Low Offset Chopper Stabilized Operational Amplifiers

1701 1703

The 1701 and 1703 incorporate all the features that make a chopper stabilized operational amplifier the **only** viable solution to a large class of op amp problems. The most salient features of these units include offset voltage and bias current errors that, in most applications, **never** have to be trimmed. Open loop gains to 126dB, CMRR of 140dB, power consumption of 150mW, and typical flicker noise of only 1μV all contribute to making the 1701 and 1703 two of the most cost-effective precision op amp buys.

	1703	1703-01	1701	1701-01
Initial Offset Voltage (μV, Max) (No external Trim)	40	15	15	15
Offset Voltage vs. Temp. (μV/°C, Max)	1	0.3	0.25	0.1
Offset Voltage vs. Time (μV/year, Typ)	5	5	5	5
Initial Bias Current (pA, Max)	50	50	50	50
Bias Current vs. Temp. (pA/°C, Max)	2	1	1	1
Slew Rate (V/μsec Max)	0.25	0.25	1.2	1.2
Flicker Noise (μV p-p, Typ) (0.016Hz to 1.6Hz)	1	1	1	1

Table 1.

Besides superior stability, additional advantages of the 1701 over the 1703 are full power bandwidth and output voltage range. The 1701 is capable of putting a 20kHz, 10Vp-p sine wave into a 2kΩ load. The 1703 has superior open loop gain and can operate all the way down to ± 6V supplies. While for most applications no zero trim is required, a 50kΩ trim potentiometer can be used to reduce the initial offset voltage at the input to sub microvolt levels. When operating under these conditions, the precautions listed in Table 2 should be followed.

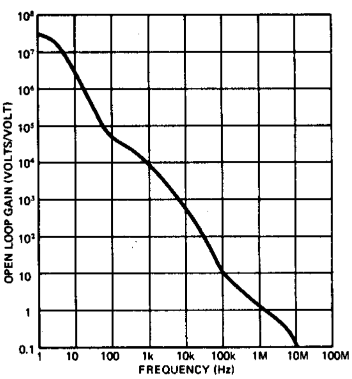


Figure 1. Model 1701 Bode Plot

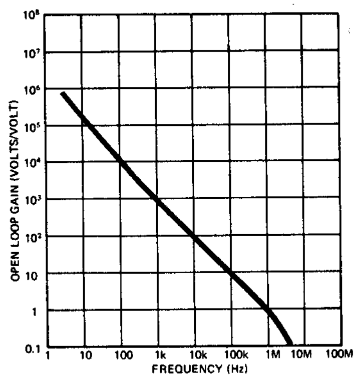
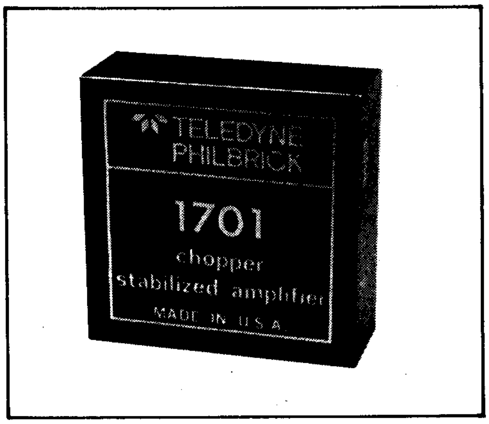


Figure 2. Model 1703 Bode Plot



FEATURES

- Low Cost
- Low Initial Offset Error
  1701 ± 15μV Max.
  1703 ± 40μV Max.
- Ultra Low Offset Drift
  1701-01 ± 0.1μV/°C
  1703-01 ± 0.3μV/°C
- ± 1pA/°C Bias Drift
- 126dB Open Loop Gain
- 140dB CMRR
- Wide Power Supply Range

APPLICATIONS

- Precision Integrators
- Stable Voltage Sources
- Low Level Amplification
- Summing Amplifiers
- Portable Precision Instruments
- Applications Where Periodic Recalibration is Impossible

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SPECIFICATIONS (@ 25°C, V_{CC} = ±15 V, Rated Load, unless otherwise noted)

	1701		1703	
	Typical	Guaranteed	Typcial	Guaranteed
OUTPUT RANGE				
Voltage	———	±12 V	———	±10 V
Current	———	±5 mA	———	±5 mA
VOLTAGE GAIN (dc Open Loop)				
Rated Load	120 dB	112 dB	126 dB	120 dB
FREQUENCY RESPONSE (Inverting)				
Small Signal (Unity Gain, Open Loop)	1 MHz	———	1 MHz	———
Max Sine Power Out (3% to 5% distortion)	40 kHz	20 kHz	9 kHz	4.5 kHz
Max Peak to Peak Out (Triangle Wave)	30 kHz	———	6 kHz	———
Slew Rate	———	1.2 V/μsec	———	0.25 V/μsec
Overload Recovery Time (Step Input)	3 sec	———	3 sec	———
Capacitive Load Without Instability	0.01 μF	———	0.10 μF	———
INPUT VOLTAGE RANGE				
Differential (Between Inputs Abs. Max.)	$+V_{CC} - (-V_{CC})$	———	$+V_{CC} - (-V_{CC})$	———
Common Mode for DC Linear Operation	±500 mV (dc only)	———	±500 mV (dc only)	———
CMRR (DC) at CMV = ±500 mV	140 dB	———	140 dB	———
Common Mode Fault	———	$\pm V_{CC}$	———	$\pm V_{CC}$
INPUT OFFSET VOLTAGE				
Initial (without external trim) @ 25°C	———	±15 μV	———	±40 μV
Initial (without external trim) @25°C (1703-01)	———	———	———	±15 μV
Zero Adjustment (optional)	50 kΩ pot	———	50 kΩ pot	———
Vs. Temperature (Avg. over operating temp.)	———	±0.25 μV/°C	———	±1 μV/°C
Vs. Temperature (1701-01)(Avg. –25 to +85°C)	———	±0.1 μV/°C	———	———
Vs. Temperature (1703-01)(Avg. 0 to +70°C)	———	———	———	±0.3 μV/°C
Vs. Time (per year)	±5 μV	———	±5 μV	———
Vs. Power Supply	±0.2 μV/V	———	±1 μV/V	———
INPUT BIAS CURRENT				
Initial @ 25°C	———	±50 pA	———	±50 pA
Vs. Temperature	———	±1 pA/°C	———	±2 pA/°C
Vs. Temperature (1703-01)	———	———	———	±1 pA/°C
Vs. Time (per year)	±10 pA	———	±10 pA	———
Vs. Power Supply	±2 pA/V	———	±5 pA/V	———
INPUT IMPEDANCE @ dc				
Differential	500 kΩ ‖ 100 pF	———	500 kΩ ‖ 100 pF	———
Common Mode (CMV < 500 mV)	1000 MΩ		1000 MΩ	
NOISE (REFERRED TO INPUT)				
Flicker (0.016 to 1.6 Hz)				
Voltage	1 μV (p-p)	———	1 μV (p-p)	———
Current	5 pA (p-p)	———	3 pA (p-p)	———
Midband (1.6 to 160 Hz)				
Voltage	2 μV (rms)	———	2 μV (p-p)	———
Current	———	———	6 pA (rms)	———
Broadband (160 Hz ro 16 kHz)				
Voltage	5 μV (rms)	———	2 μV (rms)	———
Chopper (≈ 250 Hz)				
Voltage	10 μV (p-p)	———	2 μV (p-p)	———
Current	100 pA (p-p)	———	100 pA (p-p)	———
POWER REQUIREMENTS				
Voltage Range	±8 to ±20 V	———	±6 to ±18 V	———
Current (Quiescent)	———	±5 mA	———	±5 mA
TEMPERATURE RANGE				
Operating (Rated)	———	–25 to +85°C	———	0 to 70°C
Operating (Derated)	———	–55 to +100°C	———	–55 to +100°C
Storage	———	–55 to +125°C	———	–55 to +125°C
MTBF	———	———	>100,000 hrs.	———

DRIFT (Corrected by the Chopper-Stabilized Amplifier)

Drift may be considered to be a gradually-developing change in the offset voltage or current of an operational amplifier. Long-term drift normally averages close to zero. One can expect, however, random fluctuations weekly, hourly, or per second. Quite often the stability of an amplifier is more dependent on the external environment than the random, internally-generated changes. External drift factors include: temperature, rate of change of temperature, humidity, contamination of insulation, external component parameter changes, and power supply changes. Because apparent drift due to internal temperature instability cannot be separated from random drift, it is included in the overall drift specification of the amplifier.

Presently, the most effective method of minimizing drift is the use of a modulated-carrier or "chopper" amplifier in the "dc" and low-frequency signal path only. This preamplifier is employed to maintain the effective offset at the negative input of the main amplifier as near zero as possible; for this reason, it is called the stabilizer.

Chopper-stabilized amplifiers take advantage of the fact that generally, the offset, drift and noise levels of a narrow-band chopper-modulator/demodulator dc amplifier are 1 or 2 orders of magnitude lower than those achieved in conventional unstabilized, wideband, differential amplifiers. By combining the two types, the advantages of both are realized. At very low frequencies there are, in effect, two amplifiers working in cascade until a frequency is reached where the "feed-forward path" to the main amplifier takes over from the path through the stabilizer.

A block diagram of 1701 & 1703 (Figure 3) shows how the input signal is connected to two amplifiers: directly (dc coupling) to a chopper-modulator/demodulator (slow, narrow-band) stabilizing amplifier; and through a capacitor (ac coupling) to the main (fast, wideband) amplifier. The function of the stabilizer is to drive the effective offset at the positive input terminal to zero, and hold it there regardless of the offset generated in the main amplifier, and regardless of the configuration of the input and feedback networks. It does this by introducing a dc voltage very nearly equal to the effective voltage offset of the main amplifier into its positive terminal. The residual offset consists of switching inefficiencies and leakages in the modulator, plus the main amplifier offset divided by the gain of the stabilizer.

MINIMIZING DRIFT

- Avoid connections that could act as thermocouples
- Use low T. C. components in associated circuitry
- Use stable, well-regulated supplies
- Avoid temperature gradients across amplifier
- Avoid temperature transients. Maintain d/dt of temperature low
- Keep "R_S" as low as feasible so $\Delta I \times R$ is minimum
- Use a good grounding system
- Zero offset after amplifier has reached normal operating temperature

Table 2.

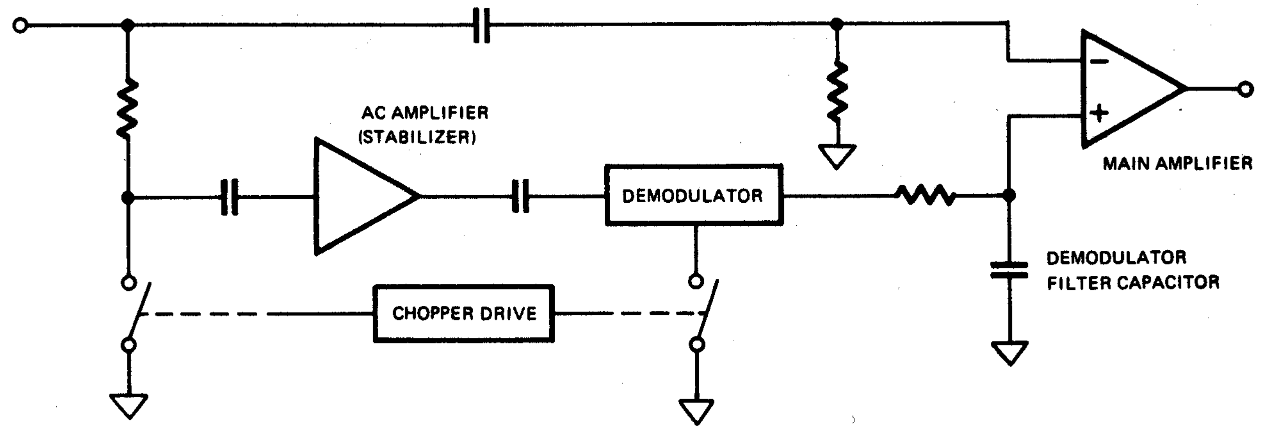


Figure 3. Block Diagram of Models 1701/1703

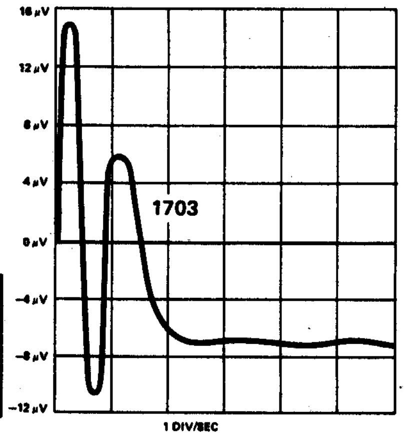


Figure 4. Input Offset Voltage vs Time

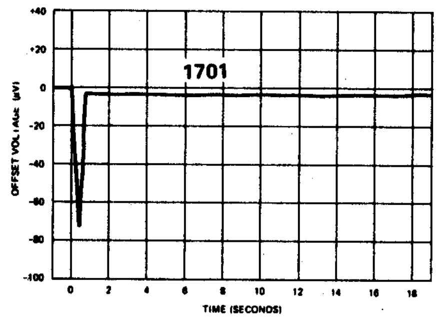


Figure 5. Warm-Up Drift

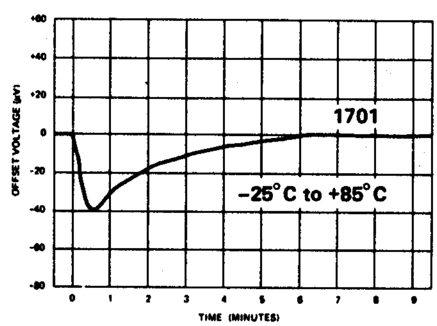


Figure 6. Thermal Shock

Drift vs Time and Temperature

A major feature of both units is minimum "warm-up drift". Either device will settle to within one microvolt of final offset voltage within 1 to 3 seconds.

Noise

Chopper related noise, a rarely mentioned but potentially troublesome parameter, has been minimized to 2 µV p-p in the 1703 and 10 µV p-p in the 1701. Both units have chopper current noise of 1.00 pA p-p. This is narrow band noise produced by a filtered 250 Hz (1703) or 300 Hz (1701) square wave, and if required can be filtered with a low pass or band rejection filter.

There are several techniques for defining noise. The specifications define it as peak to peak or RMS between the 3 dB points of three, 2-decade frequency bands, covering the range from 0.016 Hz to 16 kHz. A second method is normalized or "spot" noise in a one Hertz bandwidth.

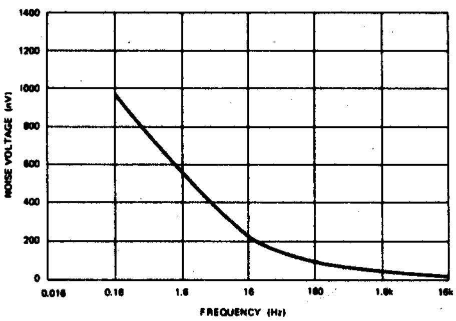


Figure 7. RMS Noise Voltage vs Frequency

APPLICATIONS

The 1701 and 1703 are used for all standard inverting operational amplifier circuits. In addition to the basic inverter, these include the current to voltage converter, integrator, absolute value circuit, peak detector, etc. To each they give the long term precision provided by high gain, low drift and low noise.

When non-inverting operation is required (follower, follower with gain) the "inside out" follower of Figure 8 is used. In this circuit the output of the amplifier is connected to signal ground, while the buffered or amplified output signal is taken from power supply common. The high impedance input is now the minus terminal of the amplifier. This circuit requires a floating or isolated power such as is readily provided by the Model 2301 DC to DC converter or batteries.

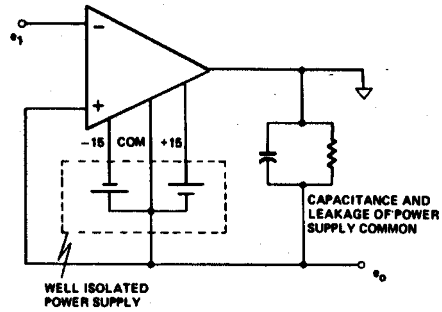
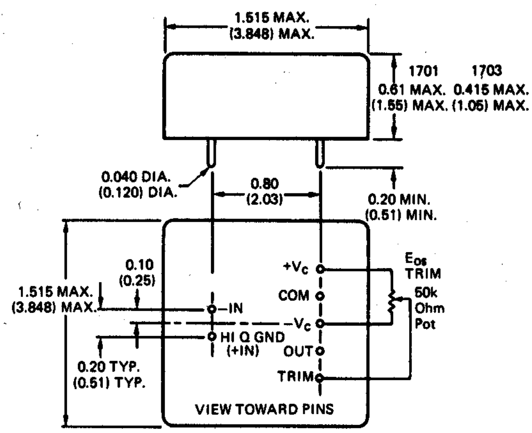


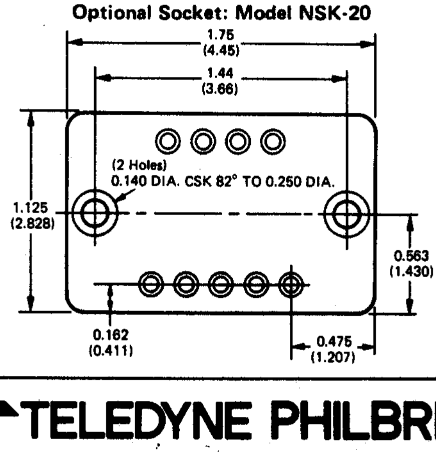
Figure 8. "Inside-out" Follower

An alternate approach is to use the TP Model 1340 integrated circuit chopper stabilized amplifier which is capable of non-inverting AND differential input operations.



±0.01 Non-cumulative tolerance between pins
±0.02 Tolerance from case edge to center of pin
NOTE: All Dimensions in Parentheses are expressed in Centimeters.

Optional Socket: Model NSK-20



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