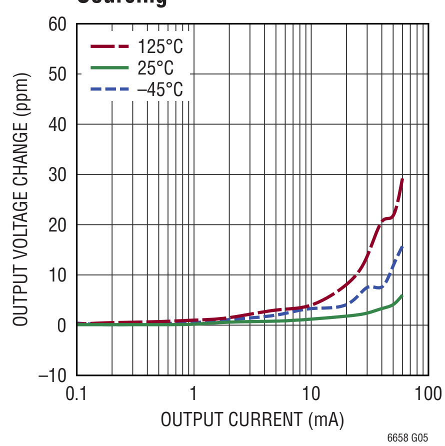
1.2V V_{OUT1} and V_{OUT2} Output Voltage vs Temperature with 150mA Load on V_{OUT1}



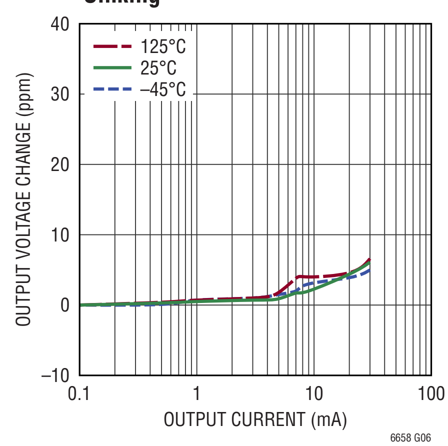
1.2V V_{OUT1} Load Regulation, Sourcing



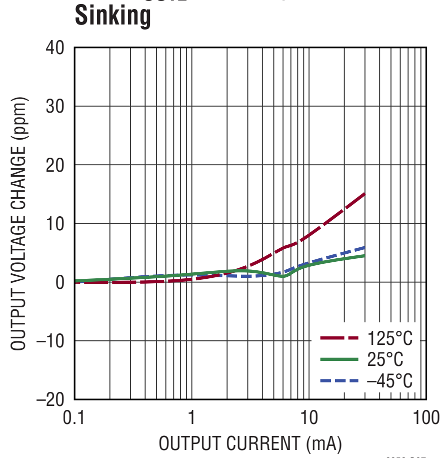
1.2V V_{OUT2} Load Regulation, Sourcing



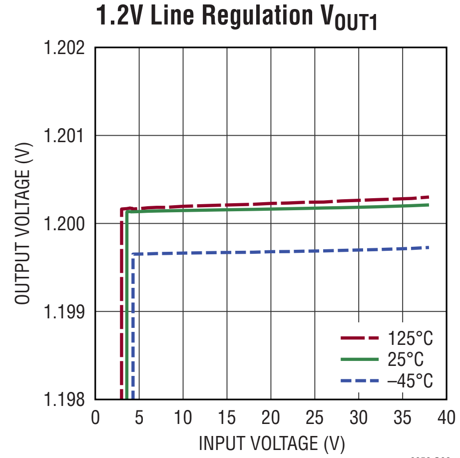
1.2V V_{OUT1} Load Regulation, Sinking



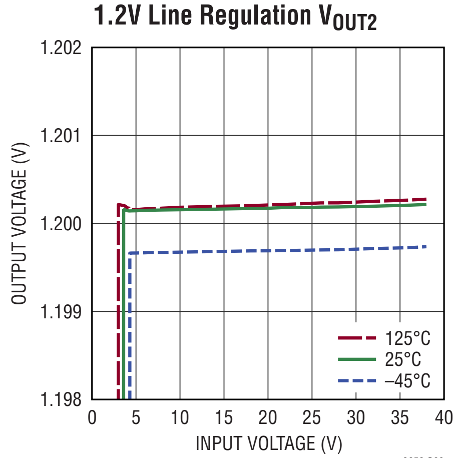
1.2V V_{OUT2} Load Regulation, Sinking



1.2V Line Regulation V_{OUT1}



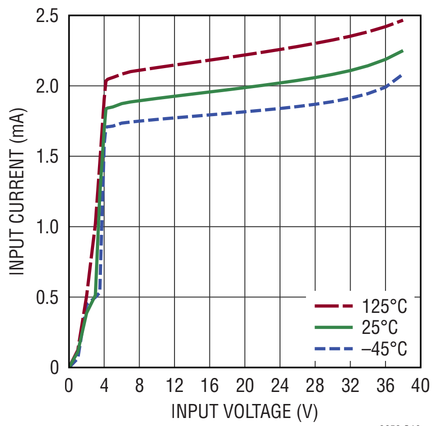
1.2V Line Regulation V_{OUT2}



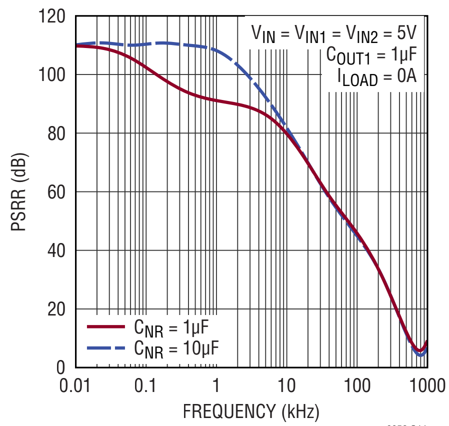
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

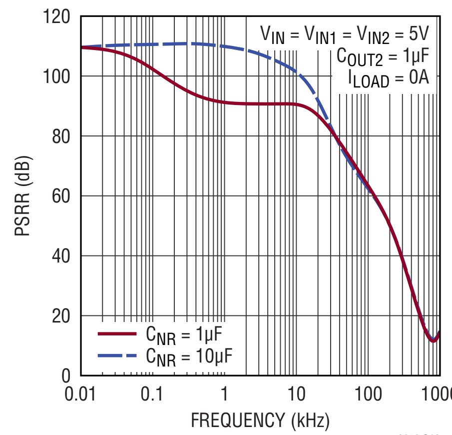
1.2V Supply Current vs Input Voltage



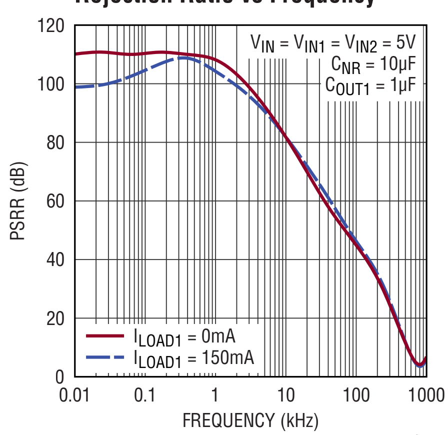
1.2V V_{OUT1} Power Supply Rejection Ratio vs Frequency



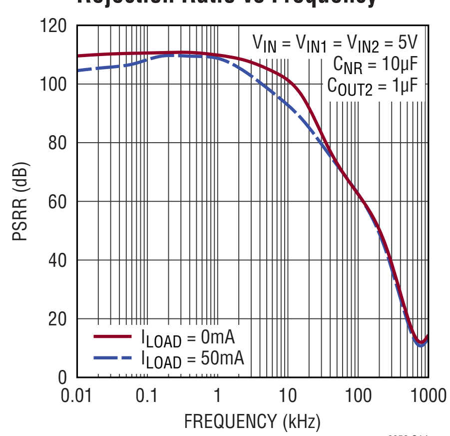
1.2V V_{OUT2} Power Supply Rejection Ratio vs Frequency



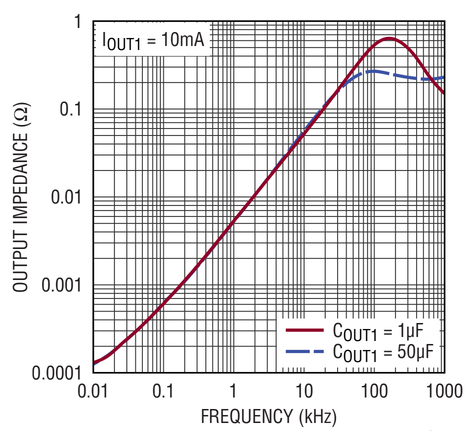
1.2V V_{OUT1} Power Supply Rejection Ratio vs Frequency



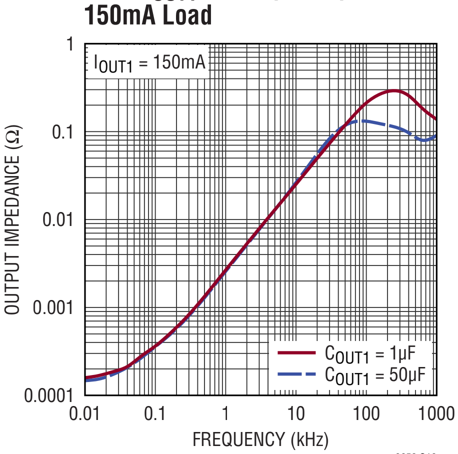
1.2V V_{OUT2} Power Supply Rejection Ratio vs Frequency



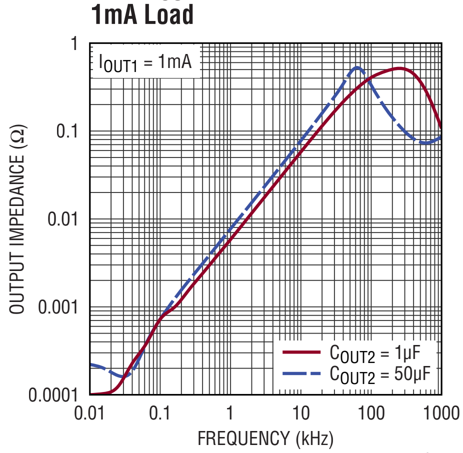
1.2V V_{OUT1} AC Output Impedance 10mA Load



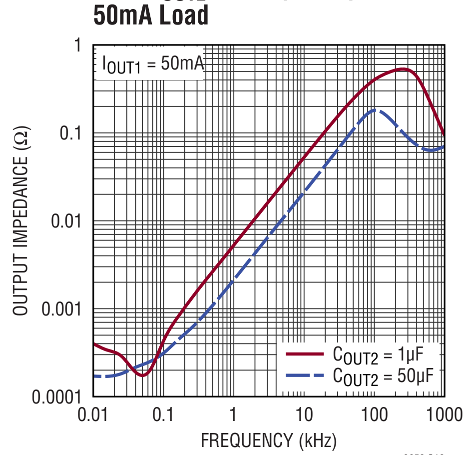
1.2V V_{OUT1} AC Output Impedance 150mA Load



1.2V V_{OUT2} AC Output Impedance 1mA Load



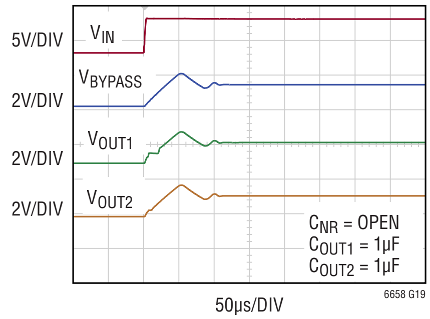
1.2V V_{OUT2} AC Output Impedance 50mA Load



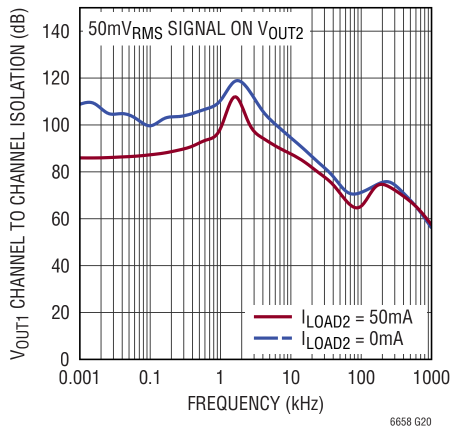
TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25°C$, $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1\_F} + 2.5V = V_{OUT2\_F} + 2.5V$ except LT6658-1.2 where $V_{IN} = V_{IN1} = V_{IN2} = 4.5V$, $C_{OUT1} = C_{OUT2} = 1µF$, $I_{LOAD} = 0mA$, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

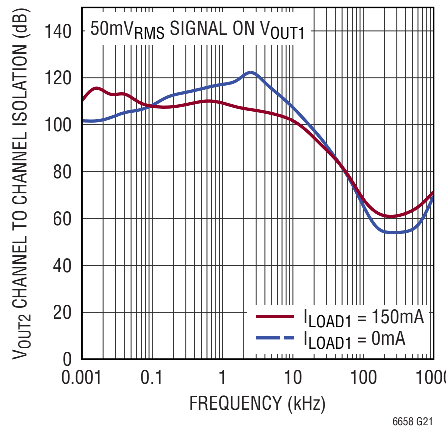
1.2V Turn-On Characteristic



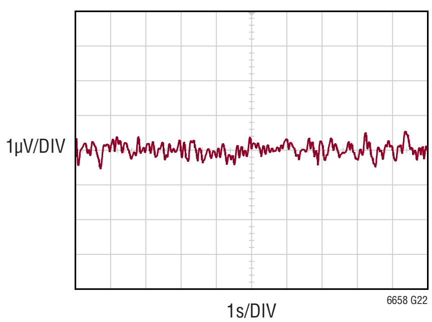
1.2V Channel to Channel Load Isolation V_{OUT2} to V_{OUT1}



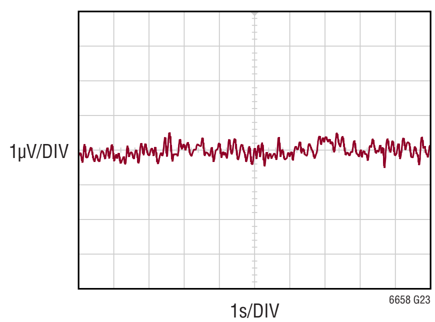
1.2V Channel to Channel Load Isolation V_{OUT1} to V_{OUT2}



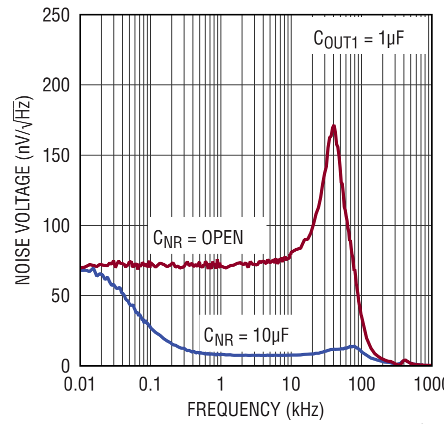
1.2V V_{OUT1} Output Noise 0.1Hz to 10Hz



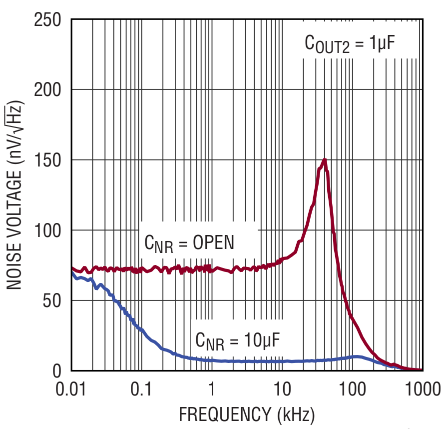
1.2V V_{OUT2} Output Noise 0.1Hz to 10Hz



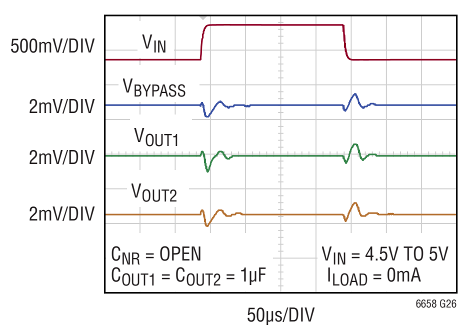
1.2V V_{OUT1} Output Voltage Noise Spectrum I_{LOAD} = 0mA



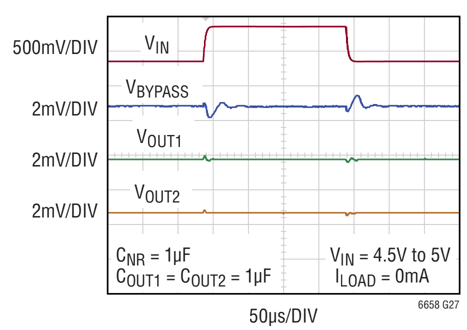
1.2V V_{OUT2} Output Voltage Noise Spectrum I_{LOAD} = 0mA



1.2V Line Transient Response



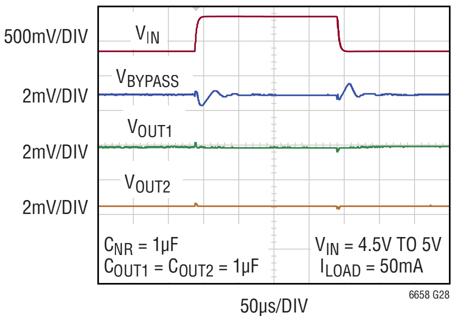
1.2V Line Transient Response



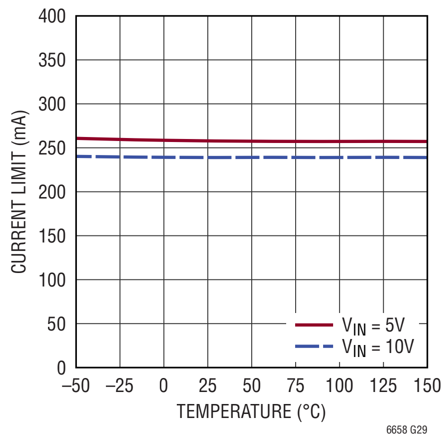
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

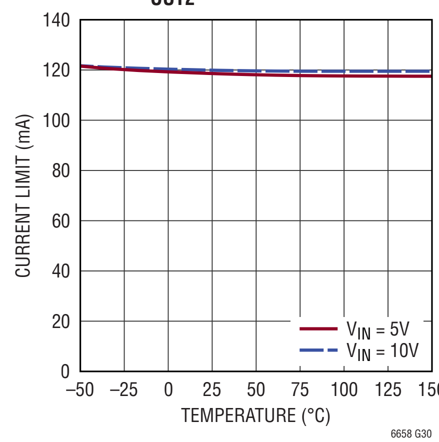
1.2V Line Transient Response



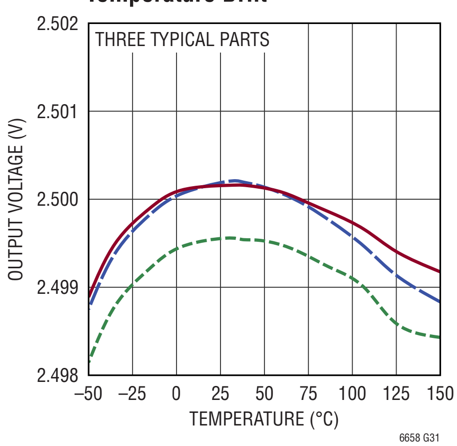
1.2V V_{OUT1} Current Limit



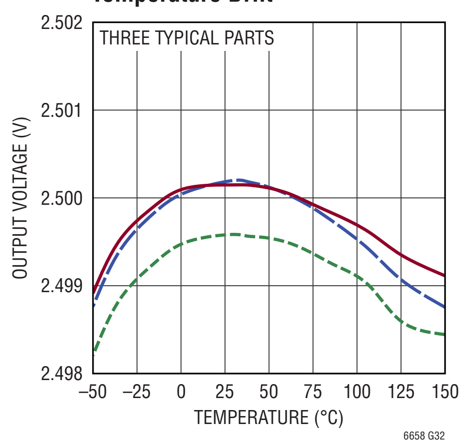
1.2V V_{OUT2} Current Limit



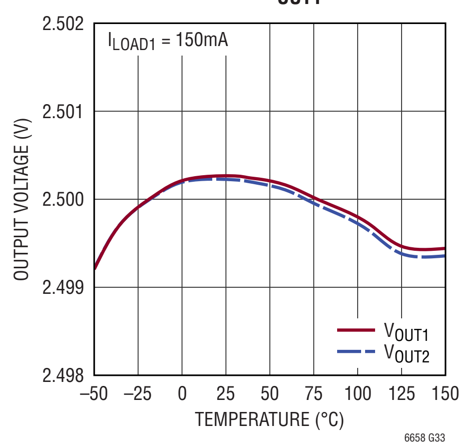
2.5V V_{OUT1} Output Voltage Temperature Drift



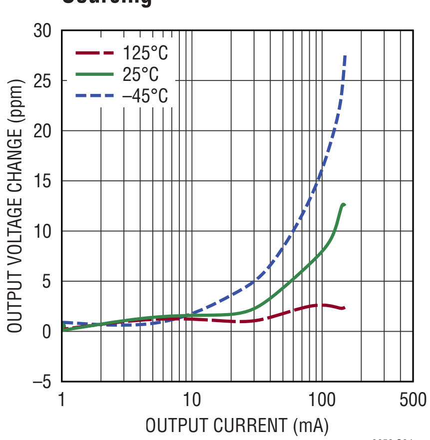
2.5V V_{OUT2} Output Voltage Temperature Drift



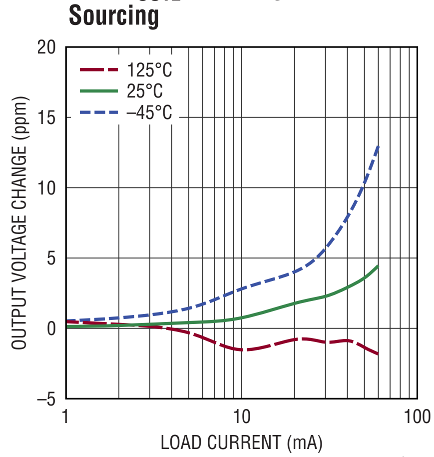
2.5V V_{OUT1} and V_{OUT2} Output Voltage vs Temperature with 150mA Load on V_{OUT1}



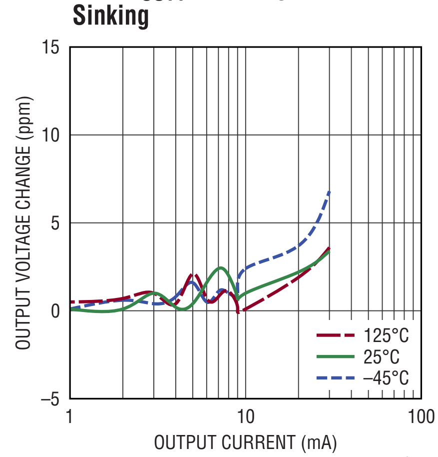
2.5V V_{OUT1} Load Regulation, Sourcing



2.5V V_{OUT2} Load Regulation, Sourcing



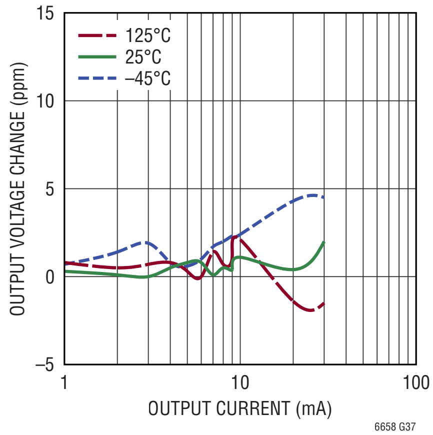
2.5V V_{OUT1} Load Regulation, Sinking



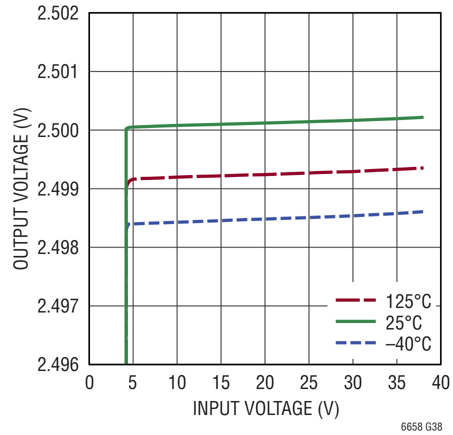
TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25°C$, $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1\_F} + 2.5V = V_{OUT2\_F} + 2.5V$ except LT6658-1.2 where $V_{IN} = V_{IN1} = V_{IN2} = 4.5V$, $C_{OUT1} = C_{OUT2} = 1µF$, $I_{LOAD} = 0mA$, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

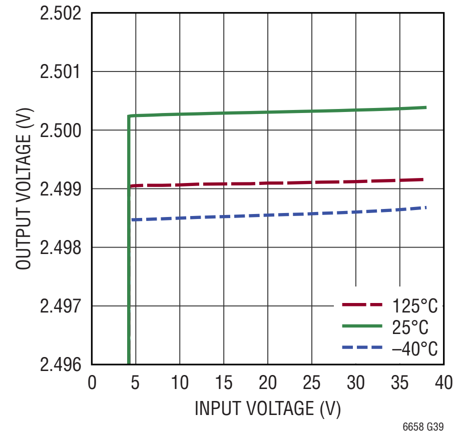
2.5V V_{OUT2} Load Regulation, Sinking



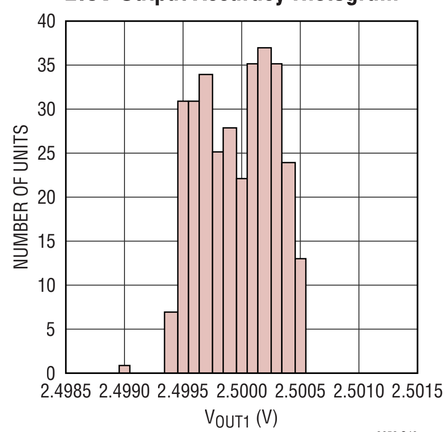
2.5V Line Regulation V_{OUT1}



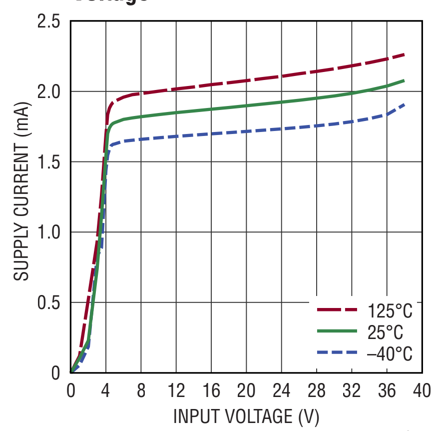
2.5V Line Regulation V_{OUT2}



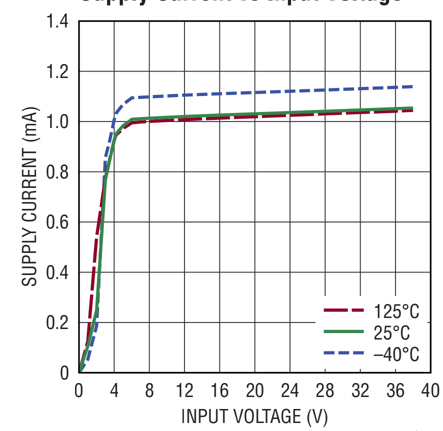
2.5V Output Accuracy Histogram



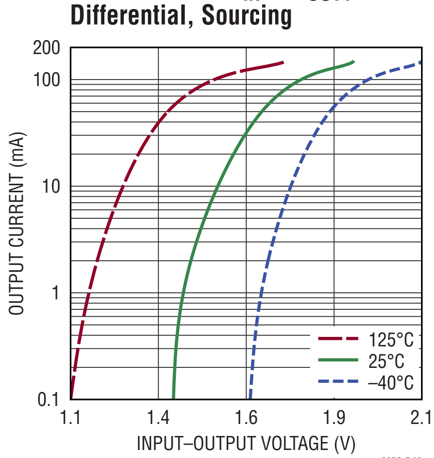
2.5V Supply Current vs Input Voltage



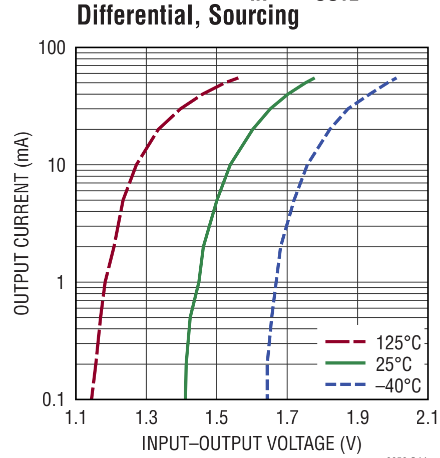
2.5V Output Disable ($\overline{OD}$) Low Supply Current vs Input Voltage



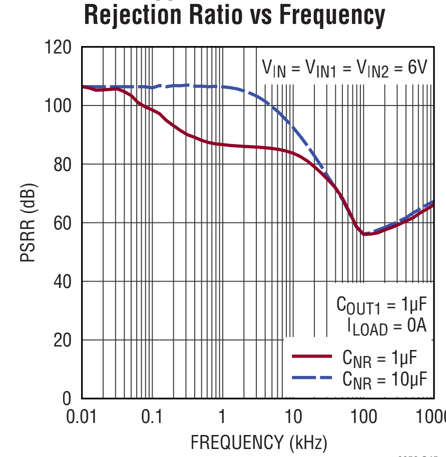
2.5V Minimum V_{IN} to V_{OUT1} Differential, Sourcing



2.5V Minimum V_{IN} to V_{OUT2} Differential, Sourcing



2.5V V_{OUT1} Power Supply Rejection Ratio vs Frequency

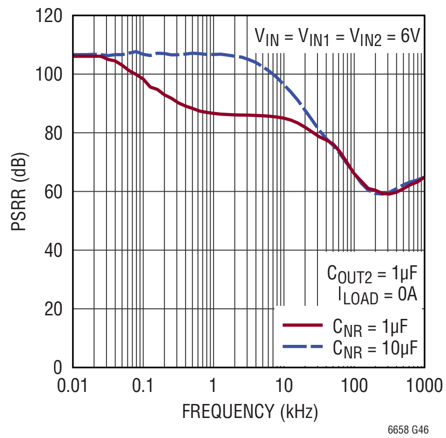


Rev B

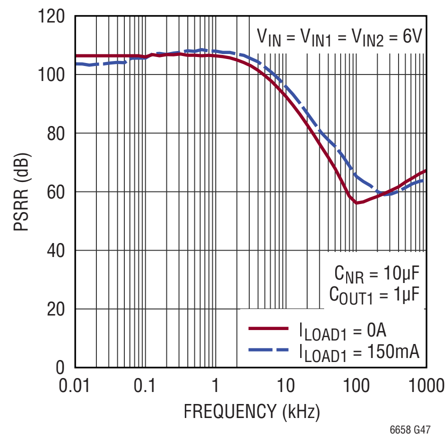
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

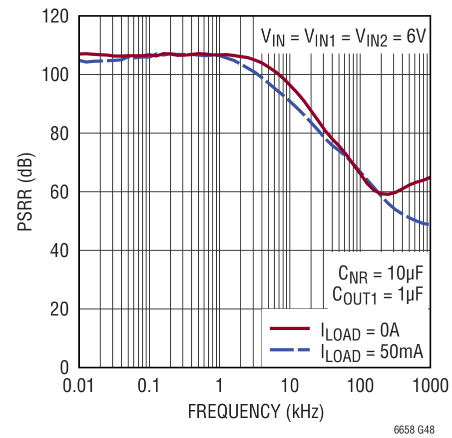
2.5V V_{OUT2} Power Supply Rejection Ratio vs Frequency



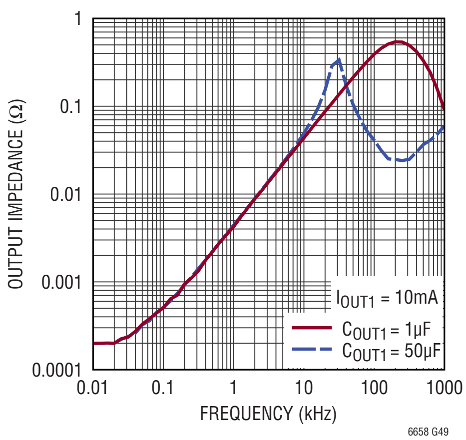
2.5V V_{OUT1} Power Supply Rejection Ratio vs Frequency



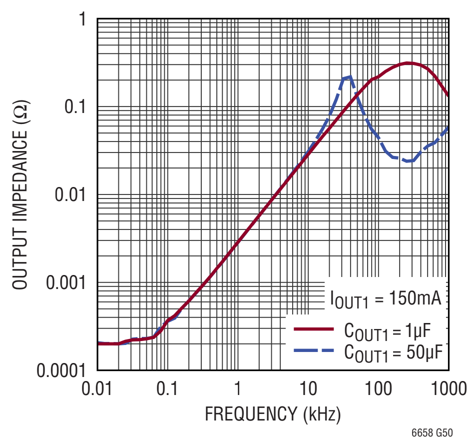
2.5V V_{OUT2} Power Supply Rejection Ratio vs Frequency



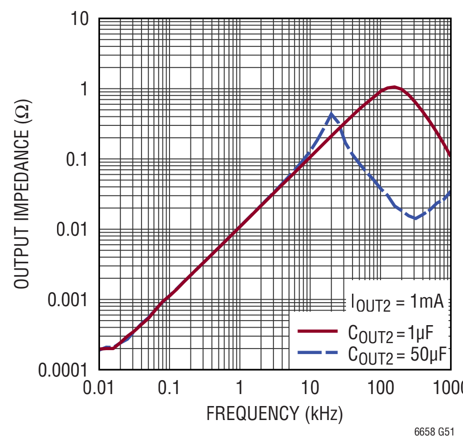
2.5V V_{OUT1} AC Output Impedance 10mA Load



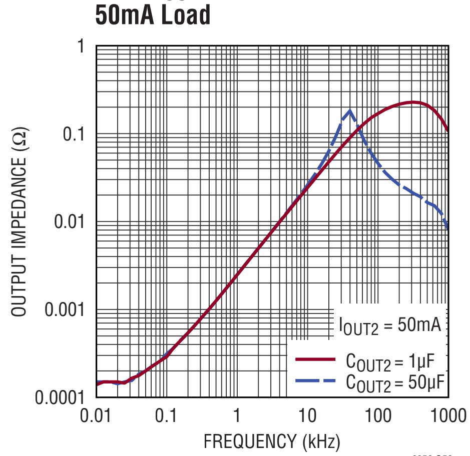
2.5V V_{OUT1} AC Output Impedance 150mA Load



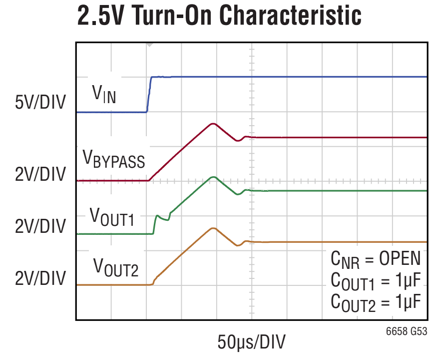
2.5V V_{OUT2} AC Output Impedance 1mA Load



2.5V V_{OUT2} AC Output Impedance 50mA Load



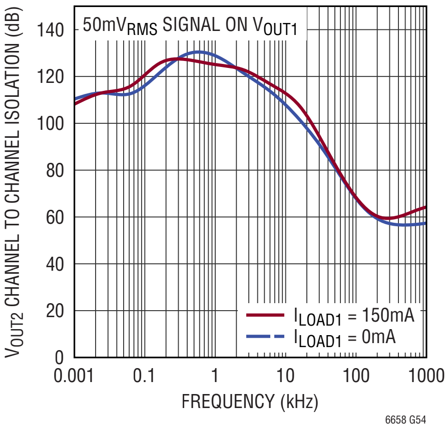
2.5V Turn-On Characteristic



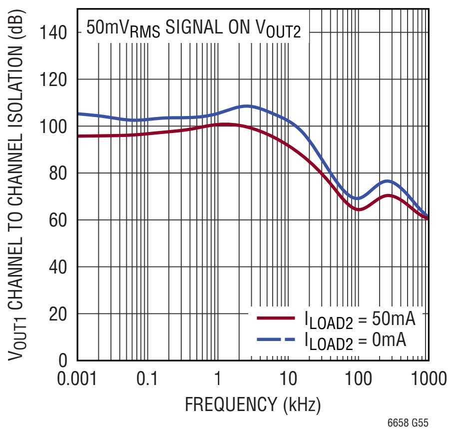
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

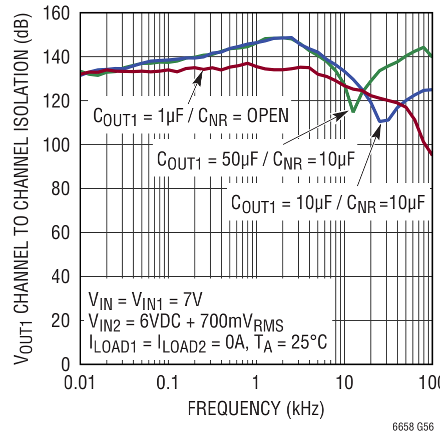
2.5V Channel to Channel Load Isolation V_{OUT1} to V_{OUT2}



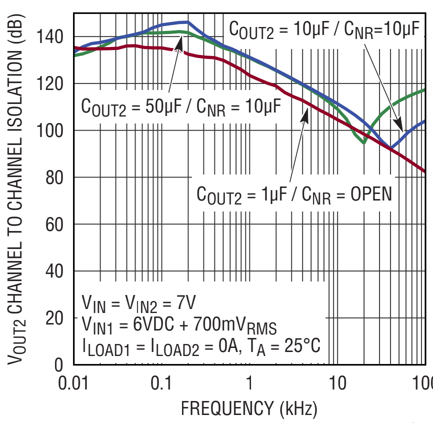
2.5V Channel to Channel Load Isolation V_{OUT2} to V_{OUT1}



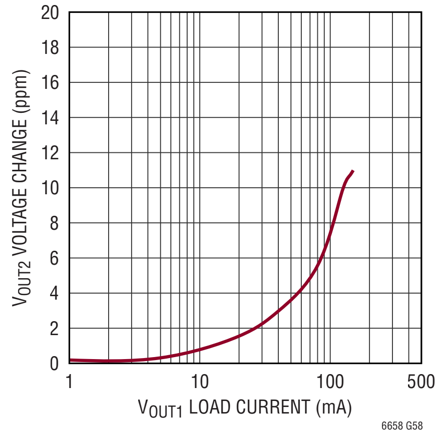
2.5V Channel to Channel Isolation V_{IN2} to V_{OUT1}



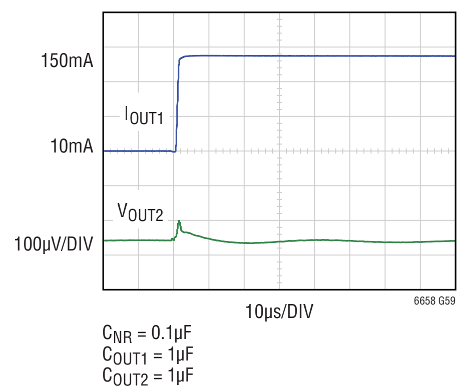
2.5V Channel to Channel Isolation V_{IN1} to V_{OUT2}



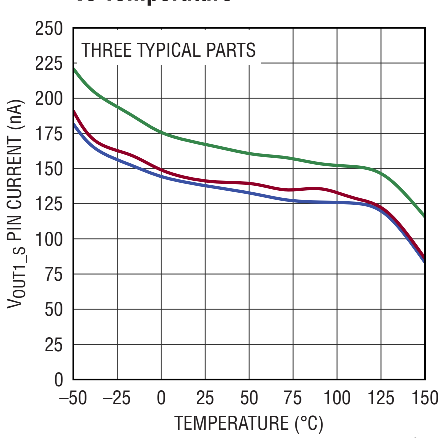
2.5V Channel to Channel Load Regulation (Effects of Heating Removed)



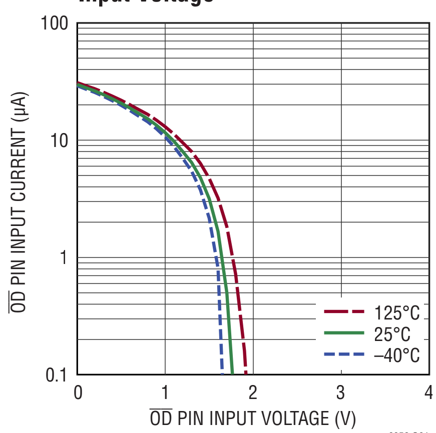
2.5V Channel to Channel Isolation, Time Domain



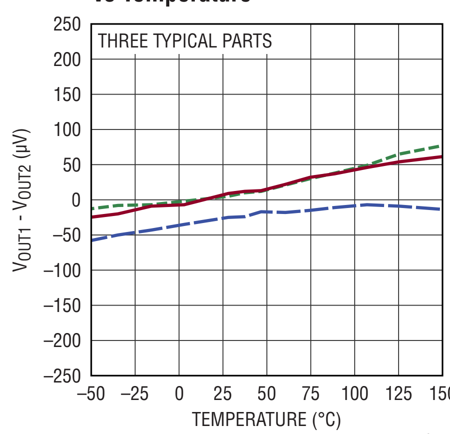
2.5V V_{OUT1_S} Pin Input Current vs Temperature



2.5V $\overline{OD}$ Pin Current vs $\overline{OD}$ Pin Input Voltage



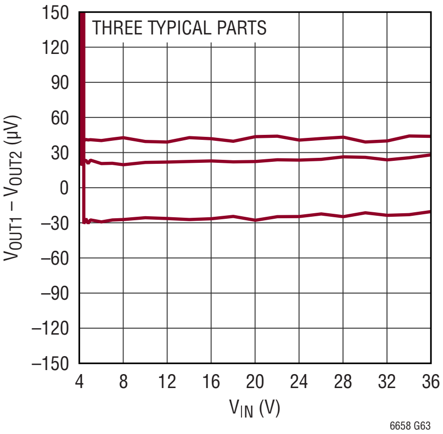
2.5V Tracking (V_{OUT1} – V_{OUT2}) vs Temperature



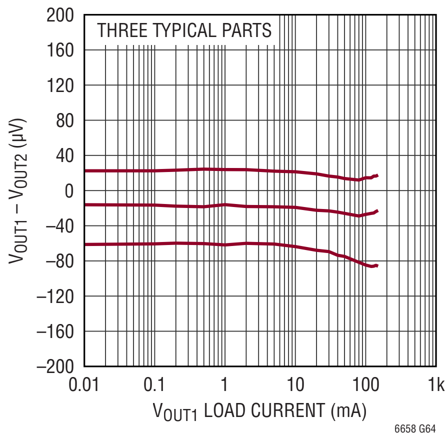
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

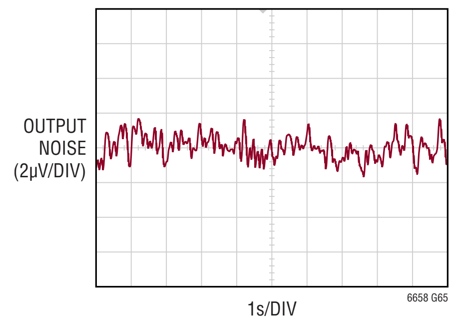
2.5V Tracking (V_{OUT1} – V_{OUT2}) vs Input Voltage



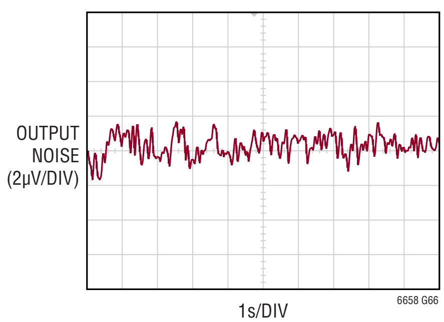
2.5V Tracking (V_{OUT1} – V_{OUT2}) vs V_{OUT1} Load Current



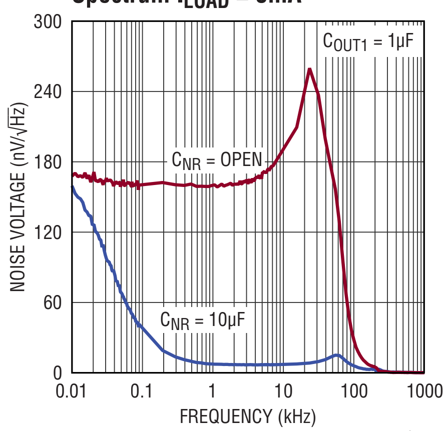
2.5V V_{OUT1} Output Noise 0.1Hz to 10Hz



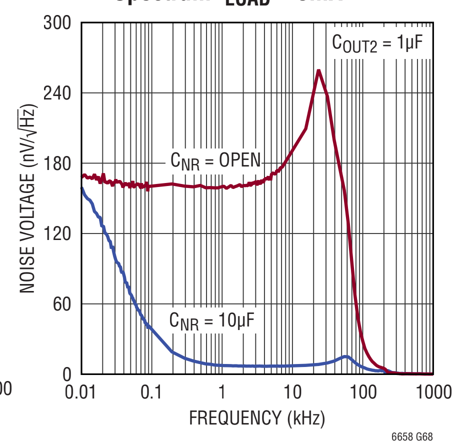
2.5V V_{OUT2} Output Noise 0.1Hz to 10Hz



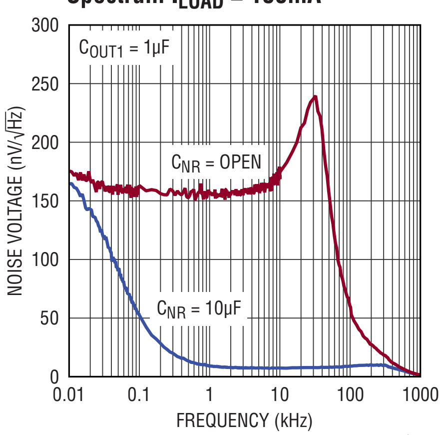
2.5V V_{OUT1} Output Voltage Noise Spectrum I_{LOAD} = 0mA



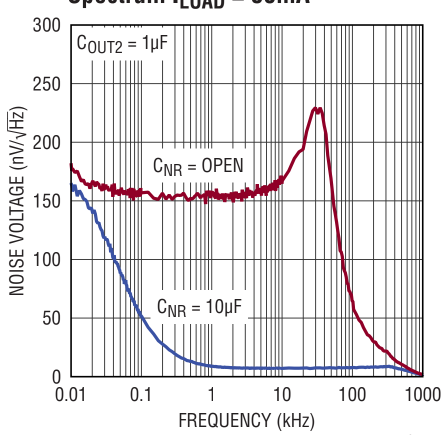
2.5V V_{OUT2} Output Voltage Noise Spectrum I_{LOAD} = 0mA



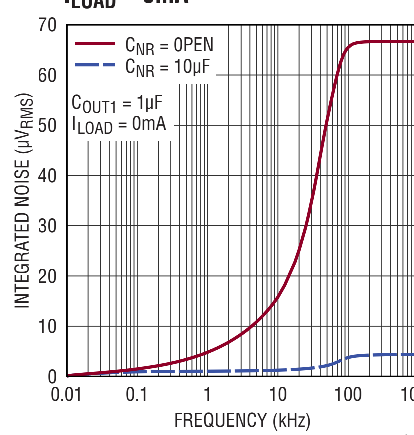
2.5V V_{OUT1} Output Voltage Noise Spectrum I_{LOAD} = 150mA



2.5V V_{OUT2} Output Voltage Noise Spectrum I_{LOAD} = 50mA



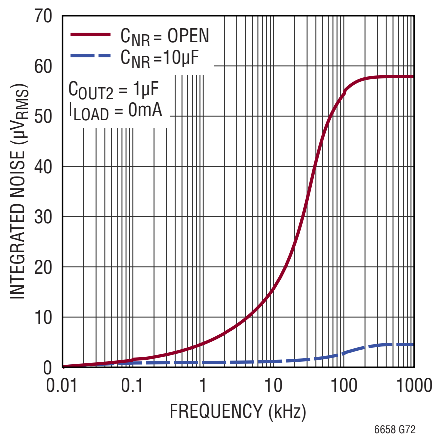
2.5V V_{OUT1} Integrated Noise I_{LOAD} = 0mA



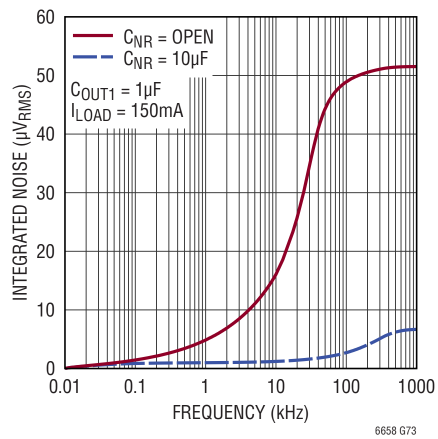
TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25°C$, $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1\_F} + 2.5V = V_{OUT2\_F} + 2.5V$ except LT6658-1.2 where $V_{IN} = V_{IN1} = V_{IN2} = 4.5V$, $C_{OUT1} = C_{OUT2} = 1µF$, $I_{LOAD} = 0mA$, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

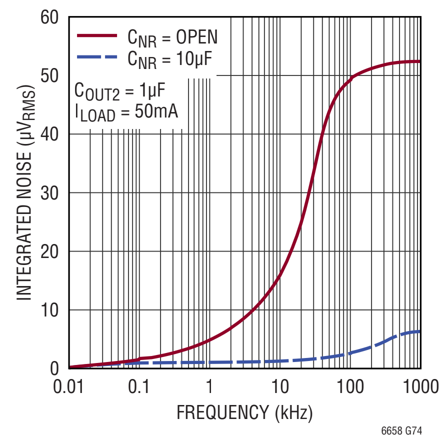
2.5V V_{OUT2} Integrated Noise I_{LOAD} = 0mA



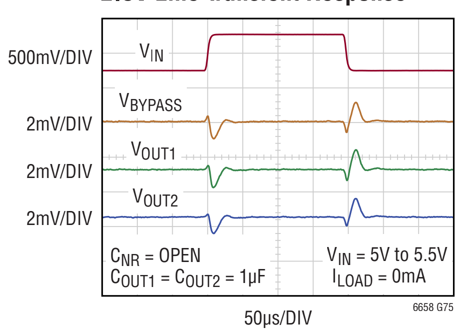
2.5V V_{OUT1} Integrated Noise I_{LOAD} = 150mA



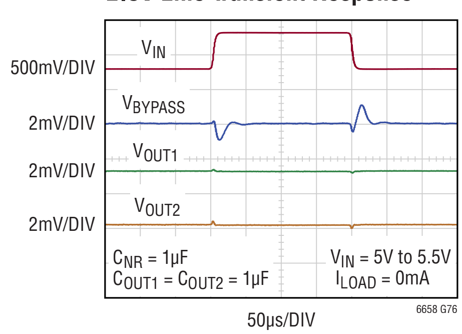
2.5V V_{OUT2} Integrated Noise I_{LOAD} = 50mA



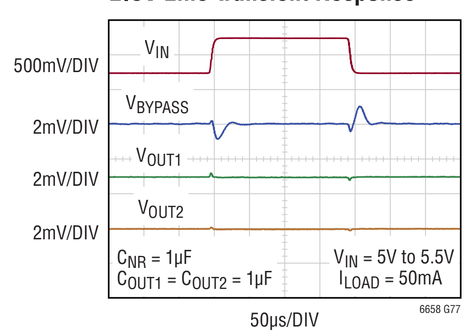
2.5V Line Transient Response



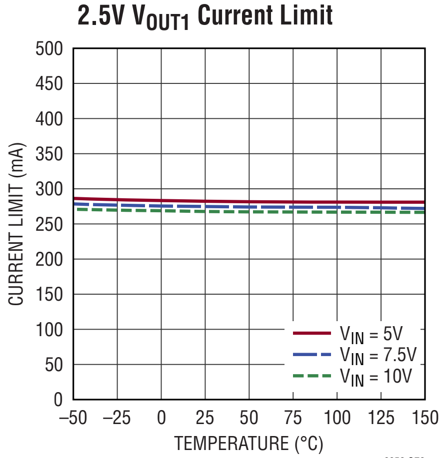
2.5V Line Transient Response



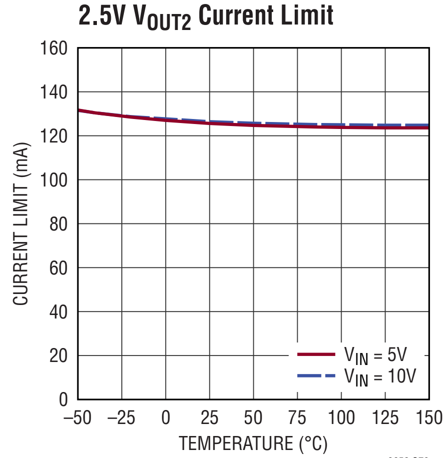
2.5V Line Transient Response



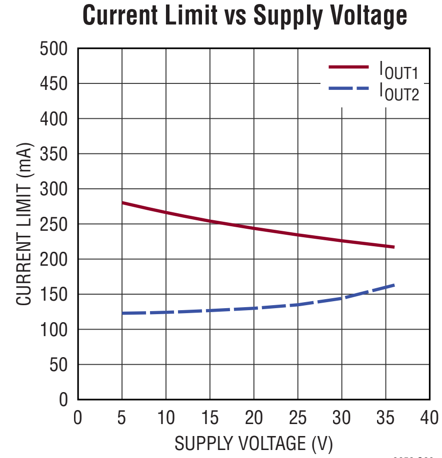
2.5V V_{OUT1} Current Limit



2.5V V_{OUT2} Current Limit



Current Limit vs Supply Voltage

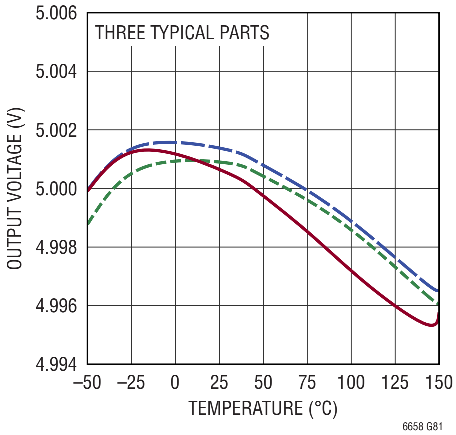


Rev B

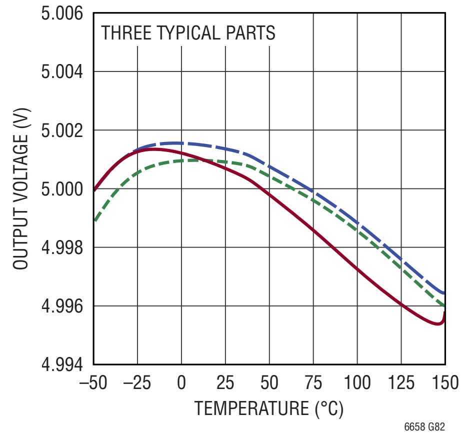
TYPICAL PERFORMANCE CHARACTERISTICS

$T_A = 25°C$, $V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1\_F} + 2.5V = V_{OUT2\_F} + 2.5V$ except LT6658-1.2 where $V_{IN} = V_{IN1} = V_{IN2} = 4.5V$, $C_{OUT1} = C_{OUT2} = 1µF$, $I_{LOAD} = 0mA$, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

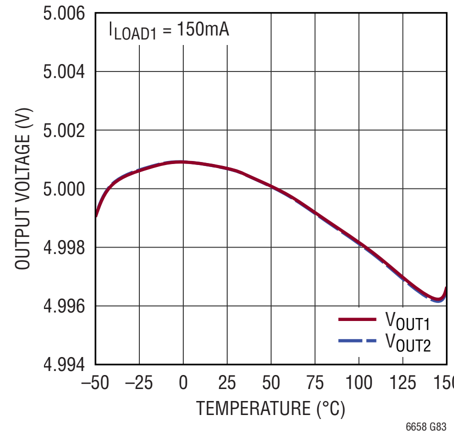
5V V_{OUT1} Output Voltage Temperature Drift



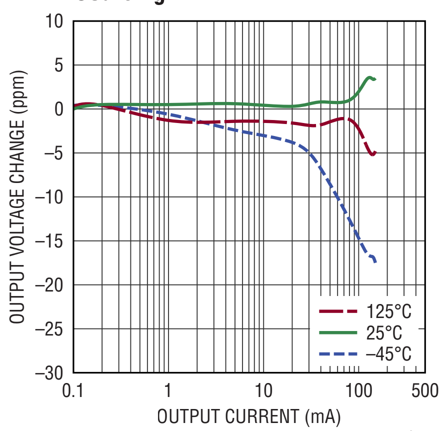
5V V_{OUT2} Output Voltage Temperature Drift



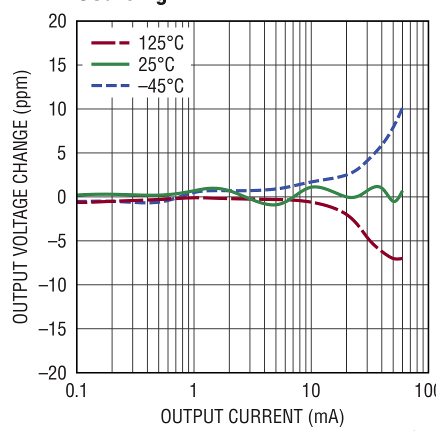
5V V_{OUT1} and V_{OUT2} Output Voltage vs Temperature with 150mA Load on V_{OUT1}



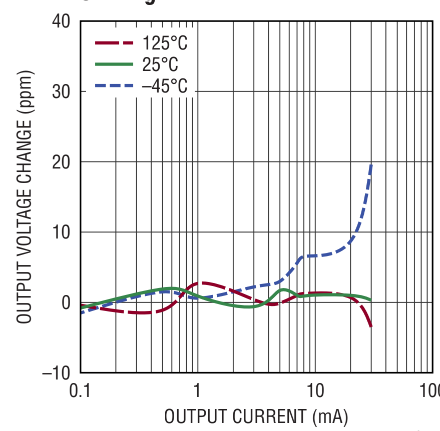
5V V_{OUT1} Load Regulation, Sourcing



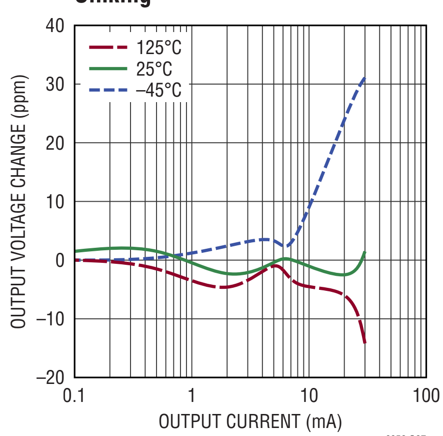
5V V_{OUT2} Load Regulation, Sourcing



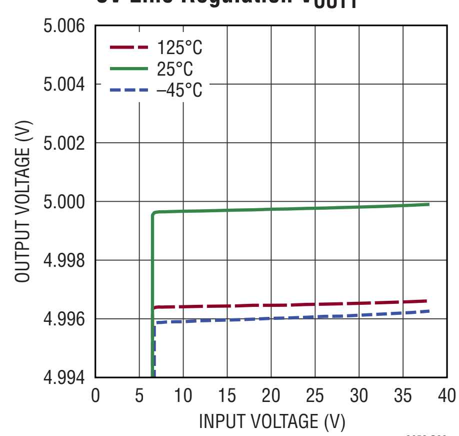
5V V_{OUT1} Load Regulation, Sinking



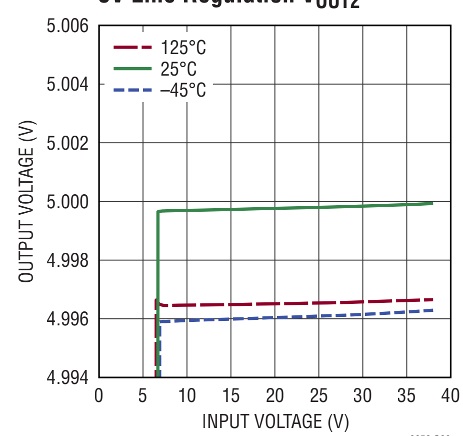
5V V_{OUT2} Load Regulation, Sinking



5V Line Regulation V_{OUT1}



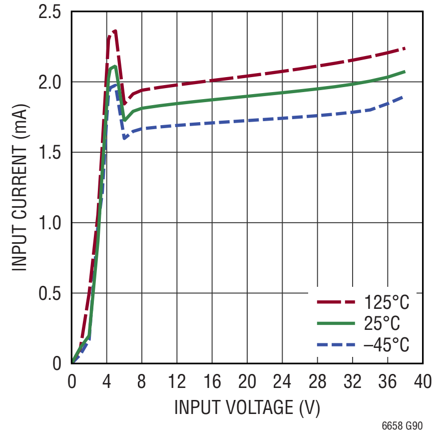
5V Line Regulation V_{OUT2}



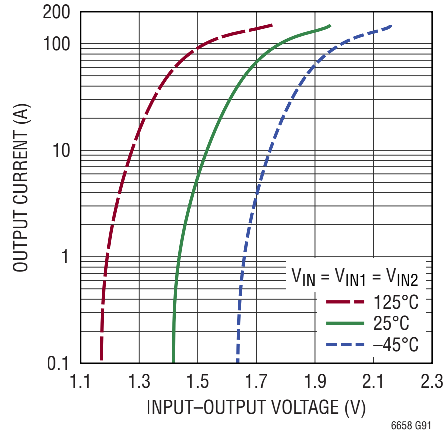
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

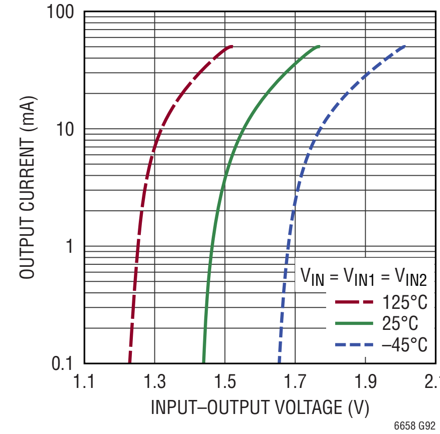
5V Supply Current vs Input Voltage



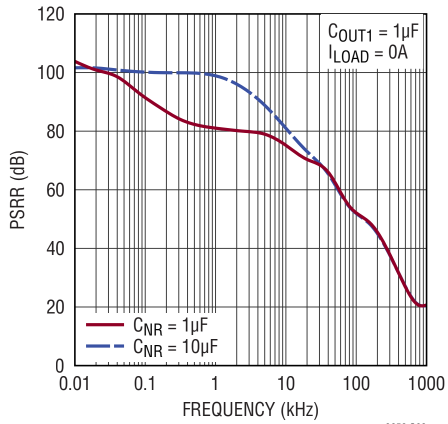
5V Minimum V_{IN} to V_{OUT1} Differential (Sourcing)



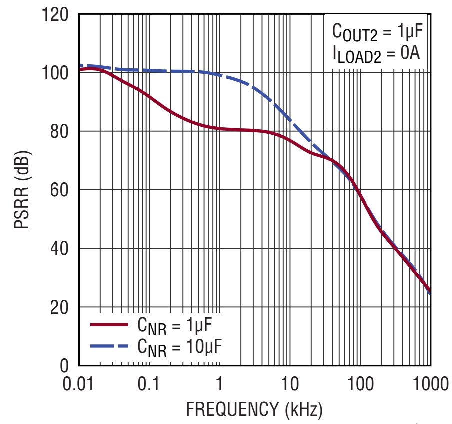
5V Minimum V_{IN} to V_{OUT2} Differential (Sourcing)



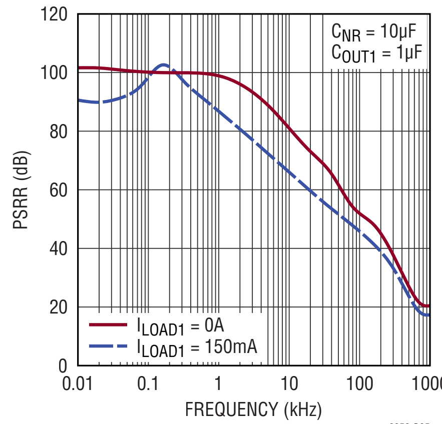
5V V_{OUT1} Power Supply Rejection Ratio vs Frequency



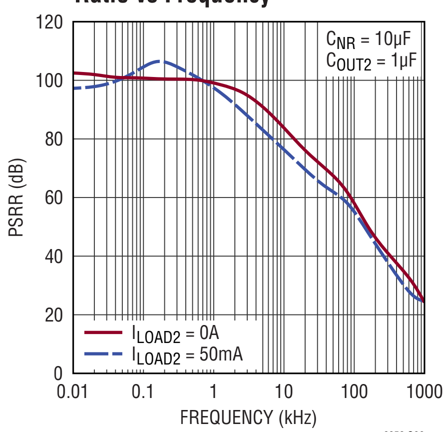
5V V_{OUT2} Power Supply Rejection Ratio vs Frequency



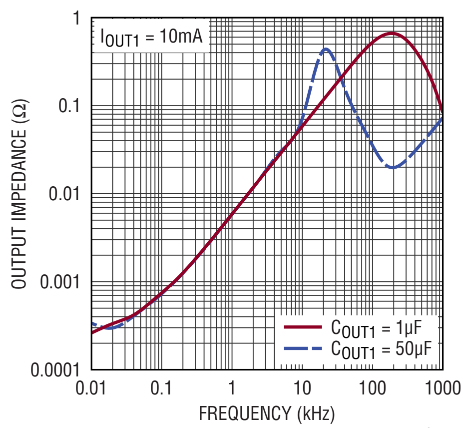
5V V_{OUT1} Power Supply Rejection Ratio vs Frequency



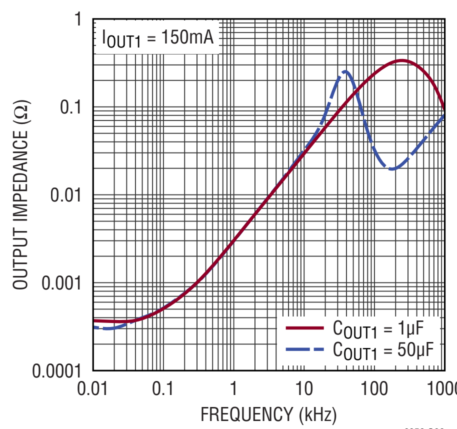
5V V_{OUT2} Power Supply Rejection Ratio vs Frequency



5V V_{OUT1} AC Output Impedance 10mA Load



5V V_{OUT1} AC Output Impedance 150mA Load

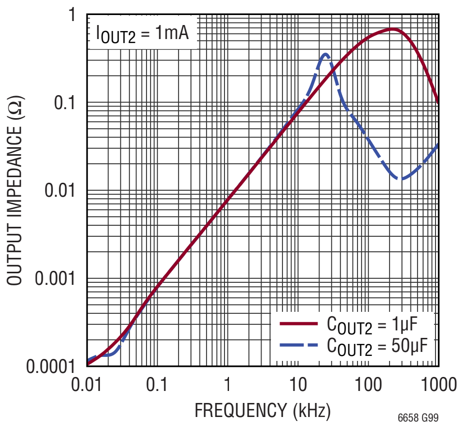


Rev B

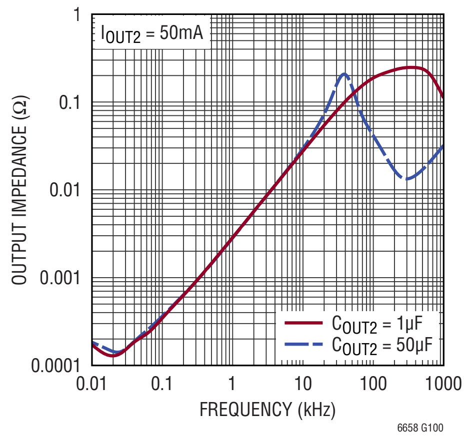
TYPICAL PERFORMANCE CHARACTERISTICS

T_A = 25°C, V_{IN} = V_{IN1} = V_{IN2} = V_{OUT1_F} + 2.5V = V_{OUT2_F} + 2.5V except LT6658-1.2 where V_{IN} = V_{IN1} = V_{IN2} = 4.5V, C_{OUT1} = C_{OUT2} = 1µF, I_{LOAD} = 0mA, unless otherwise noted. The characteristic curves are similar across the LT6658 family. Curves from the LT6658-1.2, LT6658-2.5 and the LT6658-5 represent the full range of typical performance of all voltage options. Characteristic curves for other output voltages fall between these curves and can be estimated based on their output.

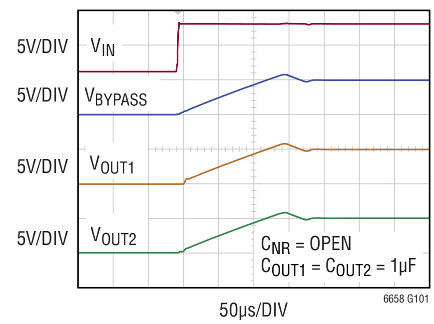
5V V_{OUT2} AC Output Impedance 1mA Load



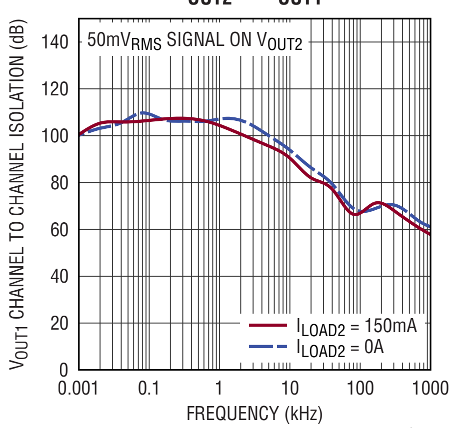
5V V_{OUT2} AC Output Impedance 50mA Load



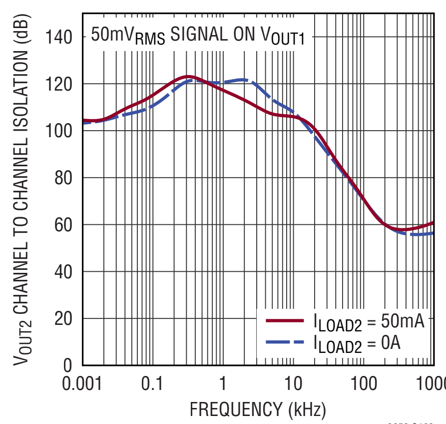
5V Turn-On Characteristic



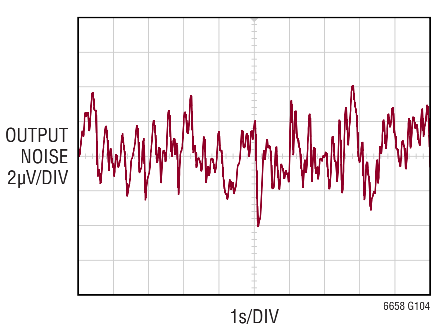
5V Channel to Channel Load Isolation V_{OUT2} to V_{OUT1}



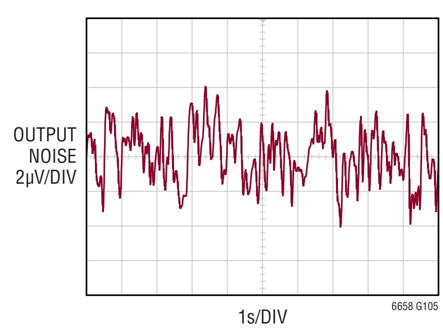
5V Channel to Channel Load Isolation V_{OUT1} to V_{OUT2}



5V V_{OUT1} Output Noise 0.1Hz to 10Hz



5V V_{OUT2} Output Noise 0.1Hz to 10Hz



TYPICAL PERFORMANCE CHARACTERISTICS

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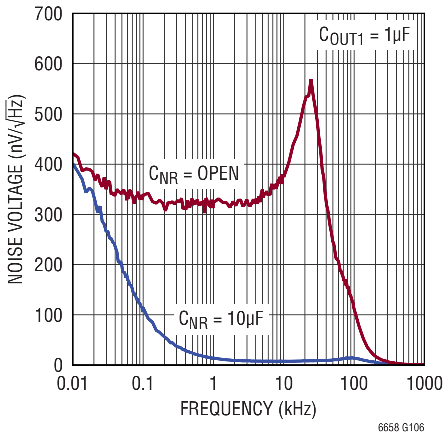
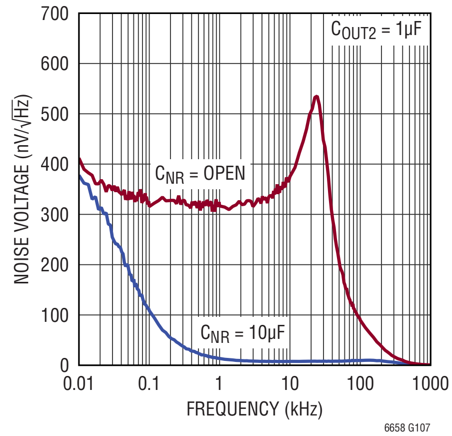
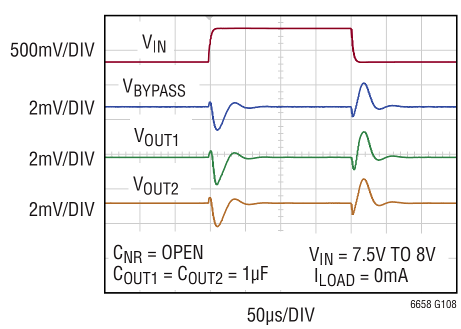
5V V_{OUT1} Output Voltage Noise Spectrum I_{LOAD} = 0mA



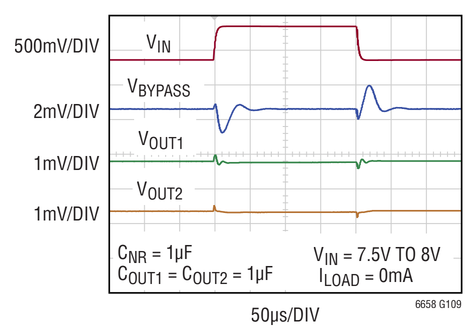
5V V_{OUT2} Output Voltage Noise Spectrum I_{LOAD} = 0mA



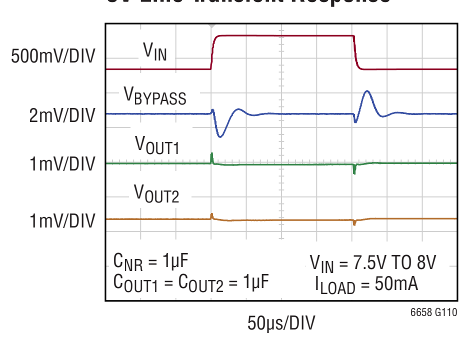
5V Line Transient Response



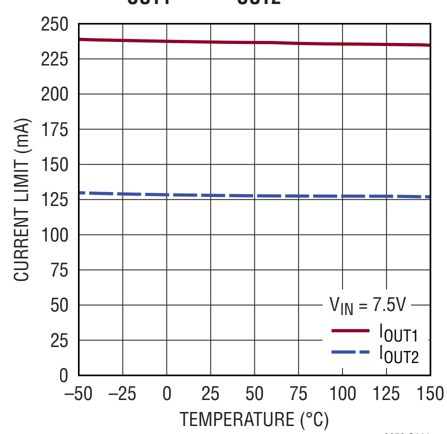
5V Line Transient Response



5V Line Transient Response



5V V_{OUT1} and V_{OUT2} Current Limit



Rev B

PIN FUNCTIONS

GND (Pins 1, 2, 6, Exposed Pad Pin 17): These pins are the main ground connections and should be connected into a star ground or ground plane. The exposed pad must be soldered to ground for good electrical contact and rated thermal performance.

BYPASS (Pin 3): Bypass Pin. This requires a 1µF capacitor for bandgap stability.

DNC (Pin 4, 16): Do Not Connect. Keep leakage current from these pins to a minimum.

NR (Pin 5): Noise Reduction Pin. To band limit the noise of the reference, connect a capacitor between this pin and ground. See Applications Information section.

V_{OUT2_S} (Pin 7): V_{OUT2} Kelvin Sense Pin. Connect this pin directly to the load.

V_{OUT2_F} (Pin 8): V_{OUT2} Output Voltage. A 1µF to 50µF output capacitor is required for stable operation. This output can source up to 50mA.

$\overline{OD}$ (Pin 9): Output Disable. This active low input disables both outputs.

V_{IN2} (Pin 10): Input Voltage Supply for Buffer 2. Bypass V_{IN2} with 0.1µF capacitor to ground. This pin supplies power to buffer amplifier 2.

V_{IN1} (Pin 11): Input Voltage Supply for Buffer 1. Bypass V_{IN1} with 0.1µF capacitor to ground. This pin supplies power to buffer amplifier 1.

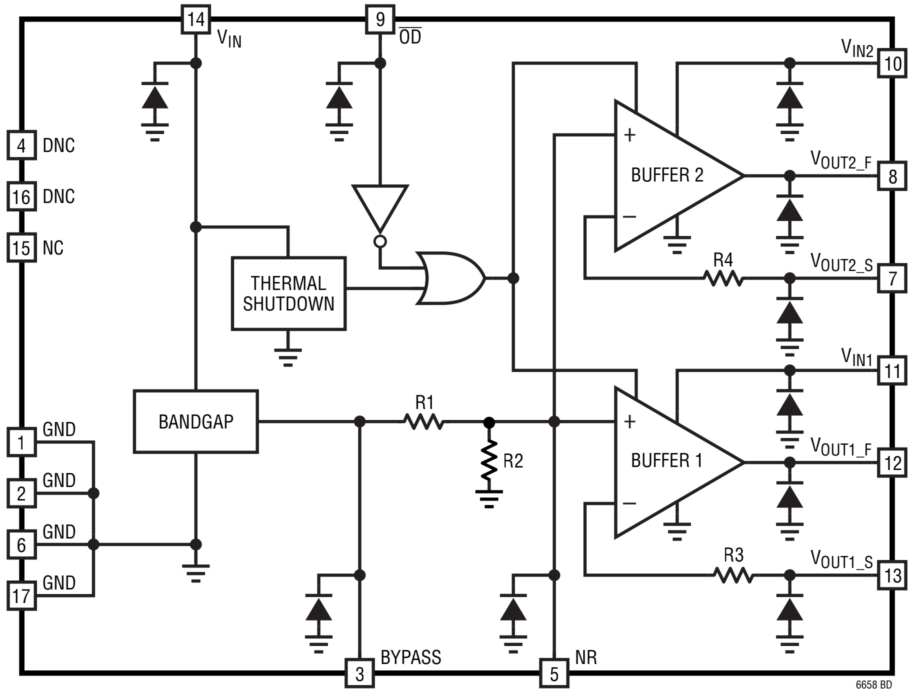
V_{OUT1_F} (Pin 12): V_{OUT1} Output Voltage. A 1µF to 50µF output capacitor is required for stable operation. This output can source up to 150mA.

V_{OUT1_S} (Pin 13): V_{OUT1} Kelvin Sense Pin. Connect this sense pin directly to the load.

V_{IN} (Pin 14): Input Voltage Supply. Bypass V_{IN} with 0.1µF capacitor to ground.

NC (Pin 15): No Connect.

BLOCK DIAGRAM



Voltage Option (V)	R1 (Ω)	R2 (Ω)	R3, R4 (Ω)
1.2	400	9600	768
1.8	400	2903	705
2.5	400	OPEN	800
3	400	OPEN	800
3.3	400	OPEN	800
5	400	OPEN	800

APPLICATIONS INFORMATION

The LT6658 combines the low noise and accuracy of a high performance voltage reference and the high current drive of a regulator. The LT6658 Refulator provides two precise low noise outputs with Kelvin sense pins that maintain their precision even when large voltage or current transients exist on the adjacent buffer.

The LT6658 architecture consists of a low drift bandgap reference followed by an optional noise reduction stage and two independent buffers. The bandgap reference and the buffers are trimmed for low drift and high accuracy. The high gain buffers ensure outstanding line and load regulation.

The guidance that follows describes how to reduce noise, lower power consumption, generate different output voltages, and maintain low drift. Also included are notes on internal protection circuits, PCB layout, and expected performance.

Supply Pins and Ground

The LT6658 can operate with a supply voltage from V_{OUT} + 2.5V, to 36V. To provide design flexibility, the LT6658 includes 3 supply pins. The V_{IN} pin supplies power to the bandgap voltage reference. The V_{IN1} and V_{IN2} pins supply power to buffer amplifiers 1 and 2, respectively. Figure 1 illustrates how current flows independently through each of the output buffers. The simplest configuration is to connect all three supply pins together. To reduce power consumption or isolate the buffer amplifiers, separate the supply pins and drive them with independent supplies.

Separate V_{IN},V_{IN1} and V_{IN2} supply pins isolate the bandgap reference and the two outputs V_{OUT1_F} and V_{OUT2_F} from each other. For example, a load current surge through V_{IN1} to V_{OUT1_F} is isolated from V_{OUT2_F} and the bandgap voltage reference. In Figure 2, a 140mA load current pulse on Buffer 1 and the resulting output waveforms are shown. Despite the large current step on Buffer 1, there is only a small transient at the output of Buffer 2. This isolation of two buffer outputs is important when providing a stable voltage reference to noise-sensitive circuits such as an ADC or DAC.

In addition, power can be minimized by providing each supply pin with its minimum voltage. For example, if Buffer 1 has a 2.5V output, V_{IN1} can be operated at 5V. If Buffer 2's output is run at 3V, run V_{IN2} at 5.5V. The power savings gained by minimizing each supply voltage can be considerable.

Excessive ground current and parasitic resistance in ground lines can degrade load regulation. Unlike an LDO, the ground of the LT6658 is designed such that ground current does not increase substantially when sourcing a large load current. All three ground pins and exposed pad should be connected together on the PCB, through a ground plane or through a separate trace terminating at a star ground.

The supply pins can be powered up in any order without an adverse response. However, all three pins need the minimum specified voltage for proper operation.

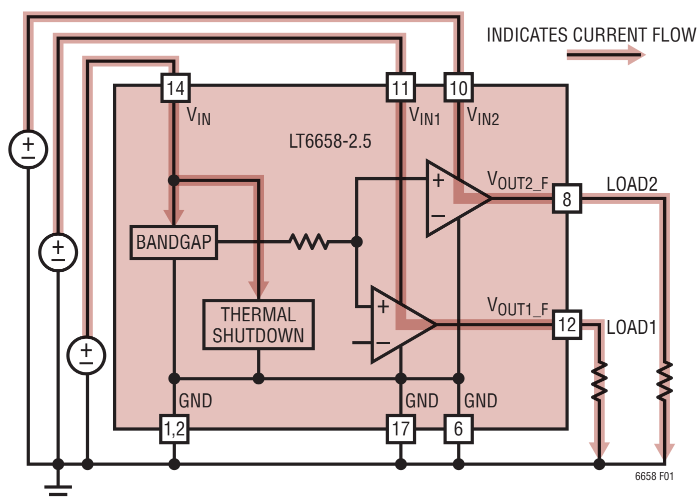


Figure 1. LT6658 Current Flow through the Supply Pins

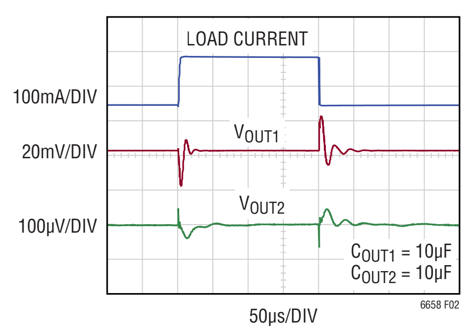


Figure 2. 10mA to 150mA Load Step on V_{OUT1}

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Input Bypass Capacitance

Each input voltage pin requires a 0.1µF capacitor located as close to the supply pin as possible. A 10µF capacitor is recommended for each supply where the supply enters the board. When the supply pins are connected together, a single 0.1µF and single 10µF capacitor can be used.

The BYPASS pin requires a 1µF capacitor for stability.

Using the BYPASS Pin as a Reference

The BYPASS pin requires a 1µF capacitor for stability and provides a bandgap voltage to the output buffers. The block diagram includes a voltage divider comprised of R1 and R2. R2 is open on the four voltage options 2.5V, 3V, 3.3V and 5V. Two voltage options, 1.2V and 1.8V, include resistor R2 creating a voltage divider. The voltage at the BYPASS pin for these two options is different than the specified output voltage. The table below summarizes the BYPASS pin voltage with respect to the output voltage.

Table 1. BYPASS Pin V Voltage

Voltage Option (V)	BYPASS Pin Voltage (V)
1.2	1.25
1.8	2.048
2.5	2.5
3.0	3.0
3.3	3.3
5.0	5.0

The BYPASS pin can be used as an additional voltage reference pin. It nominally can source and sink 10mA. Note that any loading effect on the BYPASS pin gets passed to the output buffers. That is, if the BYPASS pin is pulled down by 100mV, the output pins will respond similarly.

Stability and Output Capacitance

The LT6658 is designed to be stable for any output capacitance between 1µF and 50µF, under any load condition, specified input voltage, or specified temperature. Choosing a suitable capacitor is important in maintaining stability. Preferably a low ESR and ESL capacitor should be chosen. The value of the output capacitor will affect the settling response.

Care should be exercised in choosing an output capacitor, as some capacitors tend to deviate from their specified value as operating conditions change.

Although ceramic capacitors are small and inexpensive, they can vary considerably over the DC bias voltage. For example, the capacitance value of X5R and X7R capacitors will change significantly over their rated voltage range as shown in Figure 3. In this example the 1µF X5R capacitor loses almost 75% of its value at its rated voltage of 10V.

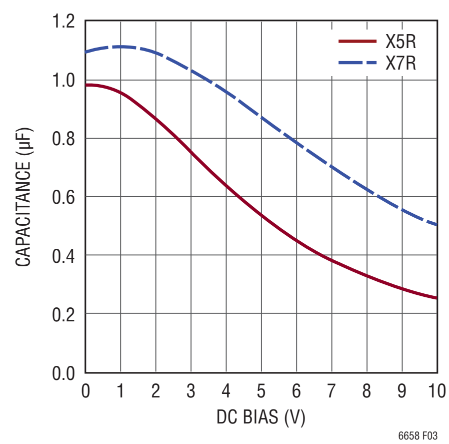

Figure 3. Capacitance Value of a 1µF X7R and 1µF X5R Over Its Full Rated Voltage

X5R and X7R capacitors will also vary up to 20% or more over a temperature range of –55°C to 125°C. This change in capacitance will be combined with any DC bias voltage variation.

Film capacitors do not vary much over temperature and DC bias as much as X5R and X7R capacitors, but generally they are only rated to 105°C. Film capacitors are also physically larger.

Effective series resistance (ESR) in the output capacitor can add a zero to the loop response of the output buffers creating an instability or excessive ringing. For the best results keep the ESR at or below 0.15Ω.

One measure of stability is the closed loop response of the output buffer. By driving the NR pin, a closed loop response can be obtained. In Figure 4 the closed loop response of the output buffer with three different output capacitance values is shown. In the Figure 5 the same plot is repeated with a 150mA load.

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A large value electrolytic capacitor with a 1µF to 50µF ceramic capacitor in parallel can be used on the output pins. The buffers will be stable, and the bandwidth will be lower.

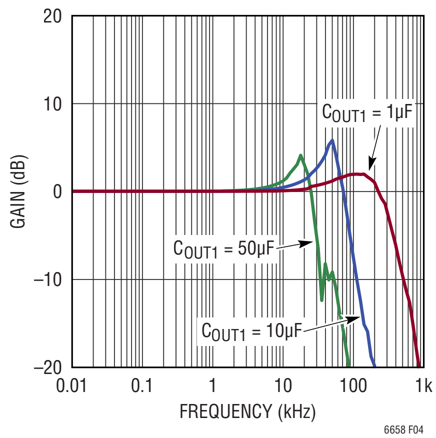

Figure 4. LT6658 Closed Loop Response of Buffer 1 for 3 Values of Output Capacitance and No Load

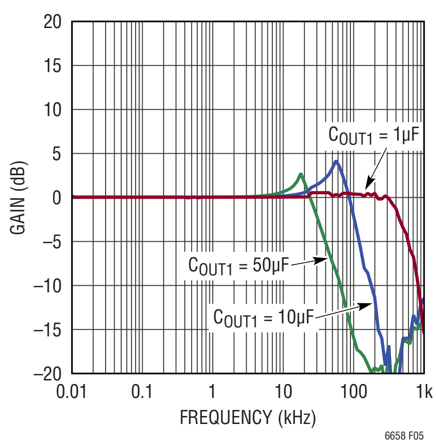

Figure 5. LT6658 Closed Loop Response of Buffer 1 for 3 Values of Output Capacitance and 150mA Load

Buffer 2 has a similar response.

Start-Up and Transient Response

When the LT6658 is powered up, the bandgap reference charges the capacitor on the BYPASS pin. The output buffer follows the voltage on the BYPASS pin charging the output capacitor. Figure 6 shows the start-up response on the BYPASS and V_{OUT1_F} pins for three different output capacitor values. The start-up response is limited by the current limit in the bandgap charging the BYPASS capacitor. The turn-on time is also restricted by the current limit in the output buffer and the size of the output capacitor. A larger output capacitor will take longer to charge. Adding a capacitor to the NR pin will also affect turn-on time.

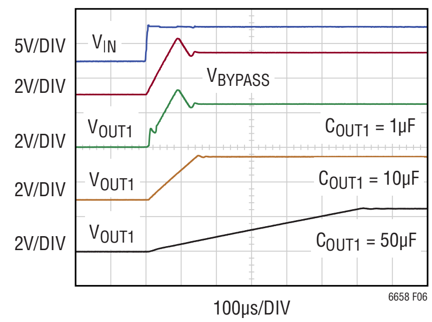

Figure 6. Start-Up Response on the BYPASS and V_{OUT1_F} Pins

The test circuit for the transient response test is shown in Figure 7. The transient response due to load current steps are shown in Figures 8, 9, and 10.

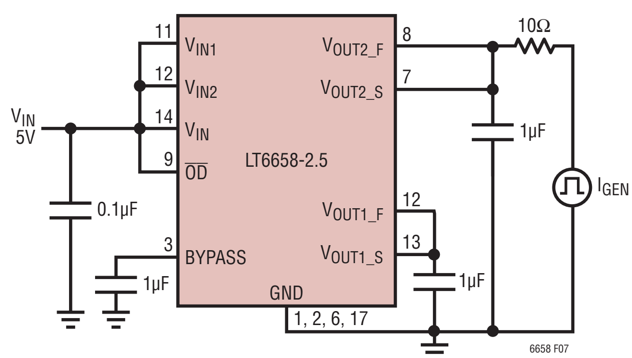

Figure 7. Load Current Response Time Test Circuit

In Figure 8 and Figure 9, a 75mA and 140mA load step is applied to Buffer 1, respectively. In Figure 10, a 40mA load step is applied to Buffer 2. The settling time is determined by the size and edge rate of the load step, and the size of the output capacitor.

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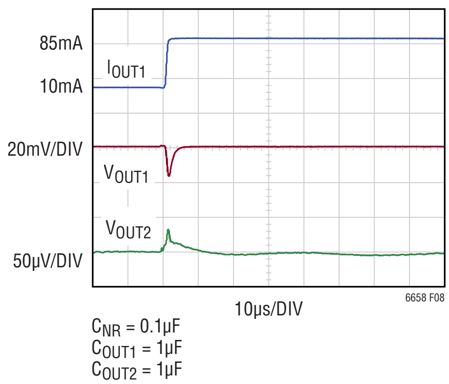

Figure 8. LT6658-2.5 Buffer 1 Response to 75mA Load Step

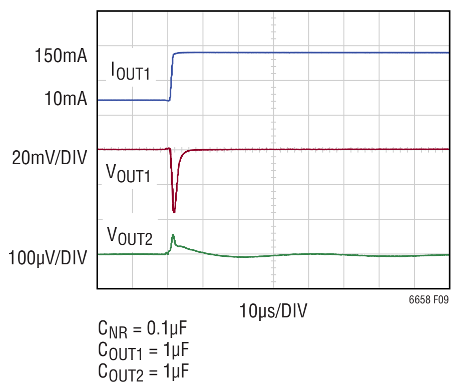

Figure 9. LT6658-2.5 Buffer 1 Response to 140mA Load Step

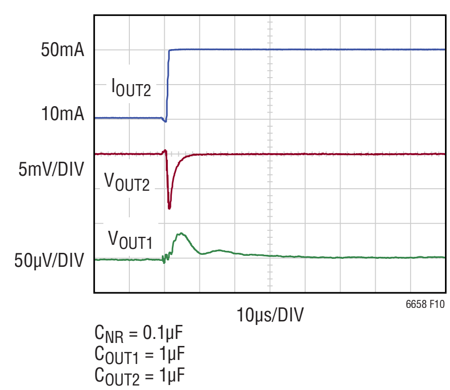

Figure 10. LT6658-2.5 Output 2 Response to 40mA Load Step

Output Voltage Scaling

The output buffers can be independently configured with external resistors to add gain, permitting non-standard output voltages. Unity gain is configured by tying the sense and force pins together.

Figure 11 provides an example where Buffer 2 is configured with a gain of 2. More examples are provided in the Typical Applications section. When configuring a gain >1, it's important to keep in mind that each output can only swing to within 2.5V of its associated supply voltage, as specified in the dropout voltage. Also note that the absolute maximum voltage on the output pins (both force and sense) is 6V. Place the feedback resistors close to the part keeping the traces short. Avoid parasitic resistance in the high current path from the feedback resistor to ground. If possible, the resistor to ground should be connected as close as possible to the chip ground.

When using non-unity gain configurations, V_{OS} drift errors are possible. There is an 800Ω resistor in the Kelvin sense line which is designed to cancel base current variation on the input of the buffer amplifier. Matching the impedances on the positive and negative inputs reduces base current error and minimizes V_{OS} drift. A feedback network will have a small base current flowing through the feedback resistor possibly causing a small V_{OS} drift.

Referring to the 2.5V V_{OUT1_S} Pin Input Current vs Temperature plot in the Typical Performance Characteristics section, the input sense current varies about 50nA between –40°C and 125°C. This 50nA variation may cause a 0.5mV voltage change across the 10kΩ feedback resistor affecting the output voltage.

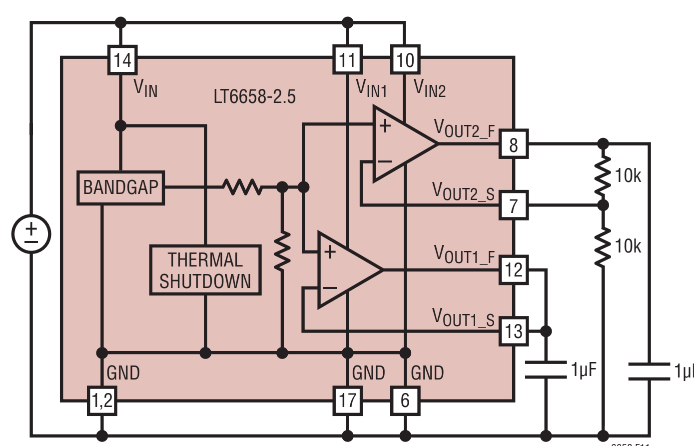

Figure 11. The LT6658-2.5 with Output 2 Configured for a 5V Output

APPLICATIONS INFORMATION

Kelvin Sense Pins

To ensure the LT6658 maintains good load regulation, the Kelvin sense pins should be connected close to the load to avoid any voltage drop in the copper trace on the force pin. It only takes 10mΩ of resistance to develop a 1.5mV drop with 150mA. This would cause an ideal 2.5V output voltage to exceed the 0.05% specification at the load. The circuit in Figure 12a illustrates how an incorrect Kelvin sense connection can lead to errors. The parasitic resistance of the copper trace will cause the output voltage to change as the load current changes. As a result, the voltage at the load will be lower than the voltage at the sense line. The circuit in Figure 12b shows the proper way to make a Kelvin connection with the sense line as close to the load as possible. The voltage at the load will now be well regulated. The V_{OUT1_S} current is typically 135nA, and a low resistance in series with the Kelvin sense input is unlikely to cause a significant error or drift.

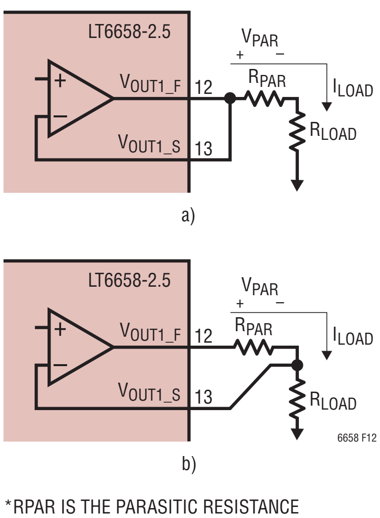

Figure 12. How to Make a Proper Kelvin Sense Connection

Output Noise and Noise Reduction (NR)

The LT6658 noise characteristic is similar to that of a high performance reference. The total noise is a combination of the bandgap noise and the noise of the buffer amplifier. The bandgap noise can be measured at the NR pin and is shown in Figure 13 with a 1µF capacitor, 10µF capacitor and no capacitor on the NR pin. The bandgap can be bandlimited by connecting a capacitor between the NR pin and ground. The RC product sets the low pass 3dB corner attenuating the out-of-band noise of the bandgap. An internal 400Ω ±15% resistor combines with the external capacitor to create a single-pole low pass filter. Table 2 lists capacitor values and the corresponding 3dB cutoff frequency.

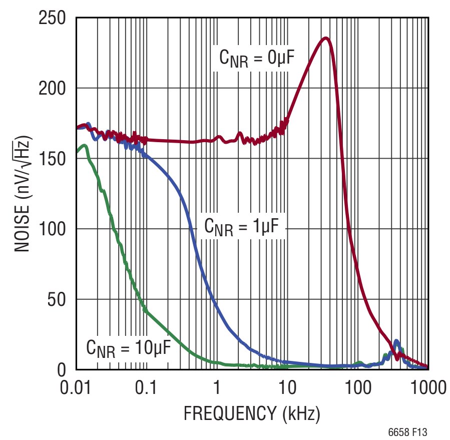

Figure 13. LT6658 Bandgap Output Voltage Noise

Table 2. NR Capacitor Values and the Corresponding 3dB Frequency

NR Capacitor (µF)	1.2V NR 3dB Frequency (Hz)	1.8V NR 3dB Frequency (Hz)	2.5V, 3V, 3.3V, 5V NR 3dB Frequency (Hz)
0.1	4145	4522	3979
0.22	1884	2055	1809
0.47	882	962	847
1	414	452	398
2.2	188	206	181
4.7	88	96	85
10	41	45	40
22	19	21	18

The primary trade-off for including an RC filter on the NR pin is a slower turn-on time. The effective resistance seen by the NR capacitor is 400Ω. The RC time constant (τ) for charging the NR capacitor is τ = R • C. To reach the initial accuracy specification for the LT6658, 0.05%, it will take 7.6τ of settling time. Example settling time