National Semiconductor

Audio, Radio and TV Circuits

LM170/LM270/LM370 agc/squelch amplifier

general description

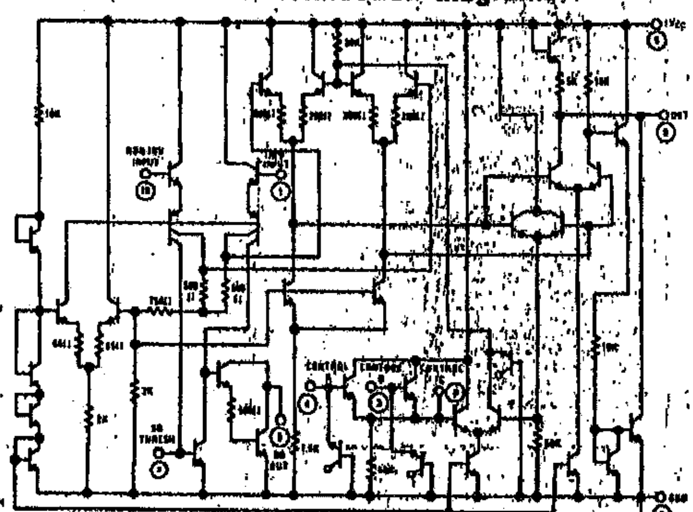
The LM170 is a direct coupled monolithic amplifier whose voltage gain is controlled by an external DC voltage. The device features:

- Large Gain Control Range
- Self-contained AGC/Squelch system, with fast-attack, slow-release.
- Low Distortion
- Minimum DC output shift as gain is varied
- Differential inputs, with large common-mode input range
- Outputs of several amplifiers may be directly summed in multichannel systems.
- Dissipates only 18 mW from +4.5V supply, usable with supply up to +24V.
- Sensitive squelch threshold, set by single external resistor.

In addition to communication system squelch and AGC applications, the LM170 is useful as constant-amplitude audio oscillator, linear low frequency modulator, single-sideband automatic load control, and as a variable DC gain element in analog computation.

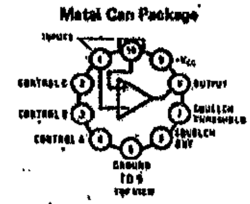
The LM170 is specified for operation over the −55°C to +125°C military temperature range. The LM270 is specified for operation over the −25°C to +75°C temperature range. The LM370 is specified for operation over the 0°C to +70°C temperature range.

schematic** and connection diagrams



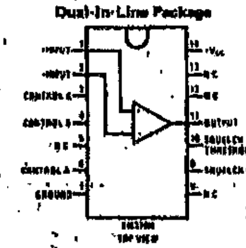
Circled numbers are pin connections.

Metal Can Package



Order Number LM170H or LM270H or LM370H
See NS Package H10C

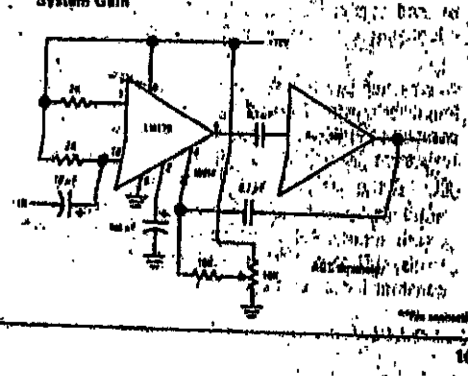
Dual-In-Line Package



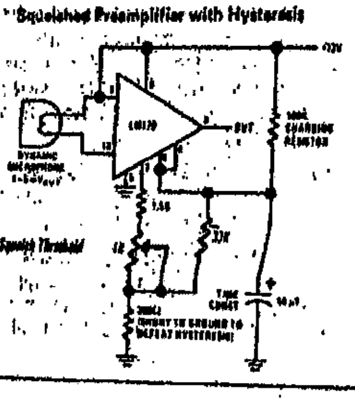
Order Number LM370N
See NS Package N14A

typical applications**

AGC Using Built-In Detection, Driven By Additional System Gain



Squelched Preamplifier with Hysteresis



**These applications shown are for metal can.

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LM170/LM270/LM370

absolute maximum ratings

Supply Voltage	24V
Storage Temperature	−65°C to +150°C
Operating Temperature LM170	−55°C to +125°C
LM270	−25°C to +75°C
LM370	0°C to +70°C
Differential Input Voltage	±19.5V
Common-mode Input Voltage	(V_{CC} + 0.4)V
Output Short Circuit Duration	Indefinite
Voltage applied to Pin 3 or 4	+6.0V
Voltage applied to Pin 2	+12.0V
Surge power into Pin 6 (1 second max)	1000 mW
Continuous power into Pin 6	100 mW

electrical characteristics (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
DC CHARACTERISTICS						
DC Output Voltage	$V_O(DC)$	V_{IN} (dd) = 0, V (gain control) = 0	+5.0	+6.0	+7.0	V
DC Output Voltage	$V_O(DC)$	V_{IN} (dd) = 0, V (gain control) = +3.0	+5.0	+6.0	+7.0	V
DC Output Shift	$\Delta V_O(DC)$	V_{IN} (dd) = 0, V (gain control) changed from 0 to +3.0V				
		LM170	−200	0	+200	mV
		LM270,	−500	0	+500	mV
		LM370	−1000	0	1000	
Power Supply Drain	I_{PS}	V_{CC} = +24V		13.5		mA
		V_{CC} = +4.5V		4.0		
		V_{CC} = +12V LM170, 270		8.0	10.0	mA
		LM370		8.0	12.0	mA
Input Bias Current	I_B	LM170, 270		6.0	10.0	µA
		LM370		6.0	12.0	
AC CHARACTERISTICS						
Voltage Gain	A_V	V (gain control) = 0				
		LM170, 270	37.5	40.0		
		LM370	35.0	40.0		dB
		f = 1 KHz				
Gain Reduction Range	ΔA_V	V (gain control) changed from 0 to +3.0V. Gain reduction occurs for control voltages between +2.1 and +2.6 volts, pin 3 or pin 4, f = 1 KHz		−80.0		dB

Note 1: $T_A = 25°C$, $V_{CC} = +12V$, $V_{IN(cm)} = +6V$.

operating notes

Voltage gain is continuously variable from a maximum value, dependent upon supply voltage, to a minimum value, by application of a DC control voltage at Pin 3 or 4. DC output voltage is substantially independent of gain changes, provided that differential DC input voltage is minimized, so that direct-coupled or fast gain-control operation is possible with minimum disturbance of succeeding amplifiers.

Input characteristics are similar to those of an operational amplifier, with common-mode input range extending from +4.5 volts up to and including the positive supply voltage. Lowest distortion occurs at input levels of 20 mV p-p or less. Outputs of several amplifiers, which will have quiescent DC levels approximately half of the positive supply, may be directly connected together in multi-channel summing systems, without damage.

Emitter-follower control inputs, Pins 3 and 4, may be used as positive peak detectors by connecting a smoothing capacitor at Pin 2, in AGC applications.

A sensitive squelch detector, independent of the amplifier's gain, provides fast-attack, slow release control at Pin 6, with threshold set by an external resistance from Pin 7 to ground. Injecting a portion of the control voltage at Pin 6 into this threshold results in a hysteresis, reducing response to erratic inputs. Since threshold is dependent on DC levels, differential DC input voltage should be held constant for squelch operation.

ECG370A

AGC/SQUELCH AMPLIFIER

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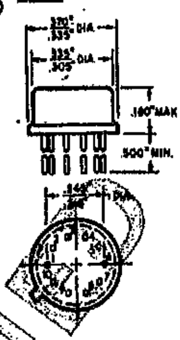


ECG370 is a direct coupled monolithic amplifier whose voltage gain is controlled by an external DC voltage. The device features:

- Large Gain Control Range
- Self-contained AGC/Squelch system, with fast-attack, slow-release.
- Low Distortion
- Minimum DC output shift as gain is varied
- Differential inputs, with large common-mode input range
- Outputs of several amplifiers may be directly summed in multichannel systems.
- Dissipates only 18 mW from +4.5V supply, usable with supply up to +24V.
- Sensitive squelch threshold set by single external resistor.

In addition to communication system squelch and AGC applications, the ECG370 is useful as constant-amplitude audio oscillator, linear low frequency modulator, single-sideband automatic load control, and as a variable DC gain element in analog computation.

absolute maximum ratings

Supply Voltage	24V
Storage Temperature	-65°C to +150°C
Operating Temperature	0°C to +70°C
Differential Input Voltage	±19.5V
Common-mode Input Voltage	(V_{CC} + 0.4)V
Output Short Circuit Duration	Indefinite
Voltage applied to Pin 3 or 4	+6.0V
Voltage applied to Pin 2	+12.0V
Surge power into Pin 6 (1 second max.)	1000 mW
Continuous power into Pin 6	100 mW

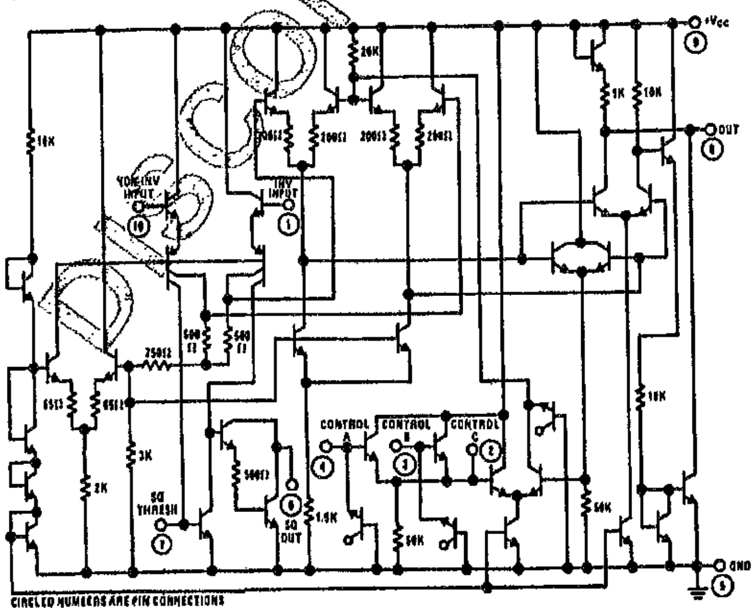


Figure 1. ECG370 Schematic

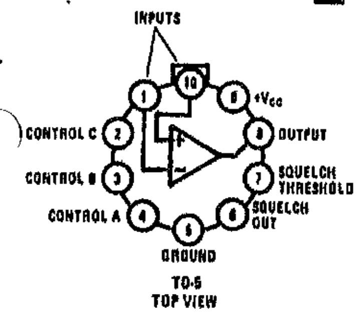
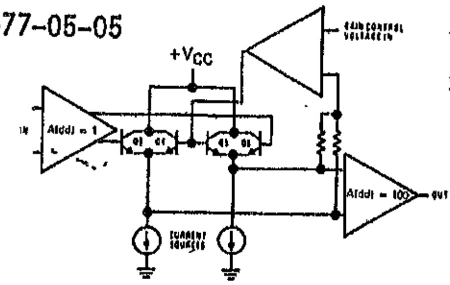


Figure 2. ECG370 Pin Connections



ECG370 System Block Diagram

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electrical characteristics (Note 1)

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DC Output Shift	$\Delta V_O(DC)$	V_{IN} (dd) = 0 V (gain control) changed from 0 to +3.0V	-1000	0	1000	
Power Supply Drain	I_{PS}	V_{CC} = +24V V_{CC} = +4.5V V_{CC} = +12V		13.5 4.0 8.0	12.0	mA mA
Input Bias Current	I_{IB}			6.0	12.0	
AC CHARACTERISTICS						
Voltage Gain	A_V	V (gain control) = 0 f = 1 KHz	35.0	40.0		dB
Gain Reduction Range	ΔA_V	V (gain control) changed from 0 to +3.0V. Gain reduction occurs for control voltages between +2.1 and +2.6 volts, pin 3 or pin 4, f = 1 KHz		-80.0		dB

Note 1: T_A = 25°C, V_{CC} = +12V, $V_{IN(cm)}$ = +6V

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Emitter-follower control inputs, Pins 3 and 4, may be used as positive peak detectors by connecting a smoothing capacitor at Pin 2, in AGC applications.

APPLICATIONS

REMOTE GAIN–CONTROLLED AUDIO AMPLIFIER

The simplest use for the ECG370 is a gain stage, Figure 3 whose gain can be manually controlled, noiselessly, by a DC voltage from a remote location. Pin 4 is bypassed by an external capacitor, to eliminate noise resulting from a long control line. The gain versus control voltage graph, Figure 4, shows the relationship to be approximately logarithmic within the control range. This is to be expected, as the variation mechanism is a PN junction, and is an advantage in audio systems, as logarithmic attenuation is achieved with linear potentiometers.

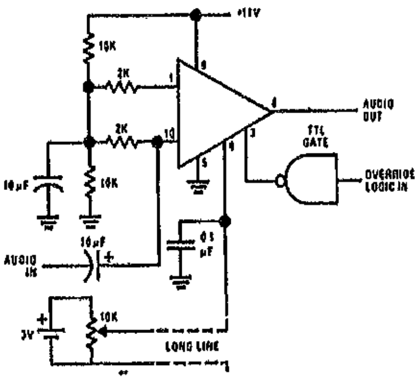

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FIGURE 3. Remote or Digital Control Amplifier

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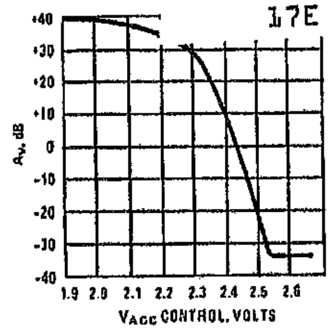

FIGURE 4. Typical Voltage Gain Vs Control Voltage, Pin 4

For the sake of illustration, Pin 3, the second control point, is simultaneously connected to a TTL gate, which can override the manual gain control, and turn off the amplifier regardless of the manual control voltage. In this example, input DC biasing is obtained via a resistive divider from the positive supply, although subsequent examples will illustrate other input biasing techniques. The common-mode input voltage may be set anywhere between $+V_{CC}$ and +4.5 volts.

AGC CIRCUIT WITH TRANSISTOR DETECTOR

In Figure 5, an external PNP transistor acts as a negative peak detector, with threshold set by a potentiometer. In its quiescent state, the PNP transistor is off; negative going signal peaks, AC coupled to the detector, cause momentary conduction, which turns on the high impedance gain control input, Pin 4. Pin 2 is bypassed by a relatively large capacitor which will charge, and maintian a sufficient DC voltage to operate the amplifier's gain at the correct level. This level, set by the threshold potentiometer, is the point at which negative peaks marginally turn on the PNP transistor. Thus, as input signal level increases, the circuit automatically lowers gain, to maintain a constant peak-to-peak output level. Since the capacitor at Pin 2 cannot follow instantaneous audio variations, audio frequency linearity is not disturbed, although charging from the low impedance of Pin 2 and discharging through a much higher resistance, causes fast attack, slow release AGC action.

In this example, common-mode input bias is obtained directly from V_{CC}, through equal resistors, to minimize offsets resulting from input bias current.

AGC USING BUILT IN DETECTORS

In most systems, the ECG370 will be followed by further voltage amplification. This may be advantageous, as it can provide increased forward gain in the AGC loop, resulting in tighter output regulation. In systems having widely varying load impedances, AGC derived from the system output can automatically compensate for additional output loading. Connected as in Figure 6, the emitter follower at Pin 4 is used as a high impedance detector, with detector smoothing performed by a capacitor at Pin 2. DC threshold for the detector is set at any desired level by a potentiometer, determining the positive peak output voltage which initiates gain regulation.

Both available AGC inputs may be used, as in Figure 7, to provide full-wave output detection, which responds to both positive and negative output peak voltages.

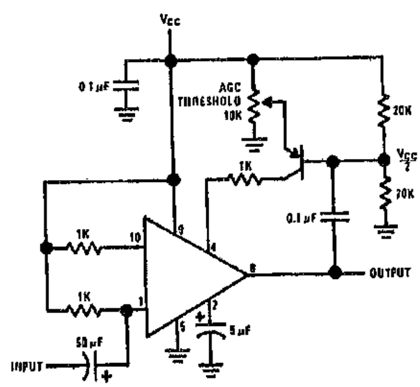

FIGURE 5. AGC Circuit

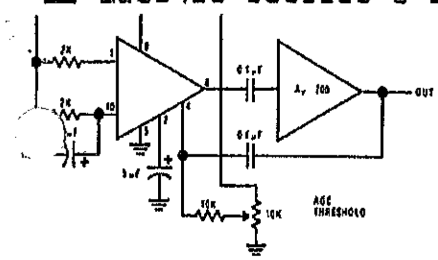

FIGURE 6. AGC Using Built-In Detection, Driven By Additional System Gain

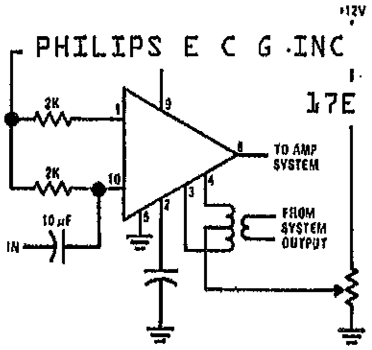

FIGURE 7. Internal Full Wave AGC Detection

SQUELCH PREAMPLIFIER WITH HYSTERESIS

Audio squelch is useful in noisy acoustic environments, to suppress background microphone noises, and in receiving systems, where the constant clatter of an unused transmission channel must be removed, until useful information is received. The squelch circuit of Figure 8 includes a number of refinements, which make it smooth-acting, and e[illegible]n the ear of the listener.

T[illegible] threshold potentiometer at Pin 7 is manually set to cut in at any desired input level. The large capacitor at Pin 6, and its associated charging resistor, may be chosen to give squelch release times of as much as several seconds, while the large current sinking capability into Pin 6 assures fast attack, so that first speech syllables are not lost.

A portion of the voltage at Pin 6 is fed back to the threshold potentiometer; since there are two stable voltage states at Pin 6, this creates a controlled amount of hysteresis in the squelch circuit. Thus, there exists a "dead band" of squelch sensitivity, which greatly enhances the circuit's immunity to rapid transmission channel fading, or erratic speech patterns. Combined with the slow-release characteristic, hysteresis gives a very well-behaved squelch system. A typical threshold control setting might be one at which amplification begins above a 20 mV p-p input. With the feedback values shown, the input level must consistently stay below 12 mV p-p before gain is cut off. The small feedback resistor may be eliminated if hysteresis is not required.

While squelch attack is abrupt, release follows the slow charging contour of the time constant capacitor, through the logarithmic gain control region. Thus, gain "fades out" following cessation of speech, rather than the less ear-pleasing effect of conventional squelch circuits, in which a rush of background noise may be heard, followed by an abrupt and often percussive cutoff.

The time constant capacitor is charged by a voltage divider, rather than a single resistor, so that its quiescent charged voltage is about +3 volts, with the values shown, from a +12 volt supply. There is no need to charge the capacitor much above this point, because gain has already been completely cut off, and further charging only makes more work for the large geometry transistor at Pin 6, in performing its rapid discharge function. In any event, if a single charging resistor is used, the timing capacitor cannot charge above about +6.5 volts, because both Pins 3 and 4 are shunted internally by protective zener diodes.

In Figure 8 , the ECG370 appears in another of its many possible input configurations. It is directly driven by a low resistance dynamic or controlled-magnetic microphone, with no other input biasing components required. The amplifier is compact enough to fit inside even the smallest commercial microphone cases; its low current drain from supplies between +4.5 and +6.0 volts would permit inclusion of batteries within the same case.

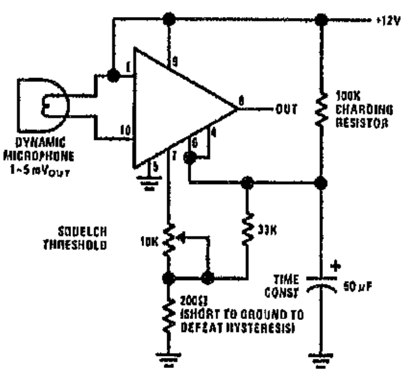

FIGURE 8. Squelched Preamplifier with Hysteresis

Figure 9 illustrates how a large number of such microphones could be directly connected to a common bus, at their outputs, to give a random access, automatic break-in public address or paging system, which might be useful, for example, at a large conference table, or in a courtroom. While background noises at each microphone location would be suppressed, close talking would immeditely allow one or more speakers to be heard. Because squelch switching levels are compatible with TTL logic, a priority logic system could be devised, which would not only give certain speakers "break-in" priority, but allow them to ut[illegible]ically cut off certain other speakers at the ar[illegible]e.

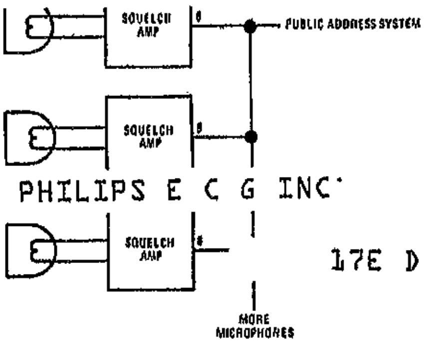

FIGURE 9. Random Access Microphone System

TWIN-TEE, REGULATED OUTPUT AUDIO OSCILLATOR

Oscillation occurs in a twin-tee circuit when loop gain equals unity (including filter losses). Conventional methods of regulating oscillator output amplitude rely either upon the attainment of a saturated limit cycle, or nonlinear loading of the gain element. With a ECG370, amplitude may be set by detecting the output, and feeding the detected voltage back to the gain-control input. In this way, amplifier gain is constantly corrected to exactly make up for filter and loading loss, and always remains linear. About 40 db of excess gain is available for this function, which is illustrated in Figu[illegible] Oscillator output is controlled by setting t[illegible] [illegible]GC threshold with an external potentiometer, and may be stabilized at any value below the maximum peak-to-peak available output swing.

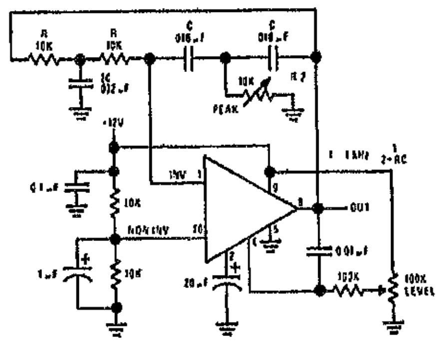

FIGURE 10. Twin-Tee Oscillator with Remote Level Control, AGC

A MODULATED 455 kHz SIGNAL GENERATOR

An inexpensive, high "Q", 455 kHz ceramic filter may be substituted for the twin-tee feedback network of the previous example, to create a regulated-output AM IF alignment generator, Figure 11. If the AGC threshold voltage, which determines stablized output, is varied at a slow (audio) rate, the output amplitude will be forced to track the audio modulation.

The input configuration shown in Figure 11 may be used when two power supplies are available elsewhere in the system, as it allows the inputs and output of the ECG370 to be referred to ground. Of course, any other suitable input biasing scheme may be used instead, for the 455 kHz signal generator.

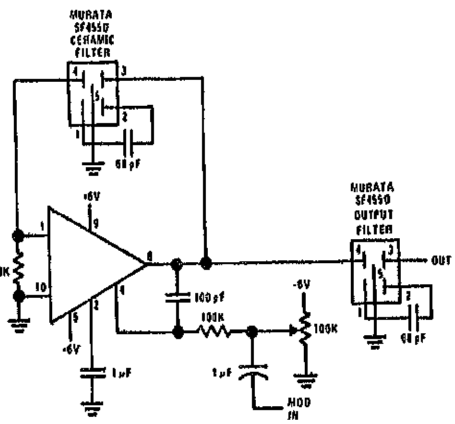

FIGURE 11. 455 kHz Modulated Constant Output Oscillator

AUTOMATIC LOAD CONTROL FOR SSB TRANSMITTER

High power linear RF amplifiers, used in Signal Sideband transmission, cause splatter and distortion, when driven even slightly beyond their linear range by the SSB exciter. Simple systems attempt to prevent such overdriving by automatic gain control in the early audio stages, but this precaution neglects the fact that the complex envelope structure of an SSB signal does not always bear the expected relation to modulation amplitude. To really assure that the power stages will not be overdriven, it is necessary to sample the RF output envelope, and provide RF excitation control in proportion to actual RF output voltage. This system, Automatic Load Control, or ALC, compensates for variations in load impedance, final amplifier tuning, and power supply variations.

The ECG370 used as in Figure 12, responds to the Peak Envelope at the transmitter's output, on both positive and negative peaks. A capacitor at Pin 2 smooths the RF, and provides an attack time constant which responds to ordinary speech transients, and releases relatively slowly. If the push-pull coupling link from the output is inconvenient, capacitor coupling may be substituted to Pin 4; the circuit will then only respond to positive output peaks, but these are generally symmetrical in ordinary speech patterns. A potentiometer adjusts the threshold point at which ALC action begins, and consequently may be used as a carrier level control, in the absence of modulation. The approximately 2 mHz bandwidth of the ECG370 allows effective amplification of a 455 kHz low level SSB signal.

TRANSMITTER OR TAPE RECORDER VOX

In addition to squelching its own gain, the ECG370 can become a voice-operated-relay control, or VOX, to switch high powered electronic or electromechanical devices. Automatic transmit-receive operation is possible in two way communication systems, or tape recorder motors may be switched on at the first syllable of infrequent speech, such as in dictation, conserving tape.

To handle large amounts of power, all that is needed is a small PNP power transistor, driving a relay, which can have multiple poles. Action is essentially the same as in squelch operation, except that the capacitor discharged by Pin 6 is charged by the relay driving circuitry. The amplifier may simultaneously be used as a continuous-running preamplifier, may be squelched along with the relay, or may even operate with an independent AGC signal, into Pin 3 or 4.

A reed relay is shown in the schematic of Figure 13, but any fast acting relay may be used. The relay coil is shunted by a diode, to protect the

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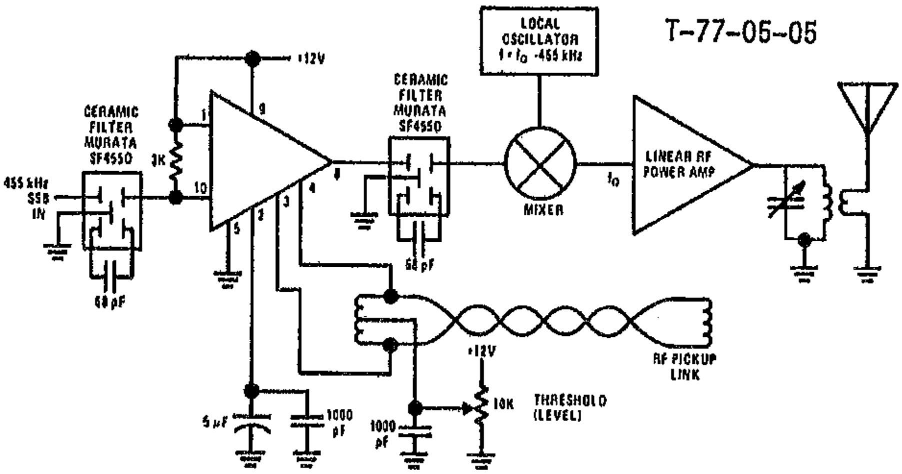

FIGURE 12. SSB ALC System

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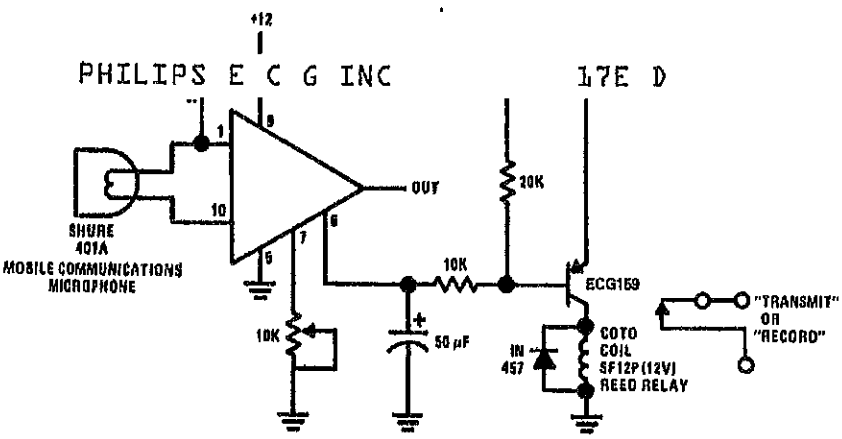

FIGURE 13. VOX Preamp

PNP transistor. If power supply impedance is high the circuit may tend to oscillate; bypassing the supply with a fairly large capacitor will eliminate the problem.

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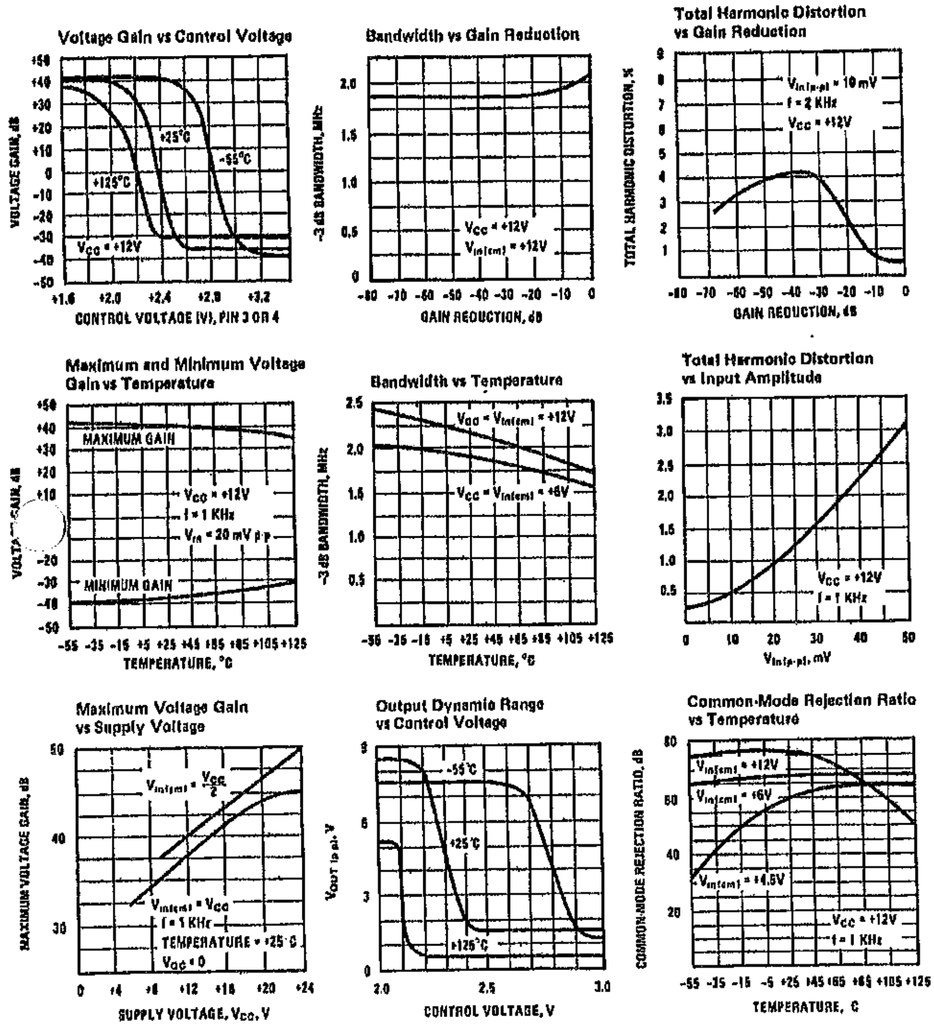
PRACTICAL OPERATING HINTS

Some general precautions should be taken with the ECG370 just as with any monolithic amplifier, for best performance. Because of the high gain-bandwidth product inherent in monolithic devices, and the multiple feedback loops used within the circuit, a "stiff" power supply can prevent instability. If there is any doubt, a supply bypass capacitor at the socket is recommended.

Gain control inputs, Pins 3 and 4, are shunted by 6.5 volt zener diodes. If control voltage is anticipated to go above +6.5 volts, and if the driving source is capable of providing more than about 10 mA under these conditions, it is advisable to protect the zeners with a series resistance at each gain control input.

While the large geometry squelch output transistor, Q21, is capable of sinking large instantaneous discharge currents from electrolytic capacitors, it is not advisable to attempt sinking large (more than 50 or 100 mA) continuous currents from "stiff" voltage sources, which may cause large dissipation on the chip.

variable gain characteristics



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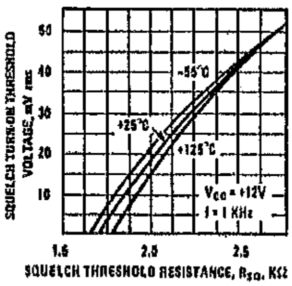
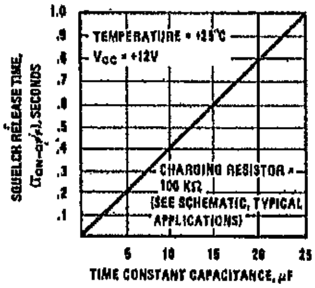
squelch characteristics

Squelch Threshold Voltage vs Threshold Resistance

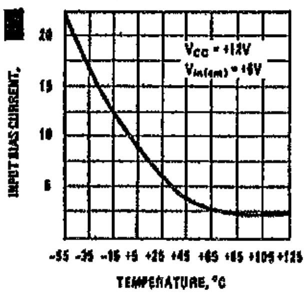


Squelch Release Time vs Time Constant Capacitance

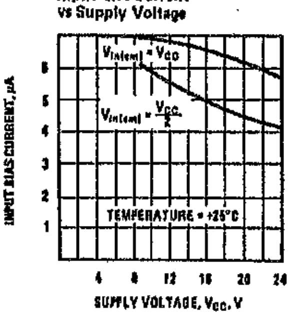


input and output characteristics

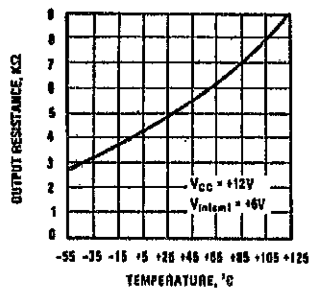
Input Bias Current vs Temperature



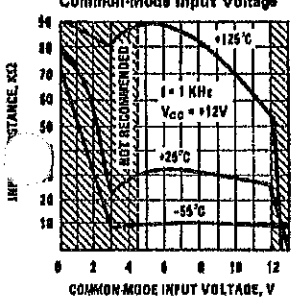
Input Bias Current vs Supply Voltage



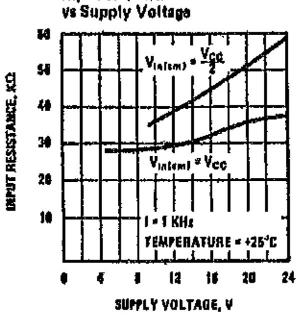
Output Resistance vs Temperature



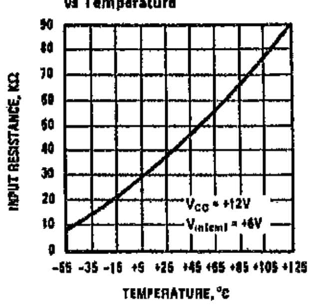
Input Resistance vs Common-Mode Input Voltage



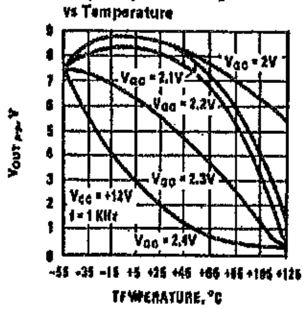
Input Resistance vs Supply Voltage



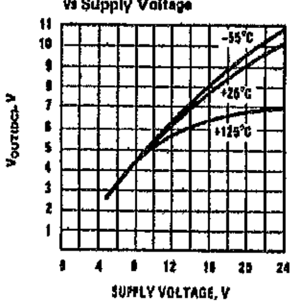
Input Resistance vs Temperature



Output Dynamic Range vs Temperature



Quiescent DC Output Voltage vs Supply Voltage



Power Supply Current vs Supply Voltage