oei

Optical Electronics Incorporated

LINEAR LOW-NOISE FET INPUT WIDEBAND PRE-AMPLIFIER

FEATURES
- HIGH CONTROLLED GAIN: 35dB Typ
- VERY LOW NOISE: 2 nV/$\sqrt{Hz}$
- HIGH SPEED: 400 V/μsec Typ
- WIDE BANDWIDTH: 100 MHz
- LOW SUPPLY CURRENT: +10mA @ gain 30
- FET INPUT: 10^{11} Ω
- SINGLE POWER SUPPLY: +15V nominal

APPLICATIONS
- INFRARED DETECTION
- LOW NOISE AMPLIFICATION
- ANALOG TO DIGITAL CONVERSION
- SONAR APPLICATION
- AUDIO PREAMPLIFIERS
- ULTRASONIC APPLICATIONS

DESCRIPTION

The AH0013 is a linear wideband preamplifier with a very low noise characteristic. Its typical noise voltage spectral density is 800 pV/$\sqrt{Hz}$ measured at an operating frequency of 1 MHz. With proper external component selection the AH0013 has a usable bandwidth in excess of 100 MHz. This is an inverting amplifier.

Only two standard, and therefore easily obtainable capacitors, are required to set lower and upper frequency rolloff. Simple RL, RC or LC circuits connected externally allow the use of the unit as a tuned amplifier with narrow to wide bandwidths, as active low, high, or bandpass filter or as an inverting amplifier. Its high speed allows applications in the digital design area as well.

These features have been made possible by the hybrid design which employs a very low noise FET coupled to a unity gain amplifier.

The standard 8-pin mini-dip package allows easy application of the amplifier for low noise requirements in commercial and military sonar devices. Audio preamplifiers, where low noise coupled with high usable gain and frequency response are required, present a large applications area. Ultrasonic equipment in the medical
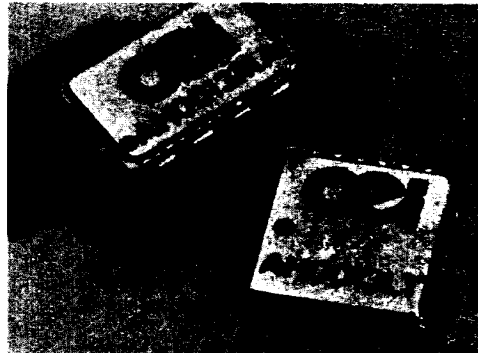
field, (sonar imaging) where frequencies in the range of 2 to 10 MHz are required, can take advantage of all main features of the device.

Further applications offer themselves in the areas of infrared detection, where extremely small temperature differentials must be detected over a wide frequency range, and in commercial as well as in military communications equipment. The low noise and high speed of the AH0013 also make it useful in digital applications for example, for low noise amplification and level setting for analog to digital (A/D) converters.

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SPECIFICATIONS

ELECTRICAL

Specifications at T_A = +25°C, Vcc = +15 VDC unless otherwise noted.

| MODEL				AH0013		
PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS	
VOLTAGE GAIN						
			35		dB	
INPUT						
Resistance			10^{11}		Ω	
Voltage	@ gain 30 dB		± 1		V	
Bias Current	@gain 30 dB		+50		pA	
Noise Spectral Density						
Noise Voltage AH0013CA/MA	SEE GRAPH FOR		1.5	2	nV/$\sqrt{\text{Hz}}$	
AH0013CB/MB	NOISE VS FREQUENCY &		2.5	3	nV/$\sqrt{\text{Hz}}$	
Noise Current	FIGURE 7 FOR TEST CIRCUIT		10		fA/$\sqrt{\text{Hz}}$	
Capacitance			4		pF	
OUTPUT						
Voltage Swing	@ gain 30 dB		3		V(P-P)	
Load Resistance				50	Ω	
Load Current			5	7.5	mA	
Output Resistance			50		Ω	
Load Capacitance				10	nF	
FREQUENCY RESPONSE						
Slewing Rate	@ gain 30 dB	350	400		V/μsec	
Full Output Frequency			20		MHz	
Overload Recovery Time			100		ns	
Gain Bandwidth Product			100		MHz	
TEMPERATURE ENVIRONMENT						
Thermal Resistance of Package	@ gain 30 dB			65	°C/W	
Quiescent Temperature Rise	@ gain 30 dB		13		°C	
Voltage		+6	+15	+18	V	
Quiescent Supply Current	@ gain 30 dB		10		mA	
Quiescent Power Dissipation			150		mW	
Socket	8 pin dual inline standard					
MTBF-per-MIL-HDBK-217C-GF			692		K hrs.	

MECHANICAL DESCRIPTION: The AH0013 is a standard 8-pin, ceramic mini-DIP. Its pins are compatible with standard 0.3-in. dual in-line sockets. Unit available in a leadless chip carrier.

AH0013MA and AH0013MB are rated at -55°C to +125°C.

AH0013CA and AH0013CB are rated at 0°C to +70°C and are epoxy sealed with ceramic lids.

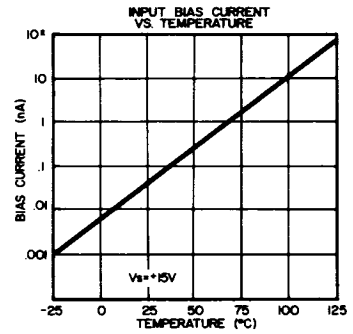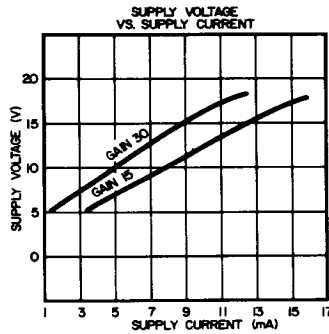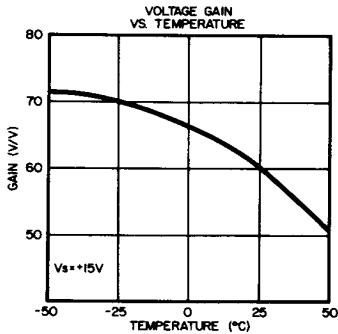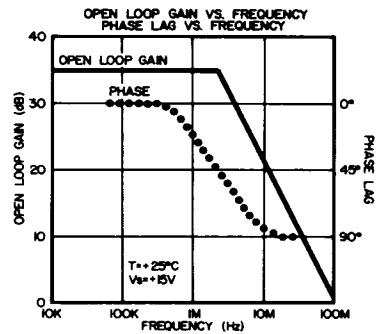| PIN CONNECTIONS |
|---|
| 1 DECOUPLE |
| 2 GAIN ELEMENT |
| 3 INPUT |
| 4 COMMON |
| 5 BYPASS |
| 6 OUTPUT |
| 7 SUPPLY |
| 8 NO CONNECTIONS |
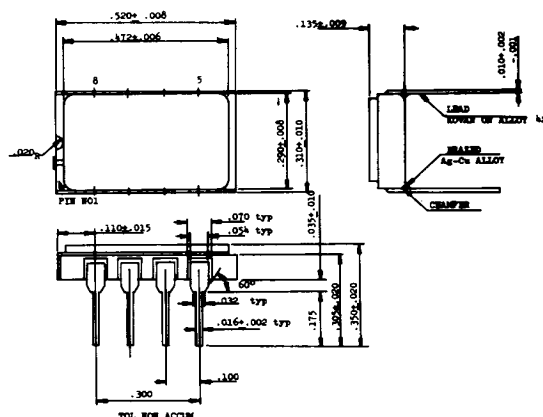
AH0013 is also available in a leadless chip carrier.

AH0013
TYPICAL PERFORMANCE CURVES
(T$_A$ = +25°C, V$_{CC}$ = +15VDC unless otherwise noted)
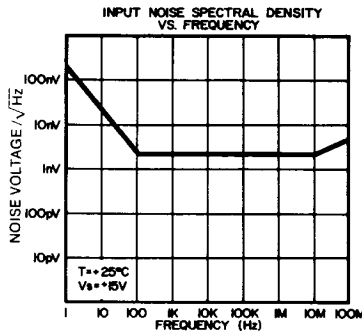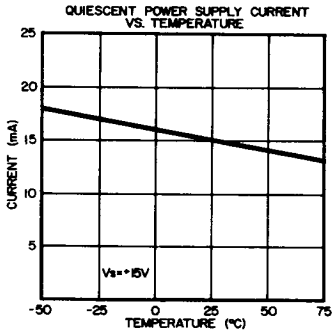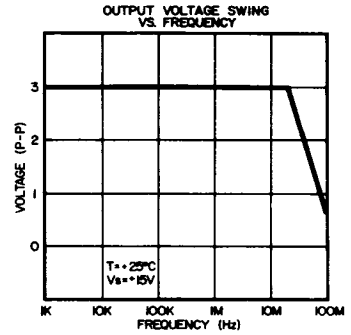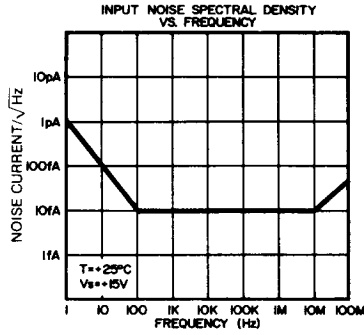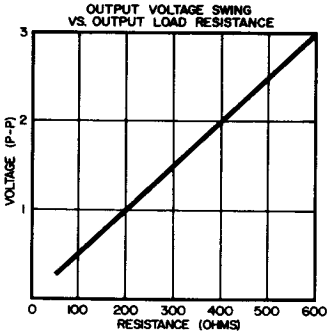
OUTPUT VOLTAGE SWING
VS. OUTPUT LOAD RESISTANCE

INPUT NOISE SPECTRAL DENSITY
VS. FREQUENCY

OUTPUT VOLTAGE SWING
VS. FREQUENCY

QUIESCENT POWER SUPPLY CURRENT
VS. TEMPERATURE

INPUT NOISE SPECTRAL DENSITY
VS. FREQUENCY

OPEN LOOP GAIN VS. FREQUENCY
PHASE LAG VS. FREQUENCY

VOLTAGE GAIN
VS. TEMPERATURE

SUPPLY VOLTAGE
VS. SUPPLY CURRENT

INPUT BIAS CURRENT
VS. TEMPERATURE

GENERAL, Typical Applications

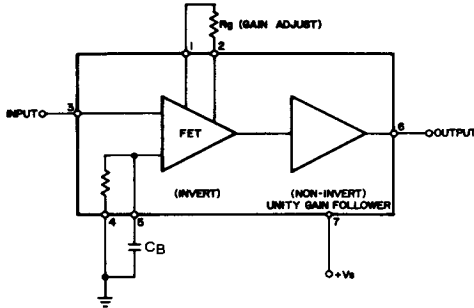Basic connections for the AH0013 are shown in figure 1.

FIGURE 1: BASIC CONNECTIONS

The diagram for a general application of the AH0013 is presented in figure 2. As can be seen only a +15 VDC (nominal) power supply is required. In order to keep noise input at its lowest the power supply ripple should not be more than 250μV. Additionally three capacitors are connected to pin 7. Typically a 15μF tantalum, a 0.1μF ceramic, and 330 pF silver mica (or glass composition) capacitor should be connected together to provide most effective supply noise suppression. These capacitors together with the common mode rejection of the device itself should provide sufficient filtering. Capacitors, as all other external components, should be mounted as closely as possible to the device.
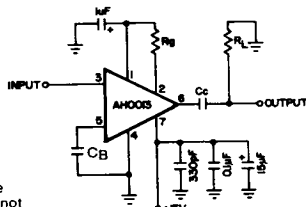
NOTE: The AH0013 is not recommended for DC amplification.

$f_L = 1.6 \times 10^{-1}/C_B$ in Hz
GAIN = 6 Rg
$C_C > 1/2\pi f_L R_L$
Where all C are in Farads.
Rg is in kΩ. R_L is in ohms.

FIGURE 2: TYPICAL APPLICATION

The input line must be shielded up to the pin and kept as short as possible to minimize noise pickup from external sources. The output line and the associated passive devices are more noise immune (depending on output impedance of course) and can thus be treated with somewhat less care (see typical PC board layout pg. 8). However, overall performance of a system will depend on each of its stages. The gain of the AH0013 is determined by the value of the resistor

RG between pins 1 and 2. If RG were chosen to be 5.1kΩ the resulting gain would be in the order of 28 to 32 (approximately 30 dB) with a linear frequency response to 7 MHz. The lower frequency rolloff point will be discussed below. RG is series connected to a device internal resistor in a voltage divider arrangement and thus determines essentially the current into the device. An increase in RG will result in an increase in gain of the AH0013. Since this will cause a smaller current the output voltage swing will drop as dictated by the two voltage divider resistors mentioned above. A bypass capacitor between pin 1 and ground will help retain the noise characteristics of the device.

The decrease in output voltage swing could, of course, be countered by appropriate biasing. This is, however, not recommended because biasing the device will unnecessarily introduce additional noise which is not desirable for the applications for which the AH0013 is intended. Further, it should be remembered that the increased RG values will also introduce additional Johnson noise. The recommended procedure is to make a tradeoff between gain and allowable noise and follow the AH0013 with an additional low noise stage of amplification with a device, that would also provide the necessary drive for other stages or signal processing.

To take full advantage of the low noise characteristics of the device, metal film resistors and capacitors of the kind mentioned above should be employed. Also, a metal housing should be considered, to electromagnetically shield the complete stage from the environment, thus preserving the low noise characteristic of the device.

Although the AH0013 is essentially DC coupled and can be used in such applications, the useful noise figures are somewhat higher at the low end of the frequency range. Therefore, employment of the AH0013 as an AC coupled device is recommended. The lower rolloff frequency is determined by capacitor C_B connected between pins 4 and 5 (5 and ground). The equations for this frequency f_L (-3 dB point), the gain and the output coupling capacitor are given in figure 2. Since there is a small bias current into the front end of the AH0013 the source must provide DC continuity or the input must be designed to provide this current.

LOW LEVEL LIGHT SENSOR

The AH0013 is shown here in an application that requires a high gain coupled with a wide bandwidth for a fast response such as photo diode or photo multiplier outputs demand. The circuit is also usable in this form for pulsed laser receivers, fast signal conditioners for A/D converter inputs, and other areas where low signal levels must be amplified with very small noise figures.

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The input device in this case is a current source. Since the AH0013 is to be considered a voltage to voltage amplifier the source should provide the very small bias current required.
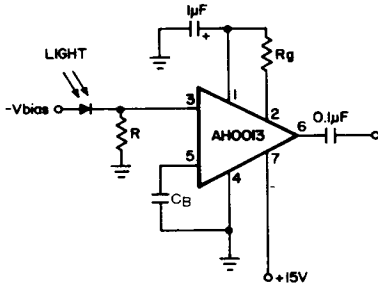

FIGURE 3: LOW LEVEL LIGHT SENSOR

The source current is "converted" to a voltage with the input resistor R. The remainder of the circuit is designed as has been discussed above. R_G, connected between pins 1 and 2, sets the gain. The capacitor between pin 1 and ground provides, together with the capacitors on pin 7 (not shown), power supply decoupling and the capacitor between pins 4 and 5 determines the lower rolloff frequency. Should it be desirable to roll off an upper frequency, an additional capacitor can be connected between pin 2 and ground. With this arrangement linearity within ¼dB is obtainable over the whole required frequency range. Shielding and mounting precautions mentioned above must be observed to preserve the inherent ultra low noise characteristic of the AH0013.

SHARP FREQUENCY RESPONSE

In some applications it is desirable to design for a peak gain at a given frequency or a peak gain over a narrow frequency range. These features are easily obtainable with the AH0013 as is shown in the following two diagrams.

$$\tau = \sqrt{LC}$$
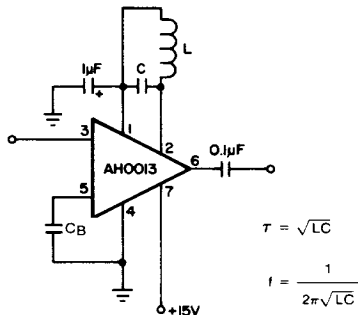
$$f = \frac{1}{2\pi\sqrt{LC}}$$

FIGURE 4: LC GAIN ELEMENTS FOR SHARP RESONANT FREQUENCY RESPONSE

The first one could be used in an active filter design where a peak and a sharp rolloff on either side of the design frequency is required. De-

pending on the Q of the tank circuit in the feedback loop of the AH0013 (pins 1 and 2), very sharp resonance can be obtained with equally sharp rolloff. Damping the LC circuit will, of course, also widen the overall frequency response. For an even broader response the capacitor can be replaced by a resistor. This circuit is then usable as a bandpass filter. The upper frequency rolloff can still be adjusted by use of a capacitor between pin 2 and ground.
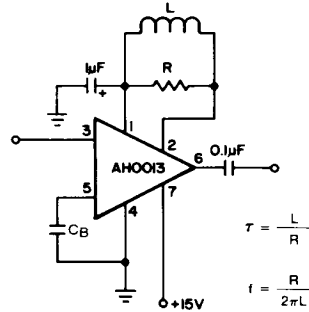

$$\tau = \frac{L}{R}$$

$$f = \frac{R}{2\pi L}$$

FIGURE 5: TUNED CIRCUIT FOR ULTRASONIC APPLICATIONS

The lower limit can be set with C_B between pin 5 and ground as has previously been discussed. In any applications involving inductive elements, special care must be taken to shield these parts from the electromagnetic environment to prevent noise pickup detrimental to the overall performance of the device in the circuit. Power supply decoupling, although not shown in either diagram, is also mandatory for the same reasons.

ACTIVE GAIN ELEMENT, GAIN 100

To obtain large gain figures, a reasonable output voltage swing and frequency range at low noise figures and without having to resort to biasing, the following application shows the use of a "rivet" circuit. The diagram depicts an active gain element for a very low noise audio amplifier with approximately 40dB of gain. This gain is achieved by use of a combination of a level setting integrator circuit and the AH0013 as follows:
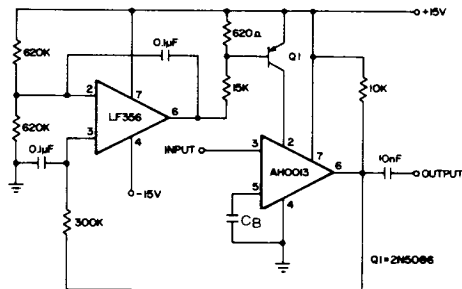

FIGURE 6: ACTIVE GAIN ELEMENT FOR AUDIO PREAMPLIFIER WITH APPROX. 100 GAIN

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A low noise LF356 is used in an integrator circuit. The two 620kΩ resistors between +15V and ground together with the 0.1μF capacitor in the feedback loop (inverting input) will cause the LF356 to settle to a given DC voltage after a few time constants.

The output at pin 6 of this integrator becomes at this time a stable DC voltage as well. This voltage together with the 15kΩ and the 620Ω resistor between pin 6 and the +15 volt supply voltage determines the bias on the transistor Q. Q is typically chosen to be a 2N5086 or an equivalent transistor.

The current, set by this base bias and multiplied by the gain of Q, is then the current into pin 2 of the AH0013 which in essence sets the gain of this stage.

The output of the AH0013 (pin 6) is taken and fed back to the non-inverting input of the LF356 via the 300kΩ resistor. Putting a capacitor between pin 3 of the LF356 and grounding the non-inverting input will help stabilize the LF356. Thus the current will be set by the first stage transistor Q. Stabilization of that current over frequency then results in a very stable gain figure over frequency of the complete preamplifier stage.

It should be noted that the stage is intended for amplification of small signals. Large signals will tend to compress the output and gain figures of 100 can no longer be achieved.

Also, of course, the usual power supply bypass and the shielding precautions mentioned earlier must be observed. The lower rolloff frequency is still determinable by C_B. A typical capacitor of 1.5μF will result in a 6dB/octave frequency rolloff point of 400 Hz. The output coupling capacitor and the capacitors in the integrator stage have little effect on the frequency.

NOISE PERFORMANCE MEASUREMENTS

Measurements of noise performance, noise figures and other noise related measurements are generally difficult to perform. Additionally, different measurement methodologies will yield different results and can lead to misunderstandings. For this reason, OEI has developed a schematic diagram in order to perform these measurements.

The diagram below shows how the various components are connected together. Metal film resistors and tantalum, silver mica or glass composition capacitors should be used close to the devices. The circuit is not critical but should not be directly exposed to strong external electromagnetic fields to prevent noise pickup.
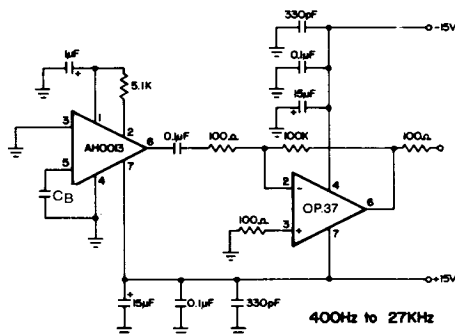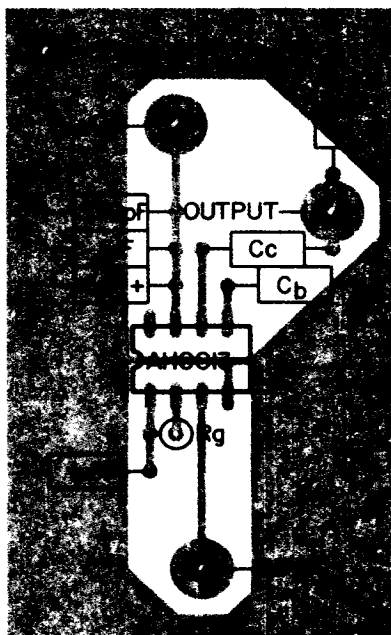

FIGURE 7: AH0013 TEST FOR NOISE

FIGURE 8: TYPICAL BOARD LAYOUT

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Looking for a Low Noise, 2nV√Hz Fast D.C. Preamp?

Generally speaking, this Preamp is not designed for DC operation; however, the following conditions will provide for DC applications.

Figure 9. In this circuit, instead of autobiasing capacitor C_B, you should apply about +1.5V to pin 5, then providing forced biasing condition for input FET stage. A step by step procedure follows.

1. Connect all terminals of AH0013 as it is indicated in Fig. 8.
2. Ground Pin 3.
3. Measure the DC voltage at Pin 5 (+1.5V).
4. Disconnect Pin 5. Apply the DC voltage measured in step 3 directly to Pin 5 via a regulated power supply.
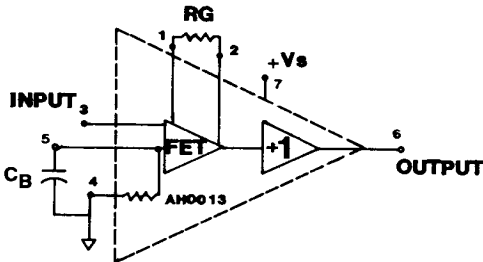
You have provided forced biasing condition for input FET stage of AH0013. See the following schematic.

At the output of AH0013, there'll be some DC biasing voltage with zero input signal. This voltage is about +7V. You have to provide the same voltage at noninverting input of the op amp in order to achieve its zero output. It is done by trimming R1. Remember—the equivalent noise voltage of the op amp, which includes the effect of its input noise current must not be greater than $e_n \, max = \dfrac{G1}{3}$.

2nV/√Hz, where G1 − voltage gain of AH0013. After you've achieved zero output voltage trim R2 for gain consideration, op amp voltage gain G2 ∼ R2 (Ω)/50.
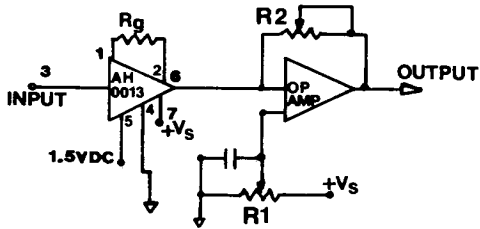

FIG. 9 BASIC CONNECTIONS

FIG. 10 FINAL CIRCUIT CONFIGURATION

AH0013LT

MECHANICAL DESCRIPTION: The AH0013LT is a standard ceramic 24 lead chip carrier.

Tolerance ± 015

PIN CONNECTIONS	
2	BYPASS
5	OUTPUT
8	+VCC
13	DECOUPLE
17	GAIN ELEMENT
19	INPUT
21	COMMON

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