

OPA600

Fast-Settling Wideband OPERATIONAL AMPLIFIER

FEATURES

- **FAST SETTLING:** 80ns to $\pm 0.1\%$
100ns to $\pm 0.01\%$
- **FULL DIFFERENTIAL FET INPUT**
- **-25°C to +85°C AND**
-55°C to +125°C TEMPERATURE
RANGES
- **$\pm 10V$ OUTPUT: 200mA**
- **GAIN BANDWIDTH PRODUCT: 5GHz**

DESCRIPTION

The OPA600 is a wideband operational amplifier specifically designed for fast settling to $\pm 0.01\%$ accuracy. It is stable, easy to use, has good phase margin with minimum overshoot, and it has excellent DC performance. It utilizes an FET input stage to give low input bias current. Its DC stability over temperature is outstanding. The slew rate exceeds $400V/\mu s$. All of this combines to form an outstanding amplifier for large and small signals.

High accuracy with fast settling time is achieved by using a high open-loop gain which provides the accuracy at high frequencies. The thermally balanced design maintains this accuracy without droop or thermal tail. External frequency compensation allows the user to optimize

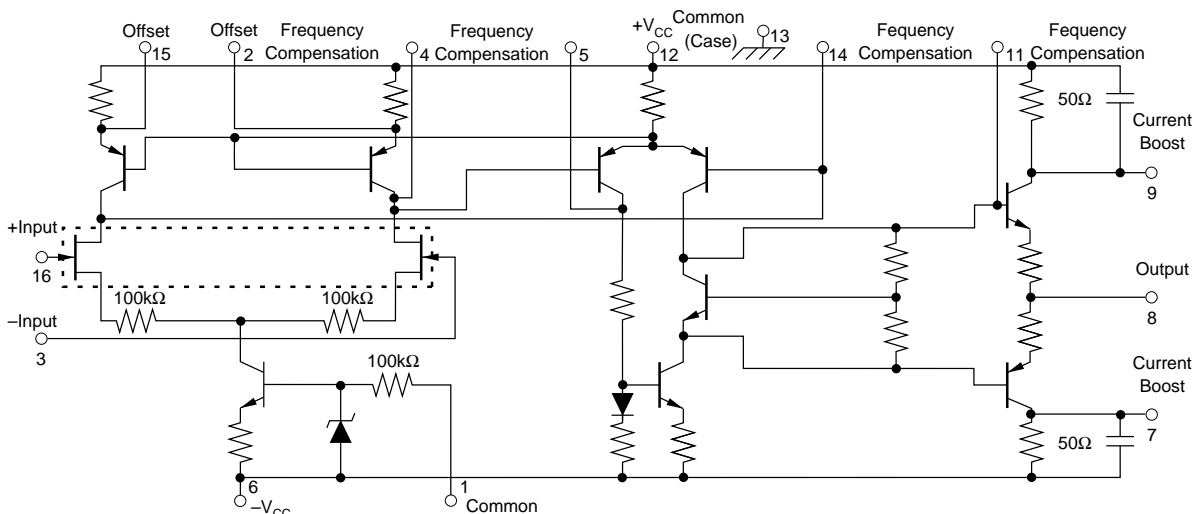
APPLICATIONS

- **VOLTAGE CONTROLLED OSCILLATOR DRIVER**
- **LARGE SIGNAL, WIDEBAND DRIVERS**
- **HIGH SPEED D/A CONVERTER OUTPUT AMPLIFIER**
- **VIDEO PULSE AMPLIFIER**

the settling time for various gains and load conditions.

The OPA600 is useful in a broad range of video, high speed test circuits and ECM applications. It is particularly well suited to operate as a voltage controlled oscillator (VCO) driver. It makes an excellent digital-to-analog converter output amplifier. It is a workhorse in test equipment where fast pulses, large signals, and 50Ω drive are important. It is a good choice for sample/holds, integrators, fast waveform generators, and multiplexers.

The OPA600 is specified over the industrial temperature range (OPA600BM, CM) and military temperature range (OPA600SM, TM). The OPA600 is housed in a welded, hermetic metal package.



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SPECIFICATIONS

ELECTRICAL

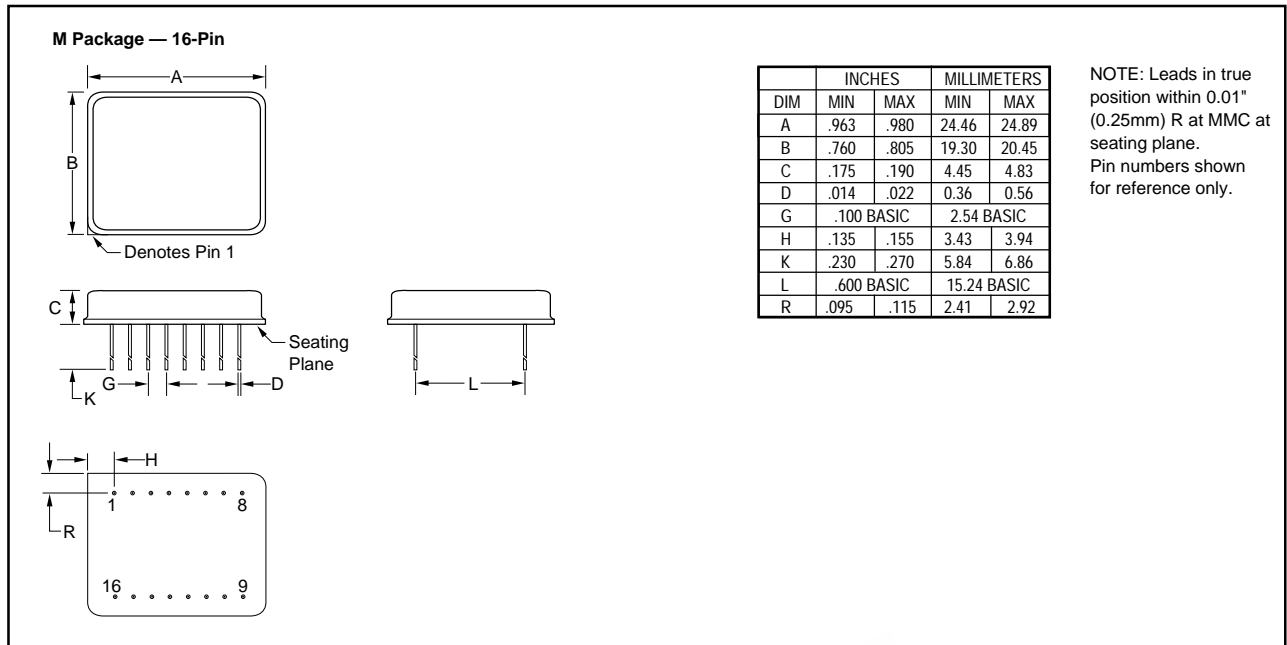
At $V_{CC} = \pm 15\text{VDC}$ and $T_A = +25^\circ\text{C}$ unless otherwise noted.

PARAMETER	CONDITIONS	OPA600CM, TM ⁽¹⁾			OPA600BM, SM			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
OUTPUT								
Voltage	$R_L = 2\text{k}\Omega$	± 10			*			V
Current	$R_L = 50\Omega^{(2)}$	± 9			*			V
Current Pulse	$R_L = 50\Omega^{(2)}$	± 180	± 200		*	*		mA
Resistance	$R_L = 50\Omega^{(3)}$	± 180	± 200		*	*		mA
Short-Circuit Current	Open Loop DC		75		*	*		Ω
	To COMMON Only, $t_{MAX} = 1\text{s}^{(4)}$		250	300		*	*	mA
DYNAMIC RESPONSE								
Settling Time ⁽⁵⁾ : to $\pm 0.01\%$ ($\pm 1\text{mV}$) to $\pm 0.1\%$ ($\pm 10\text{mV}$) to $\pm 1\%$ ($\pm 100\text{mV}$)	$\Delta V_{OUT} = 10\text{V}$		100	125		*	*	ns
	$\Delta V_{OUT} = 10\text{V}$		80	105		*	*	ns
	$\Delta V_{OUT} = 10\text{V}$		70	95		*	*	ns
Gain-Bandwidth Product (open-loop)	$C_C = 0\text{pF}, G = 1\text{V/V}$		150			*		MHz
	$C_C = 0\text{pF}, G = 10\text{V/V}$		500			*		MHz
	$C_C = 0\text{pF}, G = 100\text{V/V}$		1.5			*		GHz
	$C_C = 0\text{pF}, G = 1000\text{V/V}$		5			*		GHz
	$C_C = 0\text{pF}, G = 10,000\text{V/V}$		10			*		GHz
Bandwidth (-3dB small signal) ⁽⁶⁾	$G = +1\text{V/V}$		125			*		MHz
	$G = -1\text{V/V}$		90			*		MHz
	$G = -10\text{V/V}$		95			*		MHz
	$G = -100\text{V/V}$		20			*		MHz
	$G = -1000\text{V/V}$		6			*		MHz
Full Power Bandwidth	$V_{OUT} = \pm 5\text{V}, G = -1\text{V/V}, C_C = 3.3\text{pF}, R_L = 100\Omega$		16			*		MHz
Slew Rate	$V_{OUT} = \pm 5\text{V}, G = -1000\text{V/V}, C_C = 0\text{pF}, R_L = 100\Omega$		400	500		*		$\text{V}/\mu\text{s}$
	$V_{OUT} = \pm 5\text{V}, G = -1\text{V/V}^{(4)}$		440	440		*		$\text{V}/\mu\text{s}$
Phase Margin	$G = -1\text{V/V}, C_C = 3.3\text{pF}$		40			*		Degrees
GAIN								
Open-Loop Voltage Gain	$f = \text{DC}, R_L = 2\text{k}\Omega, T_A = +25^\circ\text{C}$	86	94			*	*	dB
INPUT								
Offset Voltage ⁽⁷⁾	$T_A = +25^\circ\text{C}$		± 1	± 4		± 2	± 5	mV
	$T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$			± 5			± 10	mV
	$T_A = -55^\circ\text{C}$ to $+125^\circ\text{C}$			± 6			± 15	mV
Offset Voltage Drift	$T_A = -25^\circ\text{C}$ to $+85^\circ\text{C}$			± 20			± 80	$\mu\text{V}/^\circ\text{C}$
	$T_A = -55^\circ\text{C}$ to $+125^\circ\text{C}$			± 20			± 100	$\mu\text{V}/^\circ\text{C}$
Bias Current	$T_A = +25^\circ\text{C}$		-20	-100		*	*	pA
	$T_A = -25^\circ\text{C}$ to $+125^\circ\text{C}$		-20	-100		*	*	nA
Offset Current	$T_A = +25^\circ\text{C}$		20			*		pA
	$T_A = -55^\circ\text{C}$ to $+125^\circ\text{C}$		20			*		nA
Power Supply Rejection Ratio Common-Mode Voltage Range	$V_{CC} = \pm 15\text{V}, \pm 1\text{V}$	-10	200	500		*	*	$\mu\text{V}/\text{V}$
	$V_{CM} = -5\text{V}$ to $+5\text{V}$	60	80	+7		*	*	V
Common-Mode Rejection Ratio Impedance	Differential and Common-Mode		$10^{11} 2$			*	*	dB
	10kHz Bandwidth		20			*	*	ΩpF
Voltage Noise						*	*	$\text{nV}/\sqrt{\text{Hz}}$
POWER SUPPLY								
Rated (V_{CC})		± 9	± 15			*	*	VDC
Operating Range				± 16		*	*	VDC
Quiescent Current			± 30	± 38		*	*	mA
TEMPERATURE RANGE (Ambient)								
Operating: BM, CM SM, TM		-25		+85		*	*	$^\circ\text{C}$
		-55		+125		*	*	$^\circ\text{C}$
Storage		-65		+150		*	*	$^\circ\text{C}$
	θ_{JC} , (junction-to-case)		30			*	*	$^\circ\text{C}/\text{W}$
θ_{CA} , (case-to-ambient)		35				*	*	$^\circ\text{C}/\text{W}$

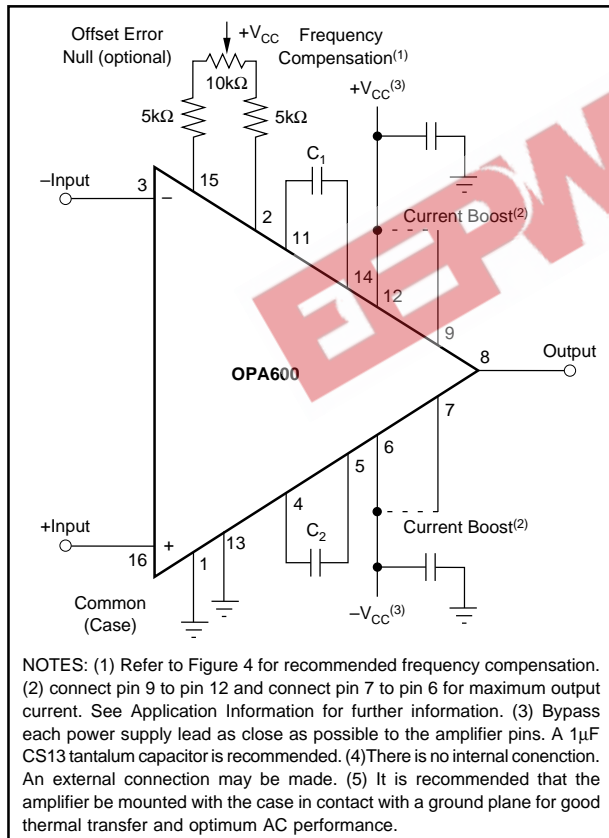
*Specification same as OPA600CM, TM.

NOTES: (1) BM, CM grades: -25°C to $+85^\circ\text{C}$. SM, TM grades: -55°C to $+125^\circ\text{C}$. (2) Pin 9 connected to $+V_{CC}$, pin 7 connected to $-V_{CC}$. Observe power dissipation ratings. (3) Pin 9 and 7 open. Single pulse $t = 100\text{ns}$. Observe power dissipation ratings. (4) Pin 9 and 7 open. See section on Current Boost. (5) $G = -1\text{V/V}$. Optimum settling time and slew rate achieved by individually compensating each device. Refer to section on Compensation. (6) Frequency compensation as discussed in section on Compensation. (7) Adjustable to zero.

MECHANICAL



CONNECTION DIAGRAM



ABSOLUTE MAXIMUM RATINGS⁽¹⁾

Supply Voltage, $+V_{CC}$ to $-V_{CC}$	$\pm 17V$
Power Dissipation, At $T_{CASE} +125^{\circ}C^{(2)}$	1.6W
Input Voltage: Differential	$\pm V_{CC}$
Common-Mode	$\pm V_{CC}$
Output Short Circuit Duration to Common	<5s
Temperature: pin (soldering, 20s)	$+300^{\circ}C$
Junction ⁽¹⁾ , T_J	$+175^{\circ}C$
Temperature Range: Storage	$-65^{\circ}C$ to $+150^{\circ}C$
Operating (case)	$-55^{\circ}C$ to $+125^{\circ}C$

NOTES: (1) Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. Exposure to absolute maximum conditions for extended periods may affect device reliability. (2) Long term operation at the maximum junction temperature will result in reduced product life. Derate internal power dissipation to achieve high MTTF.

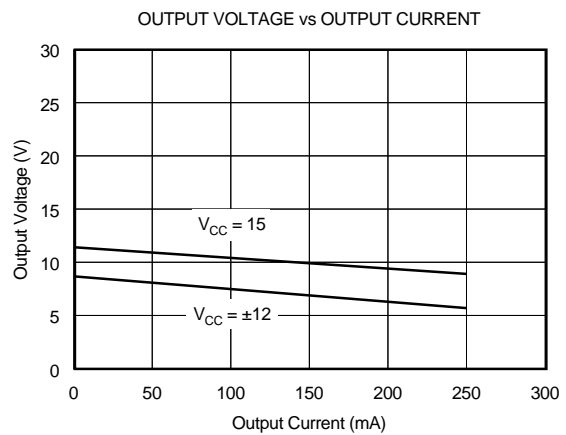
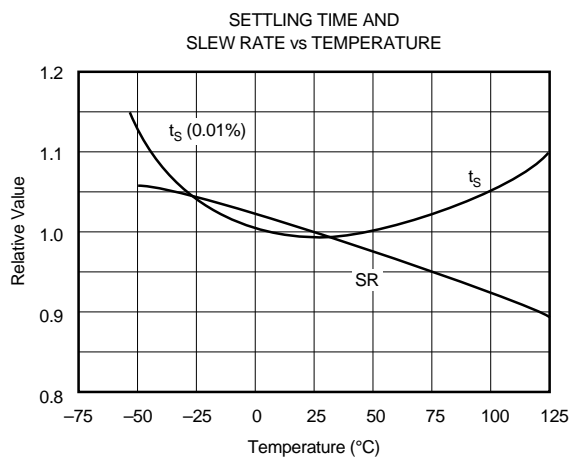
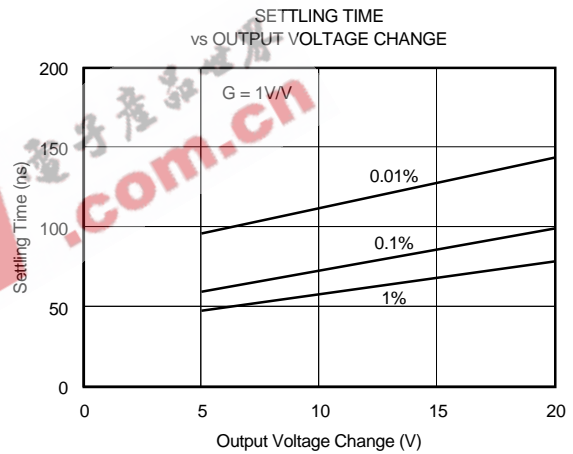
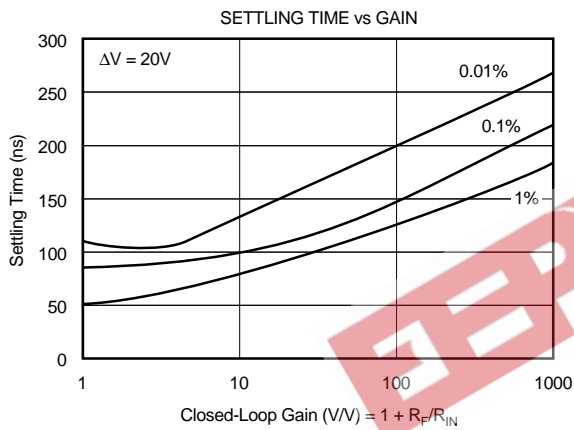
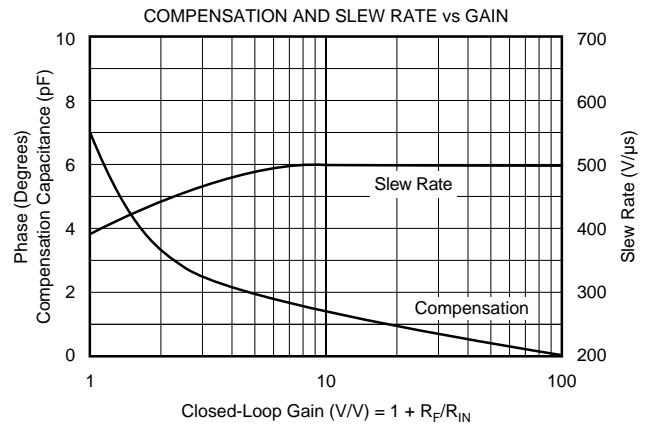
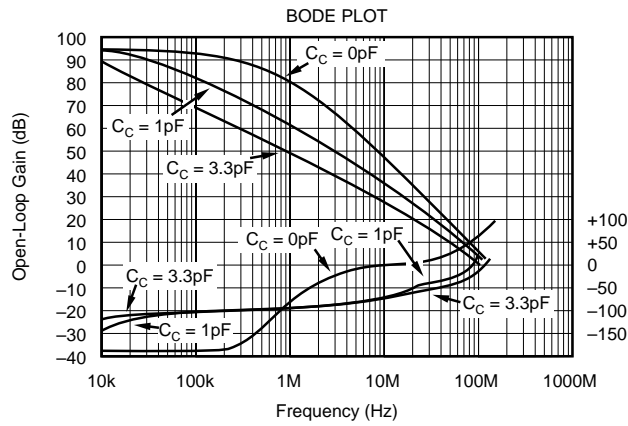
ORDERING INFORMATION

MODEL	TEMPERATURE RANGE ($^{\circ}C$)	VOLTAGE OFFSET DRIFT ($\mu V/^{\circ}C$)
OPA600BM	-25 to +85	± 80
OPA600CM	-25 to +85	± 20
OPA600SM	-55 to +125	± 100
OPA600TM	-25 to +125	± 20

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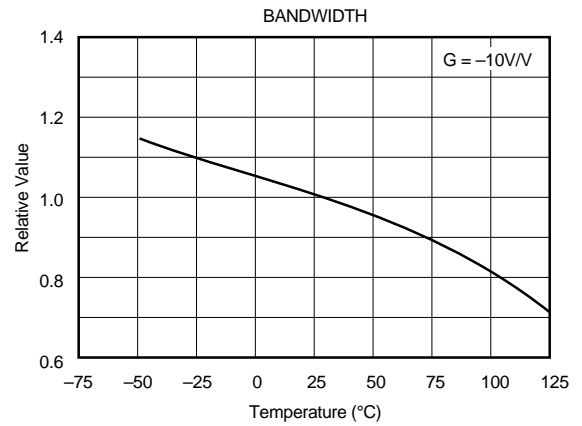
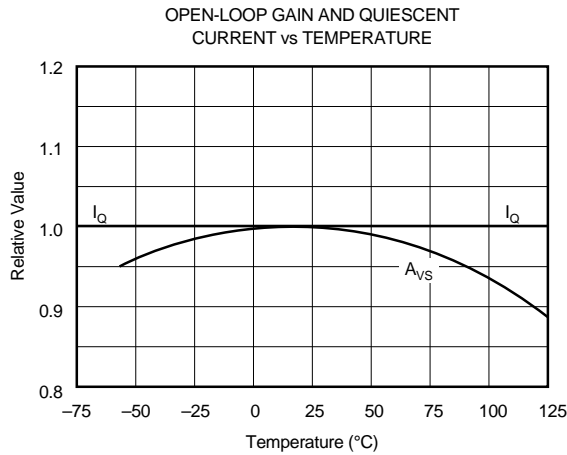
TYPICAL PERFORMANCE CURVES

Typical at $T_A = +25^\circ\text{C}$ and $\pm V_{CC} = 15\text{VDC}$, unless otherwise specified.



TYPICAL PERFORMANCE CURVES (CONT)

Typical at $T_A = +25^\circ\text{C}$, $\pm V_{CC} = 15\text{VDC}$ unless otherwise specified.



INSTALLATION AND OPERATION

WIRING PRECAUTIONS

The OPA600 is a wideband, high frequency operational amplifier with a gain-bandwidth product exceeding 5GHz. This capability can be realized by observing a few wiring precautions and using high frequency layout techniques. In general, all printed circuit board conductors should be wide to provide low resistance, low impedance signal paths and should be as short as possible. The entire physical circuit should be as small as is practical. Stray capacitances should be minimized, especially at high impedance nodes, such as the input terminals of the amplifier and compensation pins. Stray signal coupling from the output to the input should be minimized. All circuit element leads should be as short as possible and low values of resistance should be used. This will give the best circuit performance as it will minimize the time constants formed with the circuit capacitances and will eliminate stray, unwanted tuned circuits.

Grounding is the most important application consideration for the OPA600, as it is with all high frequency circuits. Ultra-high frequency transistors are used in the design of the OPA600 and oscillations at frequencies of 500MHz and above can be stimulated if good grounding techniques are not used. A ground plane is highly recommended. It should connect all areas of the pattern side of the printed circuit that are not otherwise used. The ground plane provides a low resistance, low inductance common return path for all signal and power returns. The ground plane also reduces stray signal pickup.

Point-to-point wiring is not recommended. However, if point-to-point wiring is used, a single-point ground should

be used. The input signal return, the load signal return and the power supply common should all be connected at the same physical point. This eliminates common current paths or ground loops which can cause unwanted feedback.

Each power supply lead should be bypassed to ground as near as possible to the amplifier pins. A $1\mu\text{F}$ CS13 tantalum capacitor is recommended. A parallel $0.01\mu\text{F}$ ceramic may be added if desired. This is especially important when driving high current loads. Properly bypassed and modulation-free power supply lines allow full amplifier output and optimum settling time performance.

OPA600 circuit common is connected to pins 1 and 13; these pins should be connected to the ground plane. The input signal return, load return, and power supply common should also be connected to the ground plane.

The case of the OPA600 is internally connected to circuit common, and as indicated above, pins 1 and 13 should be connected to the ground plane. Ideally, the case should be mechanically connected to the ground plane for good thermal transfer, but because this is difficult in practice, the OPA600 should be fully inserted into the printed circuit board with the case very close to the ground plane to make the best possible thermal connection. If the case and ground plane are physically connected or are in close thermal proximity, the ground plane will provide heat sinking which will reduce the case temperature rise. The minimum OPA600 pin length will minimize lead inductance, thereby maximizing performance.

COMPENSATION

The OPA600 uses external frequency compensation so that the user may optimize the bandwidth or settling time for his particular application. Several performance curves aid in the selection of the correct compensation's capacitance value. The Bode plot shows amplitude and phase versus frequency for several values of compensation. A related curve shows the recommended compensation capacitance versus closed-loop gain.

Figure 1 shows a recommended circuit schematic. Component values and compensation for amplifiers with several different closed-loop gains are shown. This circuit will yield the specified settling time. Because each device is unique and slightly different, as is each user's circuit, optimum settling time will be achieved by individually compensating each device in its own circuit, if desired. A 10% to 20% improvement in settling time has been experienced from the values indicated in the Electrical Specifications table.

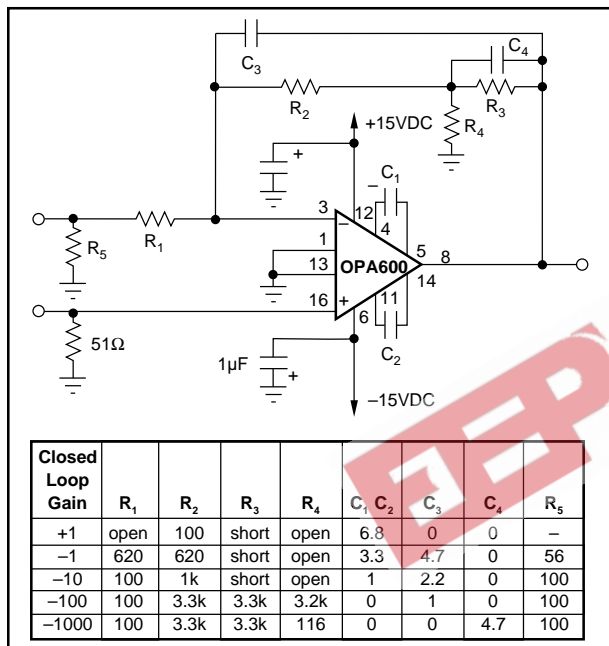


FIGURE 1. Recommended Amplifier Circuits and Frequency Compensation.

The primary compensation capacitors are C_1 and C_2 (see Figure 1). They are connected between pins 4 and 5 and between pins 11 and 14. Both C_1 and C_2 should be the same value. As Figure 1 and the performance curves show, larger closed-loop configurations require less capacitance, and improved gain-bandwidth product can be realized. Note that no compensation capacitor is required for closed-loop gains equal to or above 100V/V. If upon initial application the user's circuit is unstable, and remains so after checking for proper bypassing, grounding, etc., it may be necessary to increase the compensation slightly to eliminate oscillations. Do not over compensate. It should not be necessary to increase C_1 and C_2 beyond 10pF to 15pF. It may also be necessary to individually optimize C_1 and C_2 for improved performance.

The flat high frequency response of the OPA600 is preserved and high frequency peaking is minimized by connecting a small capacitor in parallel with the feedback resistor (see Figure 1). This capacitor compensates for the closed-loop, high frequency, transfer function zero that results from the time constant formed by the input capacitance of the amplifier, typically 2pF, and the input and feedback resistors. The selected compensation capacitor may be a trimmer, a fixed capacitor, or a planned PC board capacitance. The capacitance value is strongly dependent on circuit layout and closed-loop gain. It will typically be 2pF for a clean layout using low resistances (1k Ω) and up to 10pF for circuits using larger resistances. Using small resistor values will preserve the phase margin and avoid peaking by keeping the break frequency of this zero sufficiently high. When high closed-loop gains are required, a three-resistor attenuator is recommended to avoid using a large value resistor with its long time constant.

CAPACITIVE LOADS

The OPA600 will drive large capacitive loads (up to 100pF) when properly compensated and settling times of under 150ns are achievable. The effect of a capacitive load is to decrease the phase margin of the amplifier, which may cause high frequency peaking or oscillations. A solution is to increase the compensation capacitance, somewhat slowing the amplifier's ability to respond. The recommended compensation capacitance value as a function of load capacitance is shown in Figure 2. (Use two capacitors, each with the value indicated.) Alternately, without increasing the OPA600's compensation capacitance, the capacitive load may be buffered by connecting a small resistance, usually 5 Ω to 50 Ω , in series with the Output, pin 8.

For very-large capacitive loads, greater than 100pF, it will be necessary to use doublet compensation. Refer to Figure 3 and discussion on slew rate. This places the dominant pole at the input stage. Settling time will be approximately 50% slower; slew rate should increase. Load capacitance should be minimized for optimum high frequency performance.

Because of its large output capability, the OPA600 is particularly well suited for driving loads via coaxial cables. Note that the capacitance of coaxial cable (29pF/foot of length for RG-58) will not load the amplifier when the coaxial cable or transmission line is terminated in its characteristic impedance.

SETTLING TIME

Settling time is defined as the total time required, from the input signal step, for the output to settle within the specified error band around the final value. This error band is expressed as a percentage of the magnitude of the output transition, a 10V step.

Settling time is a complete dynamic measure of the OPA600's total performance. It includes the slew rate time, a large signal dynamic parameter, and the time to accurately reach the final value, a small signal parameter that is a function of bandwidth and open-loop gain. Performance curves show

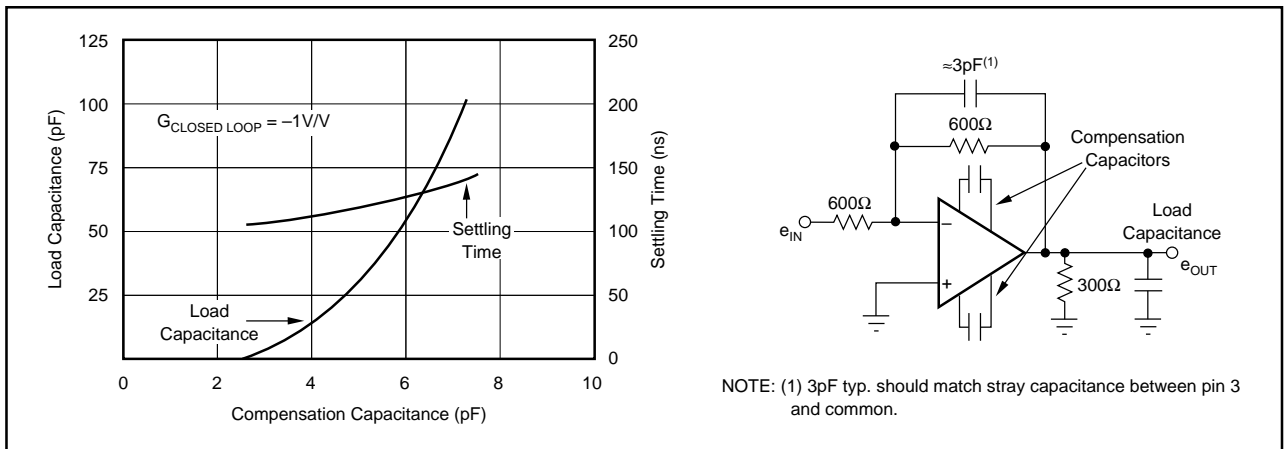


FIGURE 2. Capacitive Load Compensation and Response.

the OPA600 settling time to $\pm 1\%$, $\pm 0.1\%$, and $\pm 0.01\%$. The best settling time is achieved in low closed-loop gain circuits.

Settling time is dependent upon compensation. Under-compensation will result in small phase margin, overshoot or instability. Over-compensation will result in poor settling time.

Figure 1 shows the recommended compensation to yield the specified settling time. Improved or optimum settling time may be achieved by individually compensating each device in the user's circuit since individual devices vary slightly from one to another, as do user's circuits.

SLEW RATE

Slew rate is primarily an output, large signal parameter. It has virtually no dependence upon the closed-loop gain or small signal bandwidth. Slew rate is dependent upon compensation and decreasing the compensation capacitor value will increase the available slew rate as shown in the performance curve.

The OPA600 slew rate may be increased by using an alternate compensation as shown in Figure 3. The slew rate will increase between 700 and 800V/ μ s typical, with 0.01% settling time increasing to between 175 and 190ns typical, and 0.1% settling time increasing to between 110 and 120ns typical.

For alternate doublet compensation refer to Figure 3. For a closed-loop gain equal to -1 , delete C_1 and C_2 and add a series RC circuit ($R = 22\Omega$, $C = 0.01\mu\text{F}$) Between pins 14 and 4. Make no connections to pins 11 and 5. Absolutely minimize the capacitance to these pins. If a connector is used for the OPA600, it is recommended that sockets for pins 11 and 5 be removed. For a PC board mount, it is recommended that the PC board holes be overdrilled for pins 11 and 5 and adjacent ground plane copper be removed. Effectively, this compensation places the dominant pole at the input stage, allowing the output stage to have no compensation and to slew as fast as possible. Bandwidth and settling time are impaired only slightly. For closed-loop gains other than -1 , different values of R and C may be required.

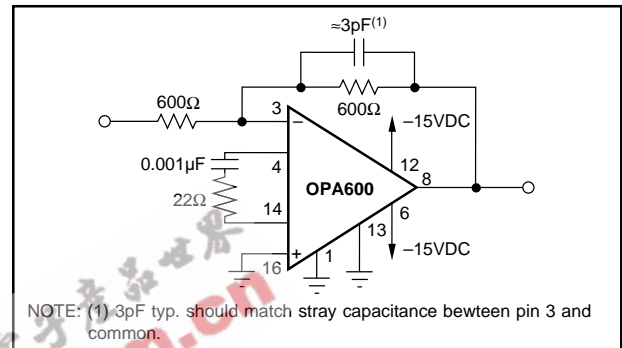


FIGURE 3. Amplifier Circuit for Increased Slew Rate.

OFFSET ADJUSTMENT

The offset voltage of the OPA600 may be adjusted to zero by connecting a 5k Ω resistor in series with a 10k Ω linear potentiometer in series with another 5k Ω resistor between pins 2 and 15, as shown in Figure 4. It is important that one end of each of the two resistors be located very close to pins 2 and 15 to isolate and avoid loading these sensitive terminals. The potentiometer should be a small noninductive type with the wiper connected to the positive supply. The leads connecting these components should be short, no longer than 0.5-inch, to avoid stray capacitance and stray signal pick-up. If the potentiometer must be located away from the immediate vicinity of the OPA600, extreme care must be observed with the sensitive leads. Locate the two 5k Ω resistors very close to pins 2 and 15.

Never connect $+V_{CC}$ directly to pin 2 or 15. Do not attempt to eliminate the 5k Ω resistors because at extreme rotation,

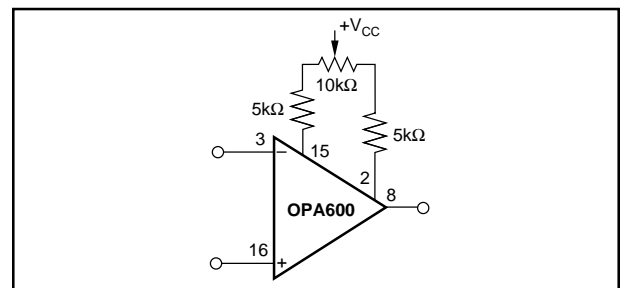


FIGURE 4. Offset Null Circuit.

the potentiometer will directly connect $+V_{CC}$ to pin 2 or 15 and permanent damage will result.

Offset voltage adjustment is optional. The potentiometer and two resistors are omitted when the offset voltage is considered sufficiently low for the particular application. For each microvolt of offset voltage adjusted, the offset voltage temperature sensitivity will change by $\pm 0.004\mu\text{V}/^\circ\text{C}$.

CURRENT BOOST

External ability to bypass the internal current limiting resistors has been provided in the OPA600. This is referred to as current boost. Current boost enables the OPA600 to deliver large currents into heavy loads ($\pm 200\text{mA}$ at $\pm 10\text{V}$). To bypass the resistors and activate the current boost, connect pin 7 to $-V_{CC}$ at pin 6 with a short lead to minimize lead inductance and connect pin 9 to $+V_{CC}$ at pin 12 with a short lead.

CAUTION—Activating current boost by bypassing the internal current limiting resistors can permanently damage the OPA600 under fault conditions. See section on short circuit protection.

Not activating current boost is especially useful for initial breadboarding. The 50Ω ($\pm 5\%$) current limiting resistor in the collector circuit of each of the output transistors causes the output transistors to saturate; this limits the power dissipation in the output stage in case of a fault. Operating with the current boost not activated may also be desirable with small-signal outputs (i.e., $\pm 1\text{V}$) or when the load current is small.

Each resistor is internally capacitively-bypassed ($0.01\mu\text{F}$, $\pm 20\%$) to allow the amplifier to deliver large pulses of current, such as to charge diode junctions or circuit capacitance and still respond quickly. The length of time that the OPA600 can deliver these current pulses is limited by the RC time constant.

The internal voltage drops, output voltage available, power dissipation, and maximum output current can be determined for the user's application by knowing the load resistance and computing:

$$V_{\text{OUT}} = 14 [R_{\text{LOAD}} \div (50 + R_{\text{LOAD}})]$$

This applies for R_{LOAD} less than 100Ω and the current boost not activated. When R_{LOAD} is large, the peak output voltage is typically $\pm 11\text{V}$, which is determined by other factors within the OPA600.

SHORT-CIRCUIT PROTECTION

The OPA600 is short-circuit-protected for momentary short to common ($< 5\text{s}$), typical of those encountered when probing a circuit during experimental breadboarding or troubleshooting. This is true only if pins 7 and 9 are open (current boost not activated.) An internal 50Ω resistor is in series with the collector of each of the output transistors, which under fault conditions will cause the output transistors to saturate and limit the power dissipation in the output stage. Extended application of an output short can damage the amplifier due to excessive power dissipation.

The OPA600 is not short-circuit-protected when the current boost is activated. The large output current capability of the OPA600 will cause excessive power dissipation and permanent damage will result even for momentary shorts to ground.

Output shorts to either supply will destroy the OPA600 whether the current boost is activated or not.

HEAT SINKING AND POWER DISSIPATION

The OPA600 is intended as a printed circuit board mounted device, and as such does not require a heat sink. It is specified for ambient temperature operation from -55°C to $+125^\circ\text{C}$. However, the power dissipation must be kept within safe limits. At extreme temperature and under full load conditions, some form of heat sinking will be necessary. The use of a heat sink, or other heat dissipating means such as proximity to the ground plane, will result in cooler operating temperatures, better temperature performance, and improved reliability.

It may be necessary to physically connect the OPA600 to the printed circuit board ground plane, attach fins, tabs, etc., to dissipate the generated heat. Because of the wide variety of possibilities, this task is left to the user. For all applications it is recommended that the OPA600 be fully inserted into the printed circuit board and that the pin length be short. Heat will be dissipated through the ground plane and the AC performance will be its best.

With a maximum case temperature of $+125^\circ\text{C}$ and not exceeding the maximum junction of $+175^\circ\text{C}$, a maximum power dissipation of 600mW is allowed in either output transistor.

TESTING

For static and low frequency dynamic measurements, the OPA600 may be tested in conventional operational amplifier test circuits, provided proper ground techniques are observed, excessive lead lengths are avoided, and care is maintained to avoid parasitic oscillations. The circuit in Figure 3 is recommended for low frequency functional testing, incoming inspection, etc. This circuit is less susceptible to stray capacitance, excessive lead length, parasitic tuned circuits, changing capacitive loads, etc. It does not yield optimum settling time. We recommend placing a resistor (approximately 300Ω) in series with each piece of test equipment, such as a DVM, to isolate loading effects on the OPA600.

To realize the full performance capabilities of the OPA600, high frequency techniques must be employed and the test fixture must not limit the amplifier. Settling time is the most critical dynamic test and Figure 5 shows a recommended OPA600 settling time test circuit schematic. Good grounding, truly square drive signals, minimum stray coupling, and small physical size are important.

The input pulse generator must have a flat topped, fast settling pulse to measure the true settling time of the amplifier. A circuit that generates a $\pm 5\text{V}$ flat topped pulse is shown in Figure 6.

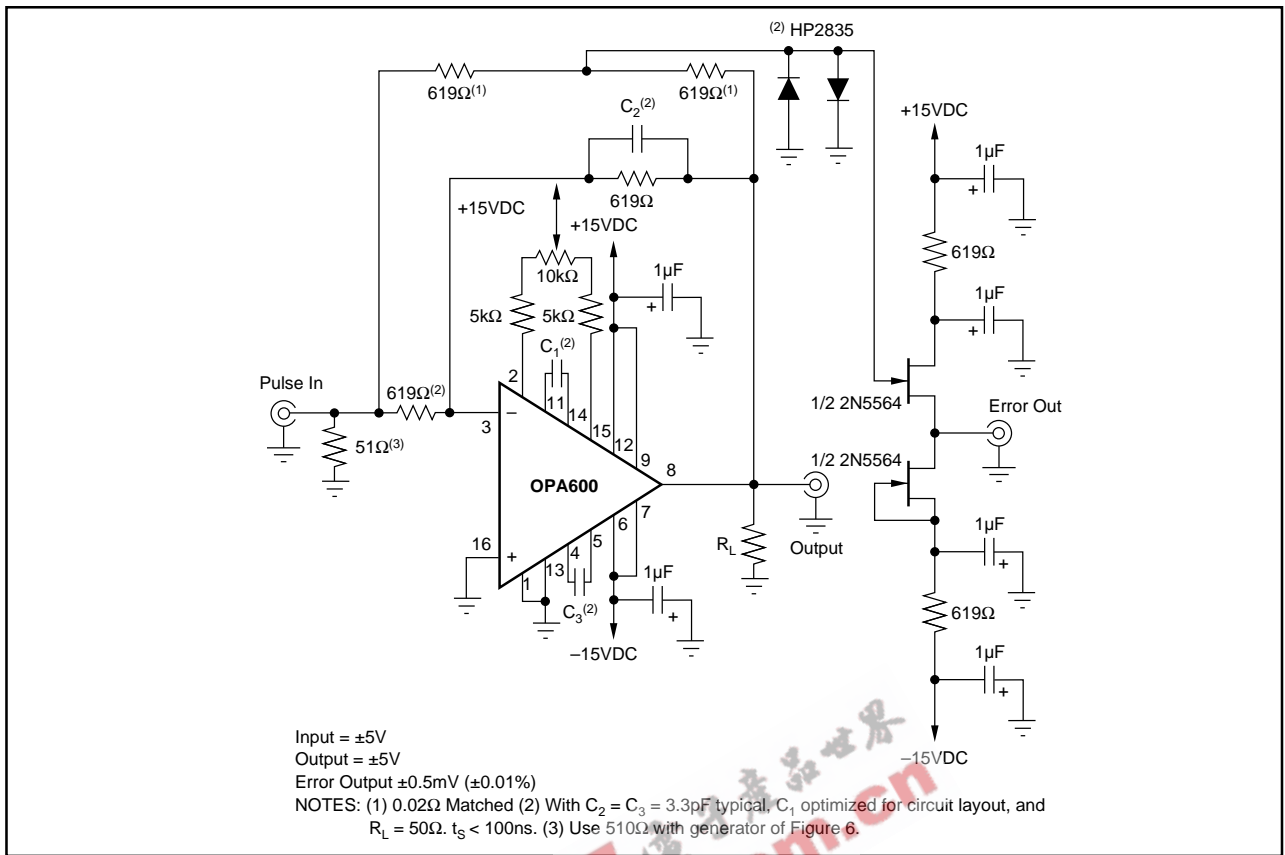


FIGURE 5. Settling Time and Slew Rate Test Circuit.

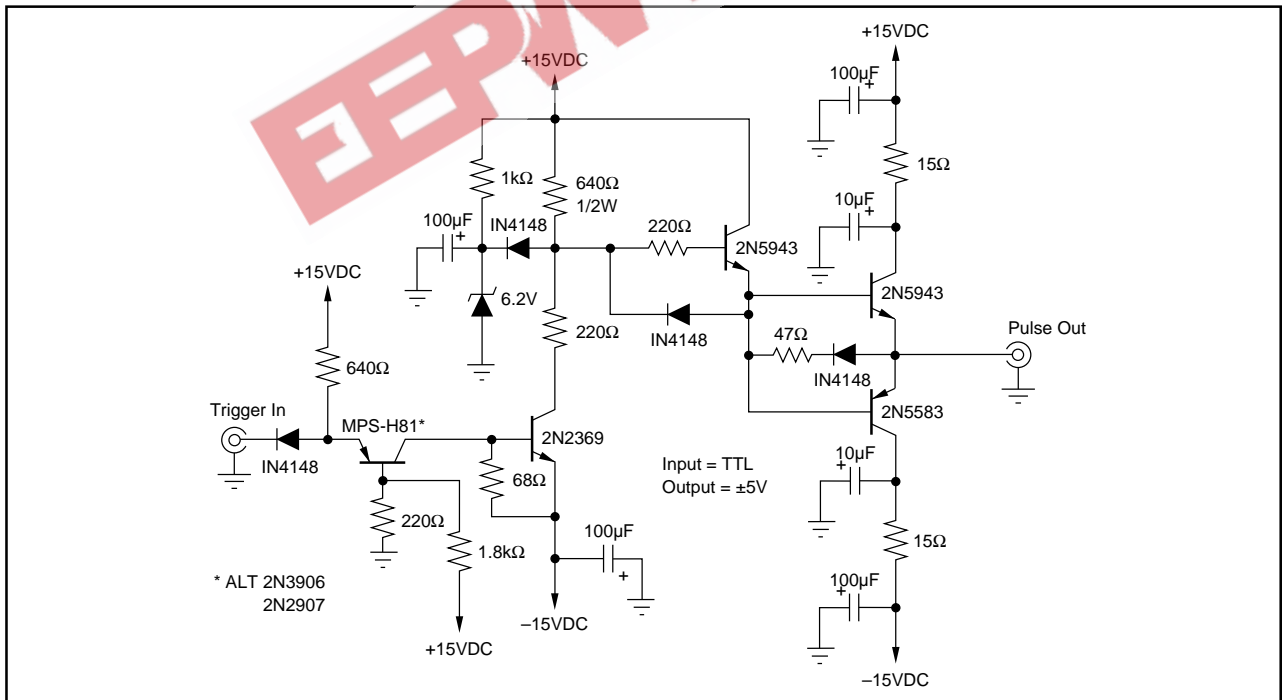


FIGURE 6. Flat Top Pulse Generator.