Dual Operational Transconductance Amplifiers with Linearizing Diodes and Buffers

Features

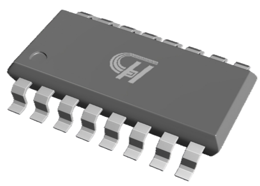
- gm Adjustable over 10 Decades
- Excellent gm Linearity
- Excellent Matching between Amplifiers
- Internal linear diode reduces output distortion
- High Impedance Buffers
- High Output Signal-to-Noise Ratio
- Available in Green SOIC16 Package

Applications

- Current-Controlled Amplifiers
- Current-Controlled Impedance
- Current-Controlled Filters
- Current-Controlled Oscillators
- Multiplexers
- Timers
- Sample-and-Hold Circuits

General Description

The HCRM13700 series consists of two current controlled tranconductance amplifiers, each with differential inputs and a push-pull output. The two amplifiers share common supplies but otherwise operate independently. Linearizing diodes are provided at the inputs to reduce distortion and allow higher input levels. The result is a 10dB signal-to-noise improvement referenced to 0.5 percent THD. High impedance buffers are provided which are especially designed to complement the dynamic range of the amplifiers. The output buffers of the HCRM13700 differ from those of the HCRM13600 in that their input bias currents (and hence their output DC levels) are independent of I_{ABC}. This may result in performance superior to that of the HCRM13600 in audio applications.



SOIC-16

Figure 1. Package Type of HCRM13700

Dual Operational Transconductance Amplifiers with Linearizing Diodes and Buffers

Connection Diagram

HCRM13700, PKG:SOIC-16

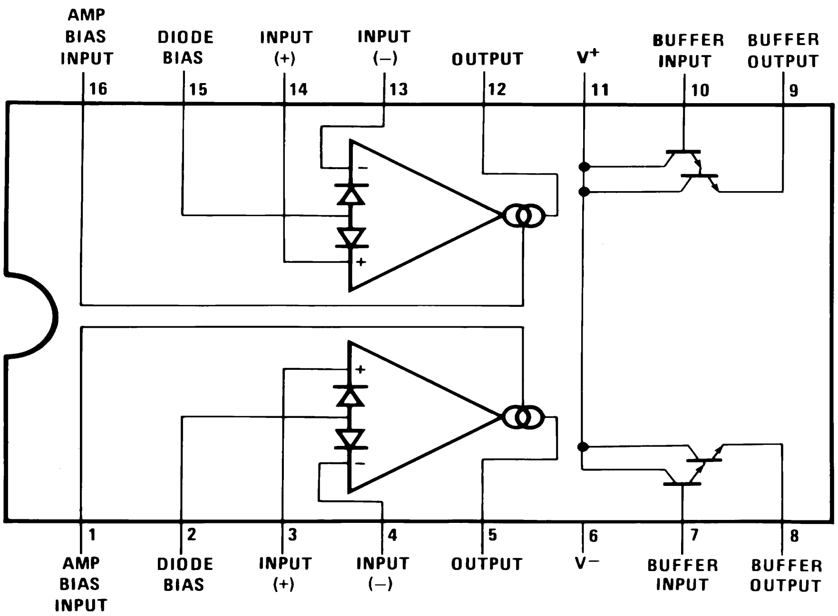


Figure 2. Connection Diagram of HCRM13700 (Top View)

Pin Function Table

Name	Pin	I/O	Function
Amp Bias Input	1, 16	I	Current Bias Input
Buffer Input	7, 10	I	Buffer Op amp Input
Buffer Output	8, 9	O	Buffer Output
Diode Bias	2, 15	I	Linear Diode Bias Input
Input (+)	3, 14	I	Positive Phase Input
Input (-)	4, 13	I	Inverting Input
Output	5, 12	O	No Buffer Output Terminal
Vs +	11	P	Positive Power Supply
Vs -	6	P	Negative Power Supply

Ordering Information note b

Circuit Type / □ □

Type: SWGM13700

Package: M16: SOIC-16

TR : Tape and Reel

Ordering Code

Part Number	Marking ID	Temperature Range	Package	Package Type
HCRM13700/M16TR	HCRM13700	-20'C to +85'C	SOIC-16	4000pcs/TR

Absolute Maximum Ratings Note 1,3

Parameter	Symbol	Value	Unit
Supply Voltage	Vs, Vs+	+36 or ±18	V
DC Input Voltage	VDC	+Vs to -Vs	V
Differential Input Voltage	VDF	±5	V
Diodes Bias Current	ID	2.0	mA
Amplifier Bias Current	IABC	2.0	mA
Output Short Circuit Duration	-	Continuous	-
Buffer Output Current	IBOC	20	mA
Power Dissipation note2, TA=25'C	PD	570	mW
Thermal Resistance @TA=+25'C — SOIC-16	θJA	110	'C/W
Junction and Storage Temperature Range	TJ, TSTG	-65 to +150	'C
Operating Temperature Range note 2	TOPR	0 to +70	'C
Lead Temperature (Soldering, 10s)	TLEAD	260	'C

Note 1: "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not ensure specific performance limits.

2. For operation at ambient temperatures above 25'C, the device must be derated based on a 150'C maximum junction temperature and a thermal resistance. Junction to ambient, as follows: HCRM13700, DIP-16, 90'C/W; HCRM13700, SOIC-16, 110'C/W.

3. Thess devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

Recommended Operating Conditions

Parameter	Symbol	Min	Max	Unit
Single Power Supply	VS	+9.5	+32	V
Dual Power Supply	VS+	4.75	+16	V
Dual Power Supply	VS-	-16	-4.75	V
Operating Temperature Range	Ta	0	+70	'C

Dual Operational Transconductance Amplifiers with Linearizing Diodes and Buffers

DC Electrical Characteristics note 1

(TA=25 `C, Vs= ±15V, Iabc=500uA, Ta=25'C No characteristic description Pin2 / pin15 is suspended, buffer input is grounded, and buffer output is suspended)

Parameter	Symbol	Conditions	Min	Type	Max	Unit
Input Offset Voltage	VOS	Over Specified Temperature Range	-	0.4	4.0	mV
		IABC = 5uA	-	0.3	4.0	
VOS Including Diodes	VOS_D	Diode Bias Current(ID)=500uA	-	0.5	5.0	mV
VOS Change	ΔVOS	5uA<=Iabc<=500uA	-	0.1	3.0	mV
Input Offset Current	IOS		-	0.1	0.6	uA
Input Bias Current	Ib	Over Specified Temperature Range	-	0.116	5.0	uA
			-	0.22	8.0	
Forward Transconductance	gm	V=10mV and 25mV	6700	9600	13000	umho
		Over Specified Temperature Range	5400	-	-	
gm Tracking	gm_t	VCM = (-VS)	-	0.3	-	dB
Peak Output Current	Ipk	RL=0, Iabc=5uA	4.3	5.0	-	uA
		RL=0, Iabc=500uA	350	500	650	
		RL=0, Over Specified Range	300	-	-	
Peak Output Voltage						
Positive	VOP	RL=∞, 5uA≤Iabc≤500uA	+12	+14.2	-	V
Negative	VON	RL=∞, 5uA≤Iabc≤500uA	-12	-14.2	-	
Supply Current	ICC	Iabc=500uA, Both Channels	-	2.6	-	mA
VOS Sensitivity						
Positive	VOP	ΔVOS/ΔV+	-	20	150	uV/V
Negative	VON	ΔVOS/ΔV-	-	20	150	
CMRR	CMRR		80	110	-	dB
Common Mode Range	ZCM		±12	±13.5	-	V
Crosstalk	ZCTK	Referred to Input note2, 20Hz<f<20KHz	-	100	-	dB
Differential Input Current	IDIC	Iabc=0, input=±4V	-	0.02	100	nA
Leakage Current	ILeaK	Iabc=0 (Refer to Test Circuit)	-	0.02	100	nA
Input Impedance	Zin		10	26	-	KΩ
Open-Loop Bankdwith	GOLB		-	2	-	MHz
Slew Rate	SR	Unity Gain Compensated	-	50	-	V/uS
Buffer Input Current	Ibin	note 2	-	0.5	2	uA
Peak Buffer Output Voltage	VP-bin	note 2	10	-	-	V

Note 1. These specifications apply for VS=±15V, TA=25'C, amplifier bias current(IABC)=500uA, pins 2 and 15 open unless otherwise specified. The inputs to the buffers are grounded and outputs are open.

2. These specifications apply for VS=±15V, IABC=500uA, ROUT=5KΩ connected from the buffer output to -VS and the input of the buffer is connected to the transconductance amplifier output.

Schematic Diagram

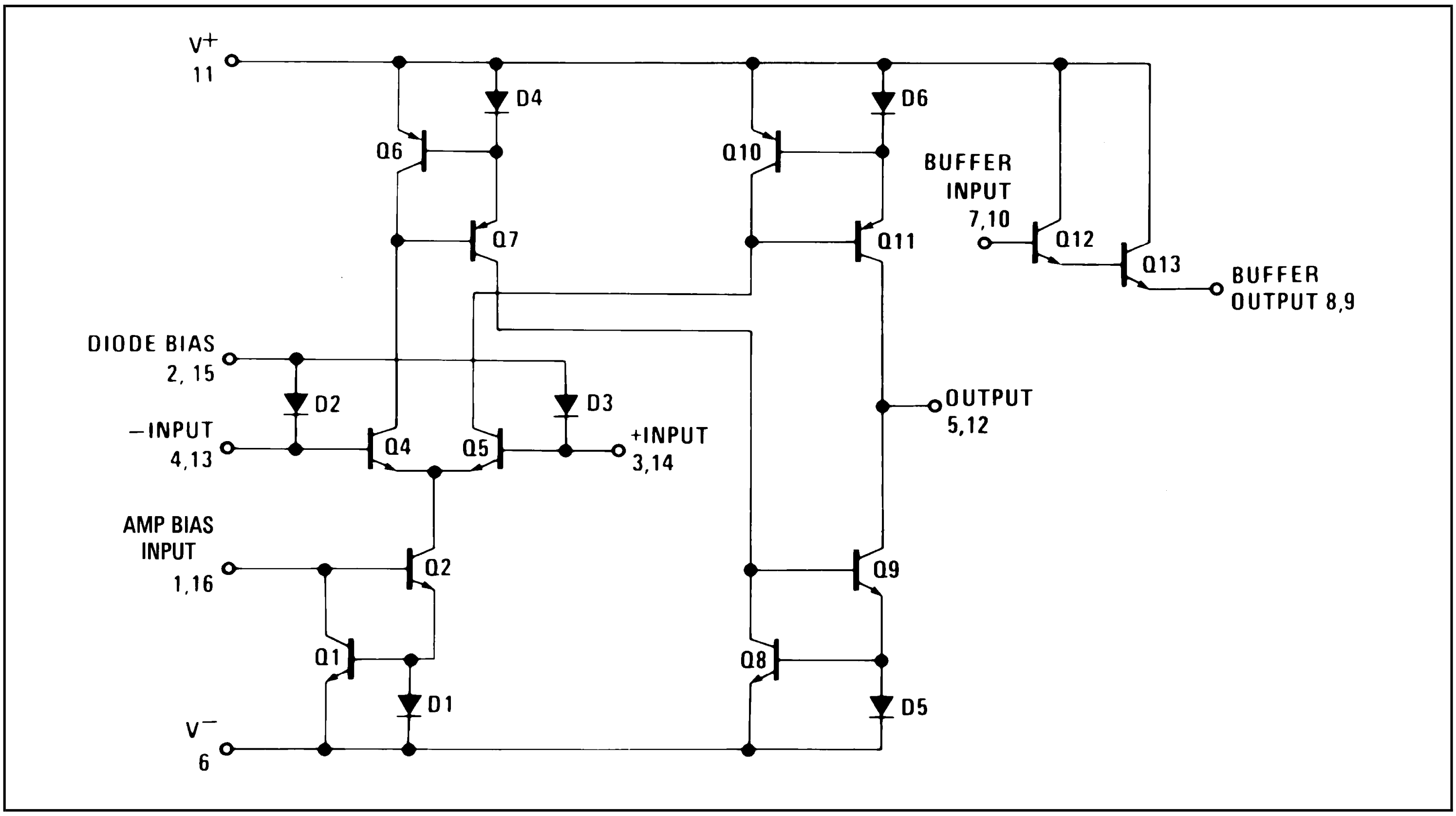


Figure 3. One Operational Transconductance Amplifier

Typical Application

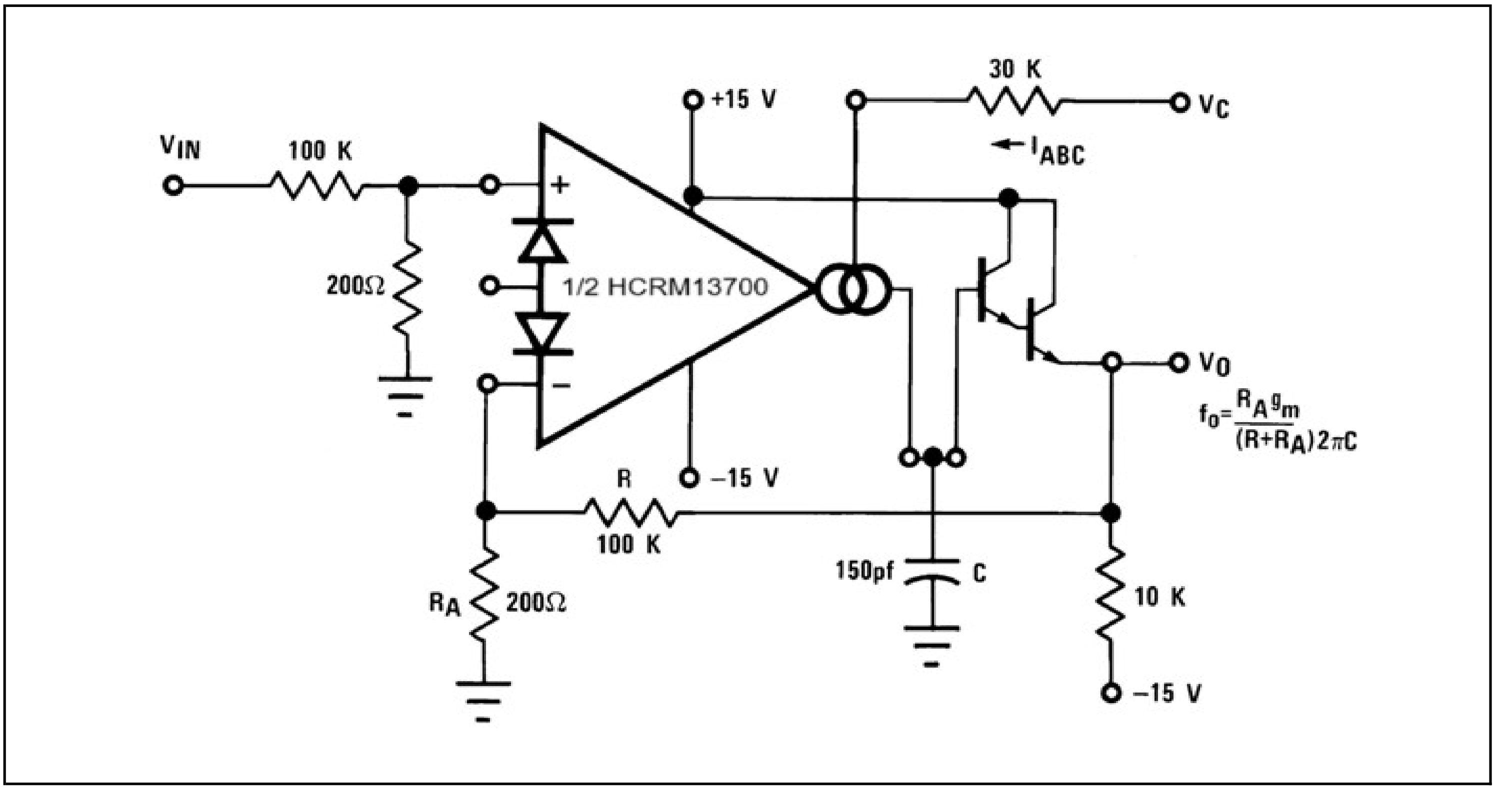


Figure 4. Typical Application of HCRM13700

Typical Performance Characteristics (Unless Otherwise Specified.)

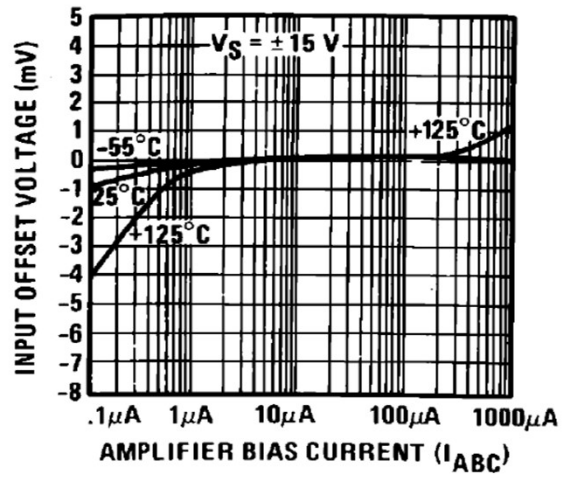


Figure 5. Input Offset Voltage

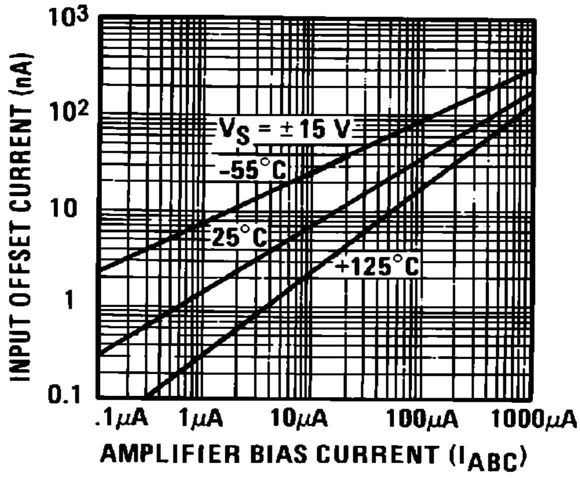


Figure 6. Input Offset Current

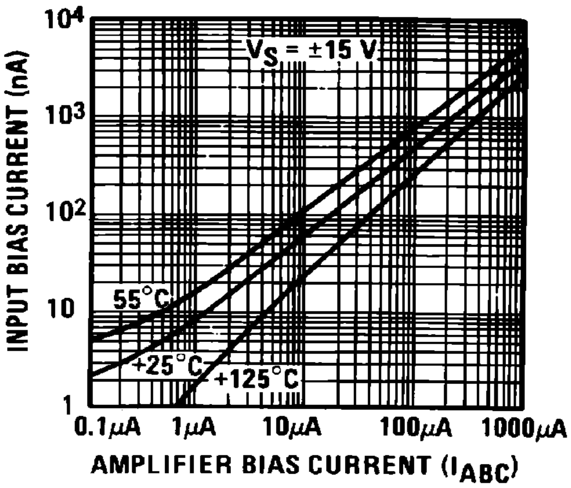


Figure 7. Input Bias Current

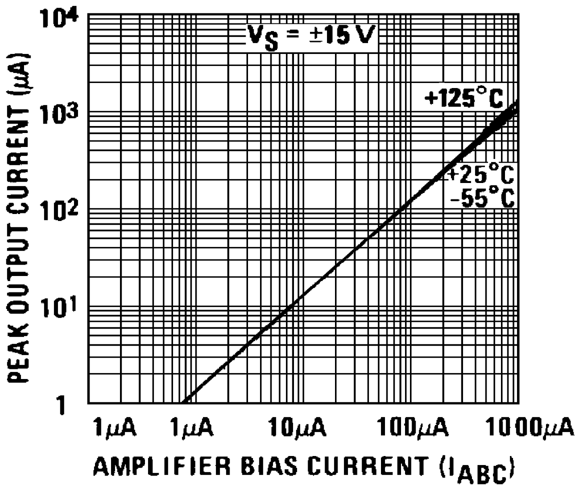


Figure 8. Peak Output Current

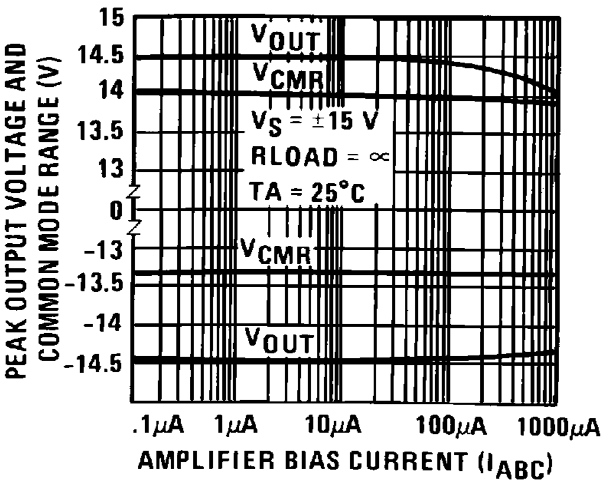


Figure 9. Peak Output Voltage and Common Mode Range

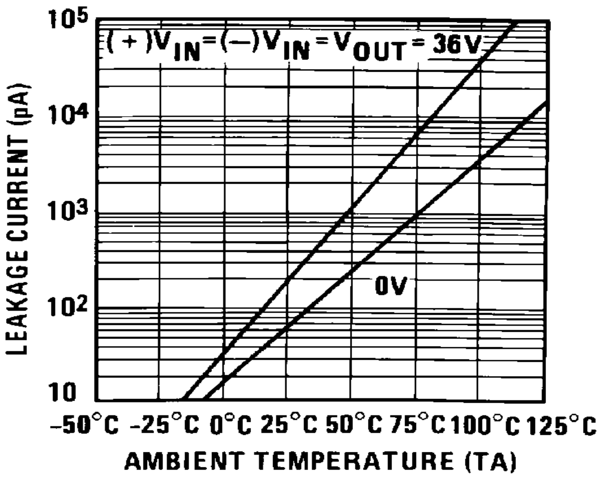


Figure 10. Leakage Current

Typical Performance Characteristics (Con.)

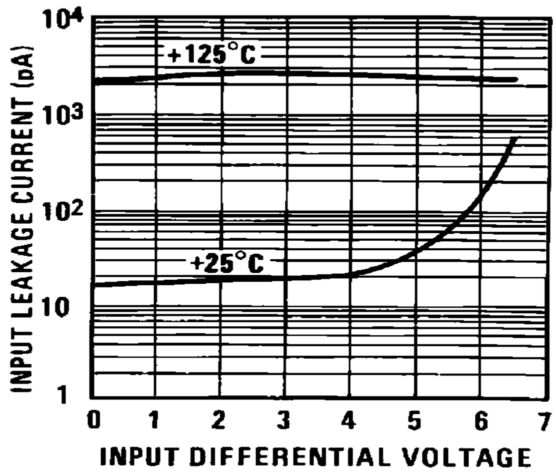


Figure 11. Input Leakage

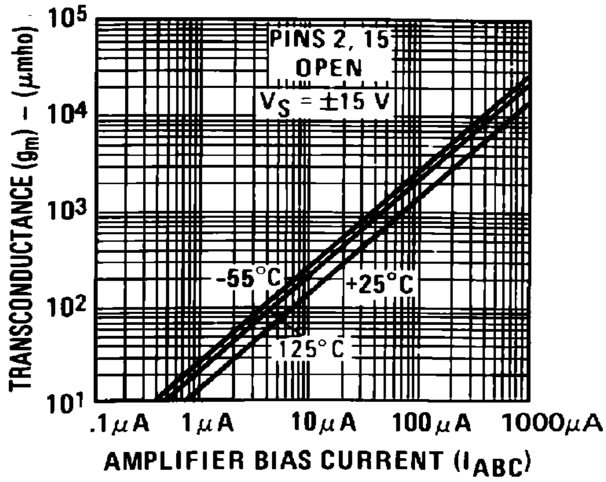


Figure 12. Transconductance

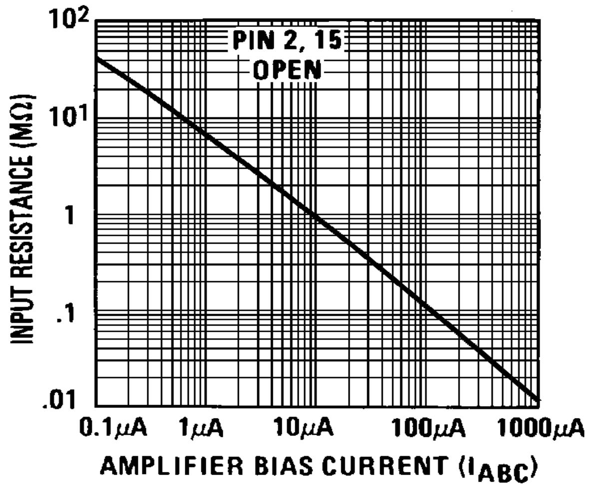


Figure 13. Input Resistance

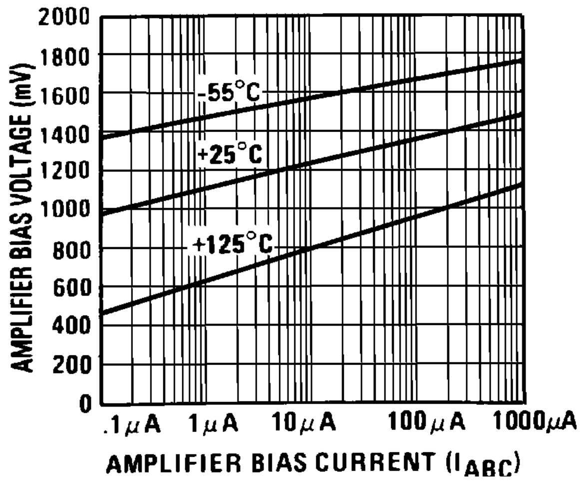


Figure 14. Amplifier Bias Voltage vs. Amplifier Bias Current

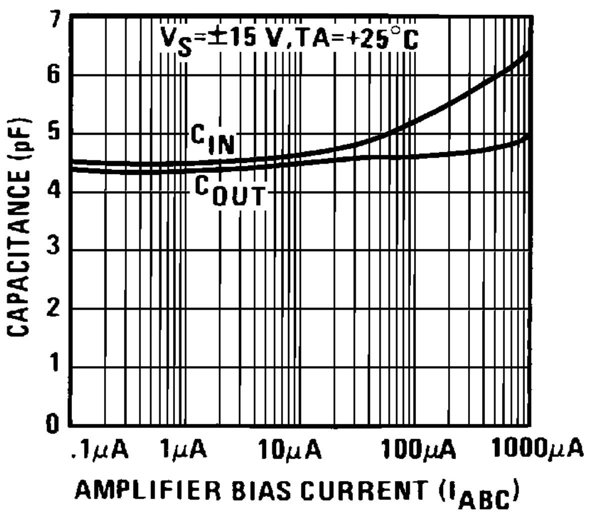


Figure 15. Input and Output Capacitance

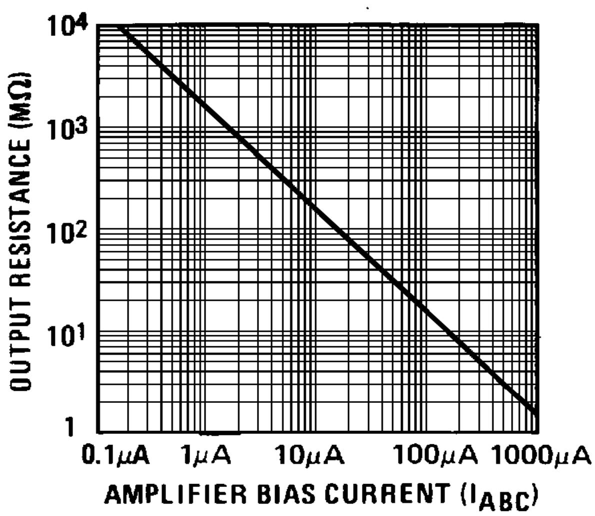


Figure 16. Output Resistance

Typical Performance Characteristics (Con.)

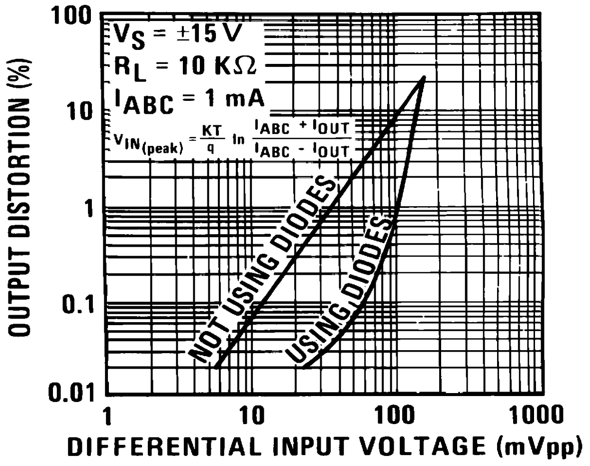


Figure 17. Distortion vs. Differential Input Voltage

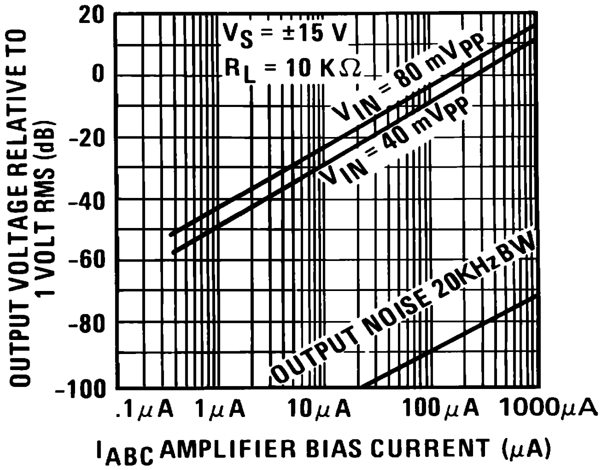


Figure 18. Voltage vs. Amplifier Bias Current

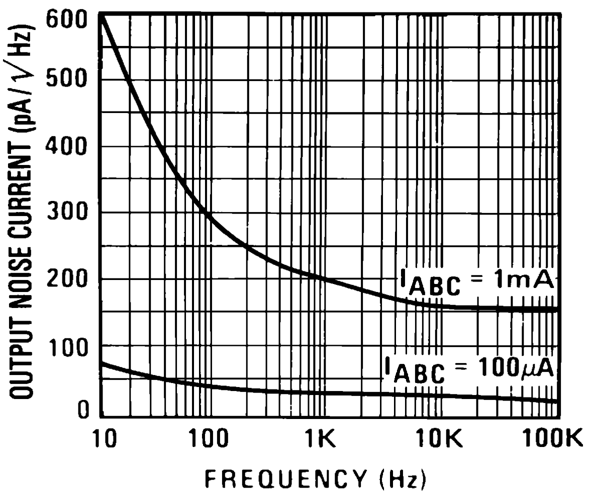


Figure 19. Output Noise vs. Frequency

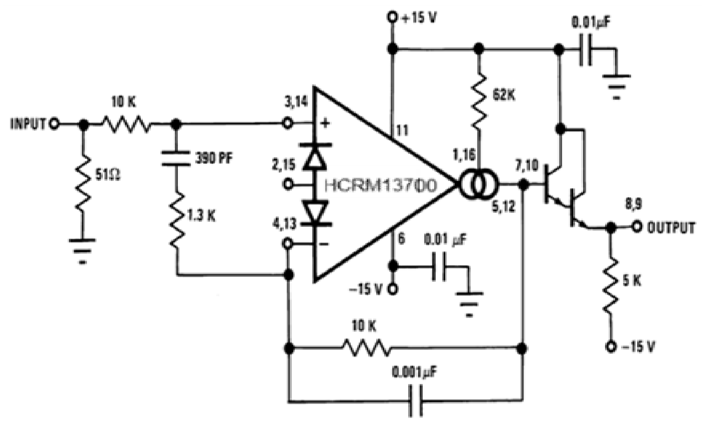


Figure 20. Unity Gain Follower

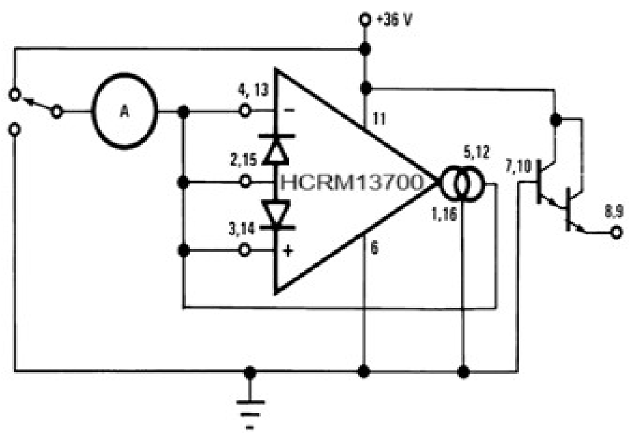


Figure 21. Leakage Current Test Circuit

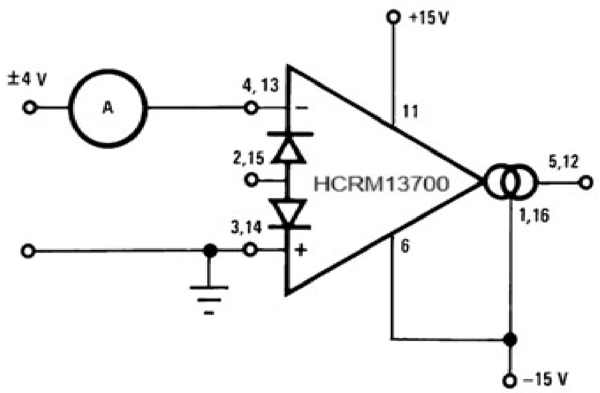


Figure 22. Differential Input Current Test Circuit

Function Description

The HCRM13700 is a two-way differential input flow -controlled transconducting operational amplifier with output buffer. The input is linear diode characteristics.

This feature reduces distortion while the output current is controlled on this port. The output ports can also be continuously protected in the event of a short-to-ground condition.

Internal circuit block diagram

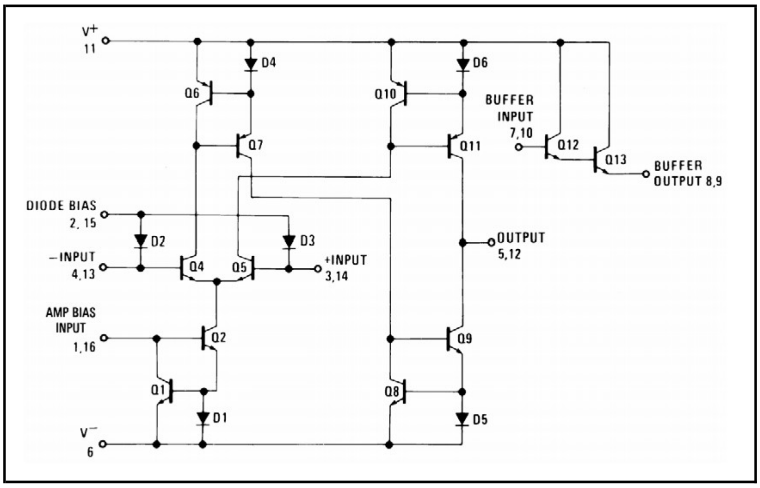


Figure 23. A transconducting operational amplifier

Circuit Description

The differential transistor pair Q4 and Q5 for a trans-conductance stage in that the ratio of their collector currents is defined by the differential input voltage according to the transfer function:

$$V_{IN} = \frac{kT}{q} \ln \frac{I_5}{I_4} \qquad (1)$$

Where V_{IN} is the differential input voltage, KT/q is approximately 26mV at 25'C and I_5 and I_4 are the collector currents of transistors Q5 and Q4 respectively. with the exception of Q12 and Q13, all transistors and diodes are identical in size. Transistors Q1 and Q2 with Diode D1 form a current mirror which forces the sum of currents I4 and I5 to equal I_{ABC}:

$$I_4 + I_5 = I_{ABC} \qquad (2)$$

Where I_{ABC} is the amplifier bias current applied to the gain pin.

For small differential input voltages the ratio of I4 and I5 approaches unity and the Taylor series of the in function can be approximated as

$$\frac{kT}{q} \ln \frac{I_5}{I_4} \approx \frac{kT}{q} \frac{I_5 - I_4}{I_4} \qquad (3)$$

$$I_4 \approx I_5 \approx \frac{I_{ABC}}{2}$$

$$V_{IN} \left[\frac{I_{ABC}q}{2kT} \right] = I_5 - I_4 \qquad (4)$$

Circuit Description（Con.)

Collector currents I_4 and I_5 are not very useful by them selves and it is necessary to subtract one current from the other. The remaining transistors and diodes form three current mirrors that produce an output current equal to I5 minus I4 thus:

$$V_{IN} \left[\frac{I_{ABC}q}{2kT} \right] = I_{OUT} \qquad (5)$$

The term in brackets is then the transconductance of the amplifier and is proportional to I_{ABC}.

Linearizing Diodes

For differential voltages greater than a few milli volts, The equation (3) becomes less valid and the transconductance becomes increasingly nonlinear Figure 24 demonstrates how the internal diodes can linearize the transfer function of the amplifier. For convenience assume the diodes are biased with current sources and the input signal is in the form of current Is. Since the sum of I4 and I5 is I_{ABC} and the difference is I_{OUT}, currents I4 and I5 can be written as follows:

$$I_4 = \frac{I_{ABC}}{2} - \frac{I_{OUT}}{2}, \; I_5 = \frac{I_{ABC}}{2} + \frac{I_{OUT}}{2} \qquad (6)$$

Function Description(Con.)

Linearizing Diodes (Con.)

Since the diodes and the input transistors have identical geometries and are subject to similar voltages and temperatures, the following is true:

$$\frac{kT}{q}\ln\frac{\frac{I_D}{2}+I_S}{\frac{I_D}{2}-I_S} = \frac{kT}{q}\ln\frac{\frac{I_{ABC}}{2}+\frac{I_{OUT}}{2}}{\frac{I_{ABC}}{2}-\frac{I_{OUT}}{2}} \qquad (7)$$

$$\therefore I_{OUT} = I_S\left(\frac{2I_{ABC}}{I_D}\right) \text{ for } |I_S| < \frac{I_D}{2}$$

Notice that in deriving equation (7) no approximati -ons have been made and there are no temperature dependent terms. The limitations are that the signal current not exceed $I_D/2$ and that the diodes be biased with currents. In practice,replacing the current sources with resistors will generate insignificant errors.

Device function modes:

Use may require minor modifications in single- or double-ended power supplies, and the outputs can support continuous short-to-ground protection. Note that using ±5V to power the HCRM13700 may reduce its dynamic response range due to the PNP transistor's higher V_{be} than the NPN transistor.

Output Buffer:

Each channel contains a separate output buffer consisting of Darlington tubes that can drive up to 20mA.

APPLICATION NOTES

The trans-op amp is a versatile analog component of Brick 3 that can be called an ideal transistor, The HCRM13700 has a wide range of application scenarios, from voltage control op amps and filters to voltage controlled oscillators. Its unique independent channels are better used in stereo audio amplifiers.

Typical Application

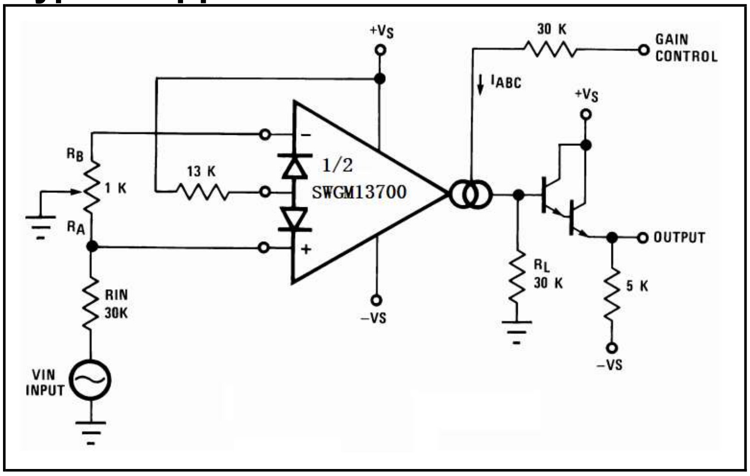


Figure 24. Voltage-controlled amplifier

Design Requirements

For this example application, the supply voltage is ±15V and the system needs to provide a THD<0.1% 1Vpp volume control input signal. The volume control range is between -13V and 15V and a signal with an adjustable range of more than 30dB needs to be provided.

Detailed Design Process

Linear diodes are recommended in most applications because they greatly reduce output distortion. The input diode bias current ID is required to be greater than twice the input current is, because when the input voltage is 0V, the voltage drop of the input bias diode is not 0V but 0.7V, The bias port is connected to V +, and a voltage drop of 14.3v will be obtained through Rd. it is appropriate to use the recommended id=1mA

Function Description(Con.)

Detailed Design Process(Con.)

Where Vs+ =15V and the voltage drop is 14.3V, the desired gain control can be obtained by connecting a standard 13KΩ resistor.

In order to meet the requirement of THD < 0.1%, When linear diode is used, The differential input voltage must be less than 60mVpp, The input divider at the input port will reduce 1Vpp to 33mVpp, which is within the required range.

Next, set the bias current. The bias current input pins (Pin1 and pin16) are two diode voltage drops and power supply V-, so Vbias = 2Vbe + V-, because this application V- = -13.67V and Vc =15V, Therefore, 1mA current can be obtained by connecting a 28.6KΩ resistor in series. When 30KΩ is the standard resistance value, the gain is directly proportional to the applied voltage.

Relationship Between Signal and Control Voltage

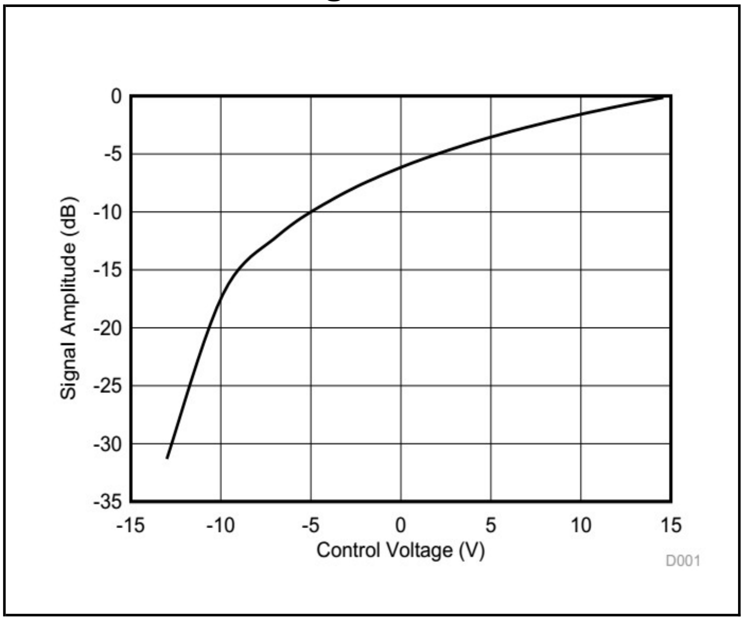


Figure 25. Signal Amplitude and Control Voltage

System Application Example

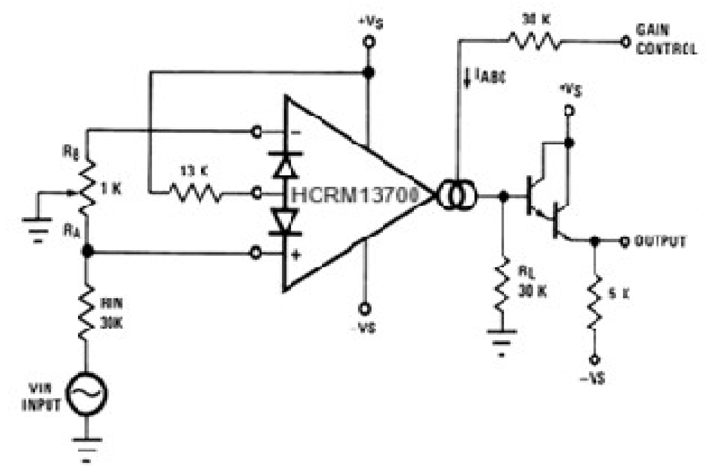


Figure 26. Voltage Control Amplifier

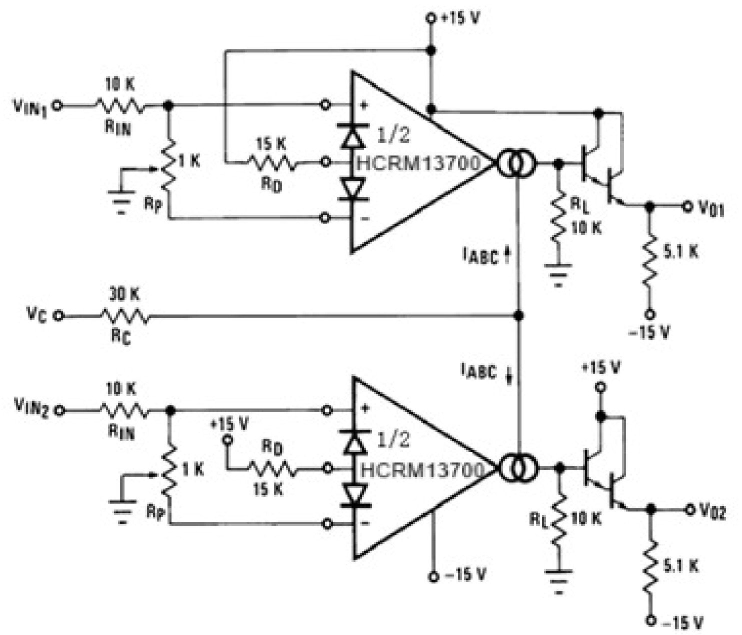


Figure 27. Stereo Audio Amplifier

System Application Example (Con.)

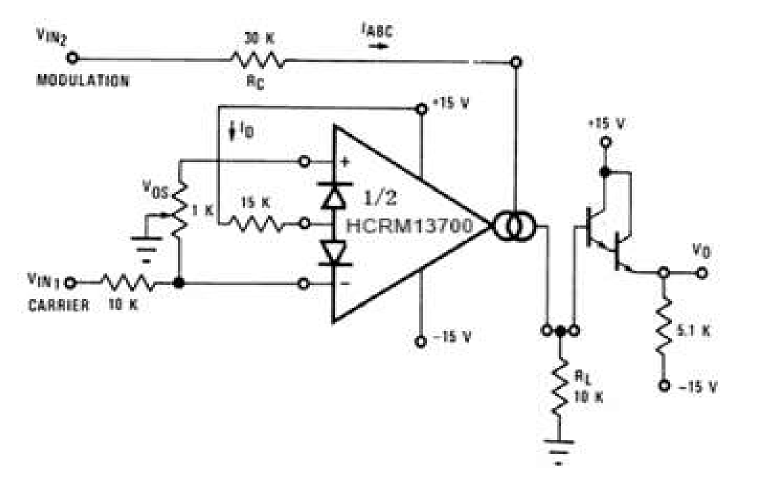


Figure 28. Amplitude modulator

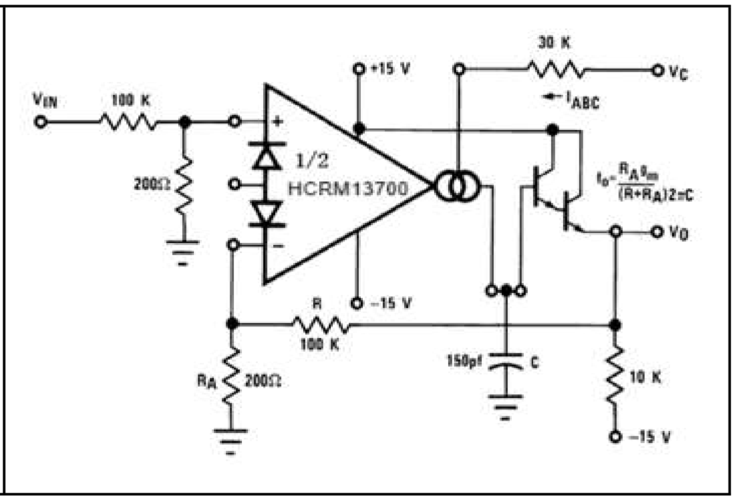


Figure 29. Voltage Controlled Low Pass Filter

System Application Example-3

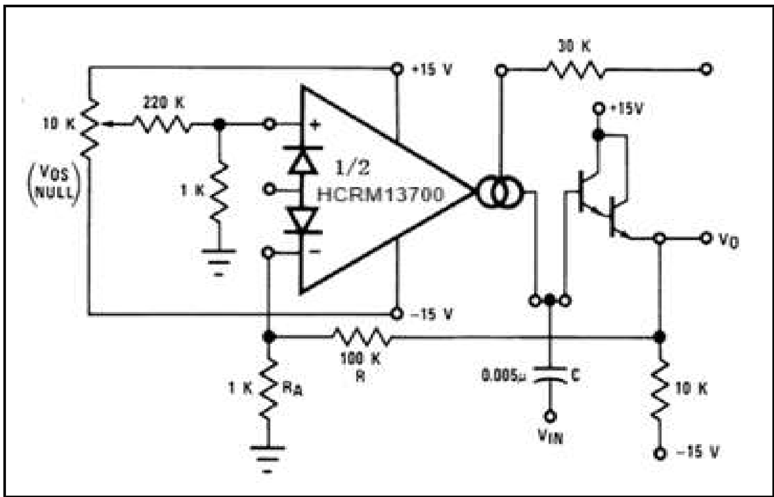


Figure 30. Voltage Controlled High Pass Filter

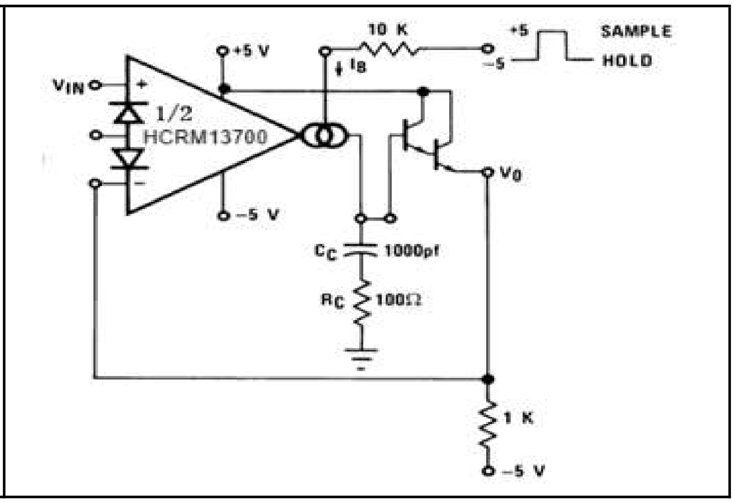


Figure 31. Sample and Hold Circuit

System Application Example-4

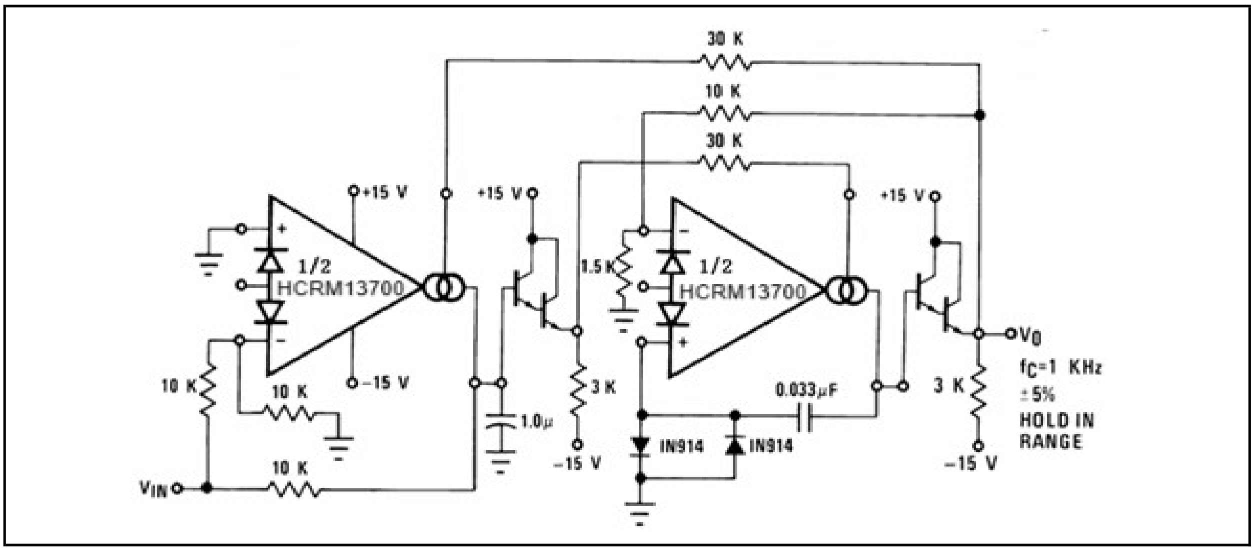


Figure 32. Phase Locked Loop

System Application Example-5

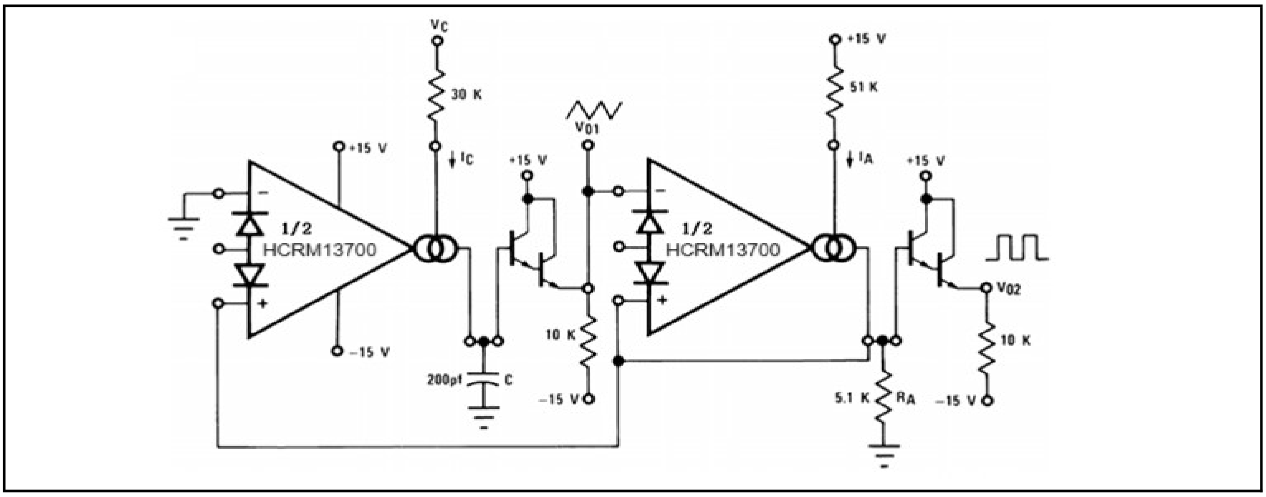


Figure 33. Triangular Wave / Rectangular Wave Voltage Controlled Oscillator

System Application Example-6

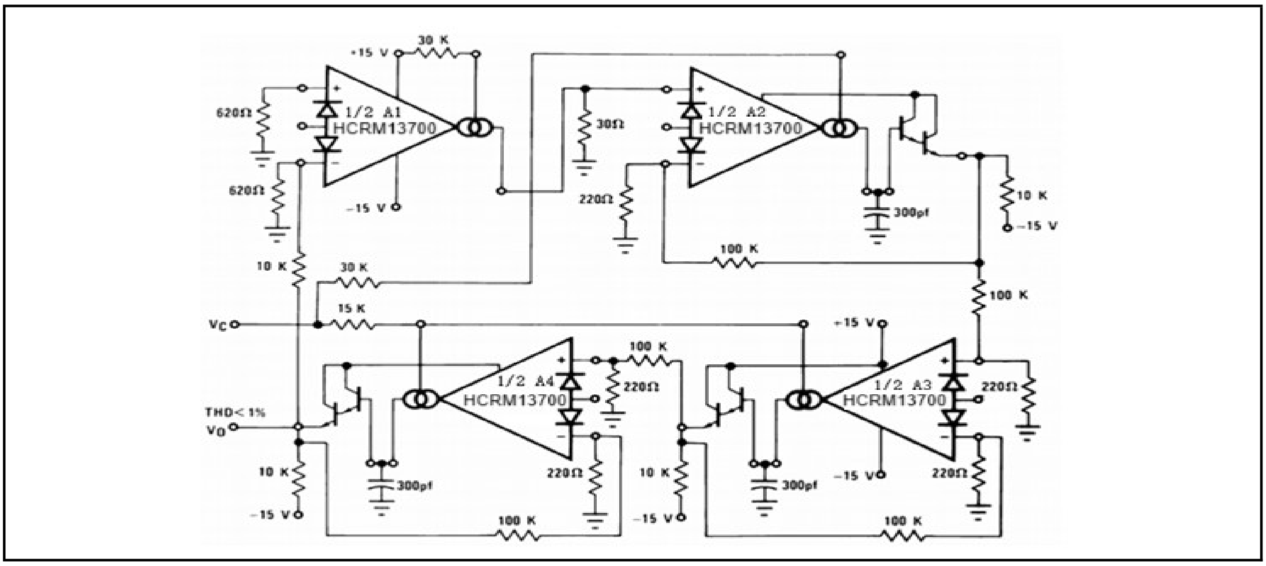


Figure 34. Sine Wave Voltage Controlled Oscillator

System Application Example-7

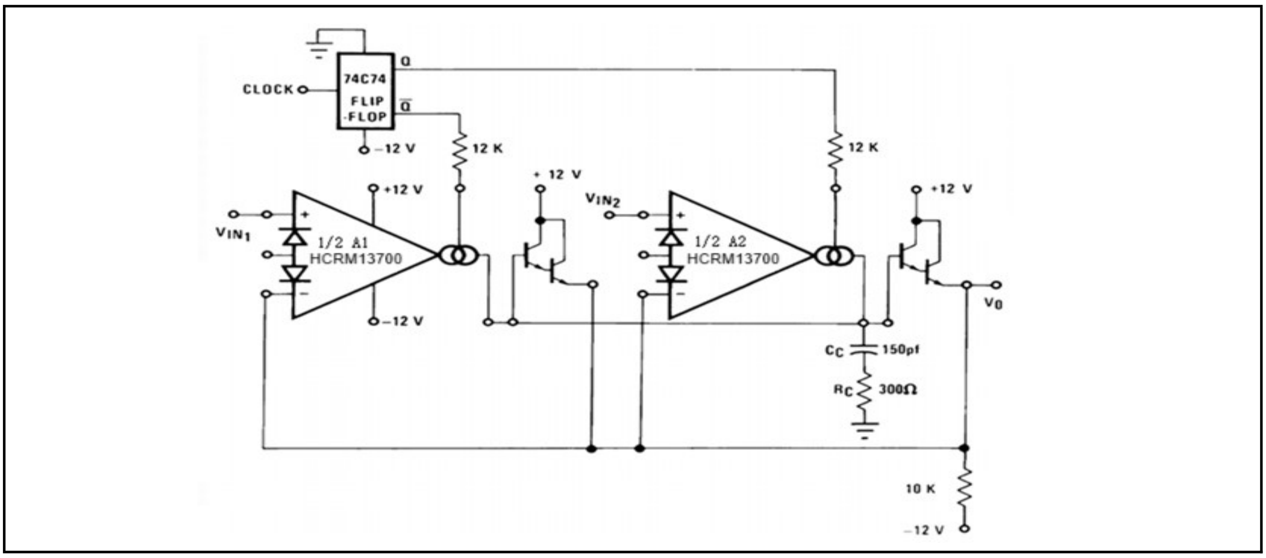
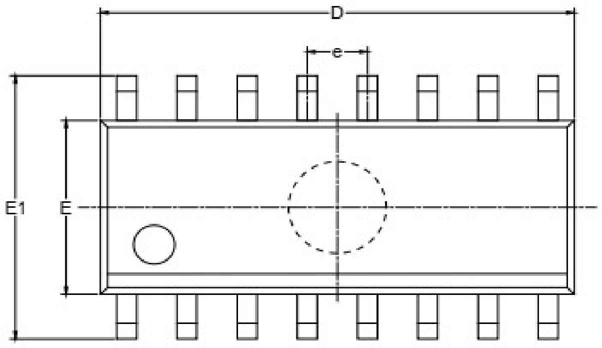


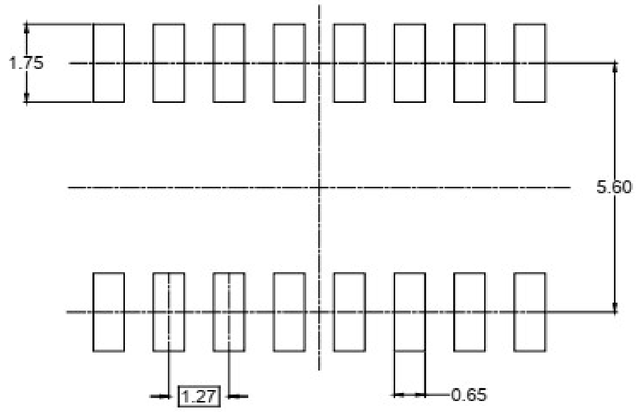
Figure 35. Multiplexer

Mechanical Dimensions

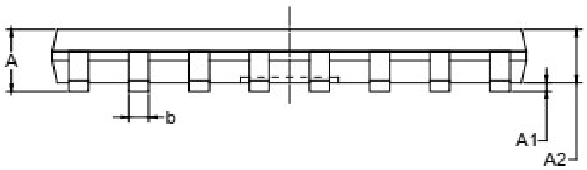
PKG: SOIC-16 (M16)

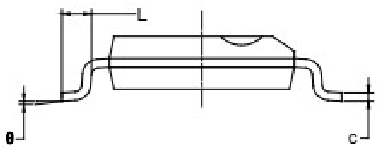
Unit:mm





RECOMMENDED LAND PATTERN (Unit: mm)



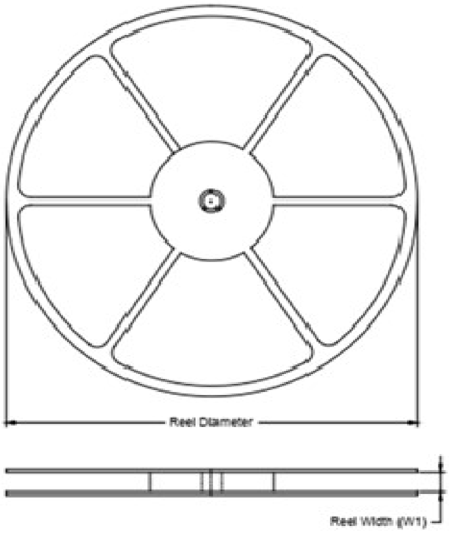


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	9.800	10.200	0.386	0.402
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.27 BSC		0.050 BSC	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

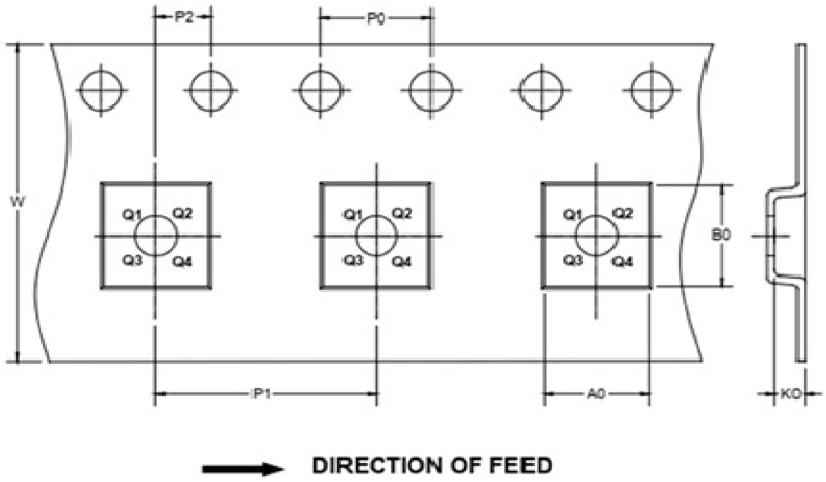
NOTES:
1. Body dimensions do not include mode flash or protrusion.
2. This drawing is subject to change without notice.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS

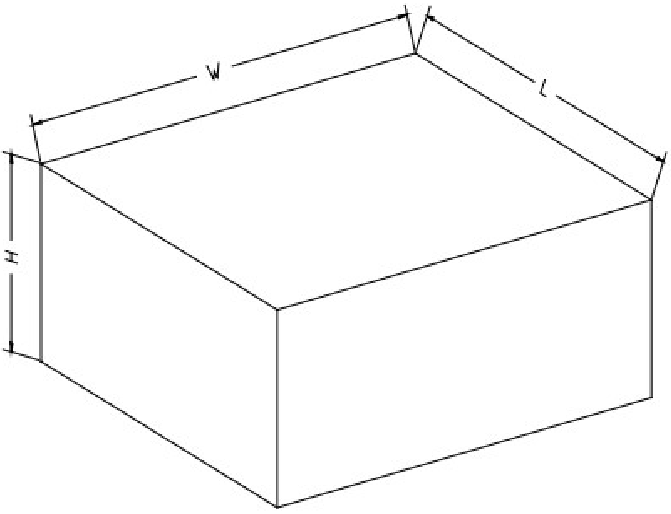


NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOIC-16	13"	16.4	6.5	10.3	2.1	4.0	8.0	2.0	16.0	Q1

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
13″	386	280	370	5

Statements And Notes

The name and content of Hazardous substances or Elements in the product

Part name	Hazardous substances or Elements									
	Lead and lead compounds	Mercury and mercury compounds	Cadmium and cadmium compounds	Hexavalent chromium compounds	Ploybrominated biphenyls	Polybrominated biphenyl ethers	Dibutyl phthalate	Butylbenzyl phthalate	Di-2-ethylhexyl phthalate	Diisobutyl phthalate
Lead frame	o	o	o	o	o	o	o	o	o	o
Plsatic resin	o	o	o	o	o	o	o	o	o	o
Chip	o	o	o	o	o	o	o	o	o	o
The lead	o	o	o	o	o	o	o	o	o	o
Plastic sheet installed	o	o	o	o	o	o	o	o	o	o
explanation	o: Indicates that the content of hazardous substances or elements in the detection limit of the following the SJ/T11363-2006 standard. X: Indicates that the content of hazardous substances or elemuents exceeding the SJ/T11363-2006 Standard limit requirements.									

Notion

Recommended carefully reading this information before the use of this product;

The information in this document are subject to change without notice;

This information is using to the reference only, the company is not responsible for any loss;

The company is not responsible for the any infringement of the third party patents or other rights of the responsibility.