SISTEMA
GENERADOR
DE
MODULACIONES
DE
ONDA

SIGMO-1

PROFESOR TUTOR: AUTOR:

FELIX HERNANDEZ CABRERA. MANUEL J. LUQUE BRITO.

I N D I C E

* 0. INTRODUCCION :

En este estudio se tratara de analizar los diferentes tipos de modulacion de onda y crear un sistema capaz de generarlos. Para su mejor comprension hemos dividido dicho estudio en dos apartados claramente diferenciados; primeramente, de cada tipo de modulacion haremos un pequeno resumen teorico que nos aclare basicamente cuales son los principales elementos que las componen. A continuacion pasaremos a exponer el desarrollo experimental, elaborado en el laboratorio, de cada una de ellas; asi como de un generador de funciones que produzca las senales moduladoras para cada caso, y de su fuente de alimentacion simetrica, regulada y estabilizada.

Tambien se incluye el diseno de las mecanormas correspondientes a los seis circuitos impresos, asi como su elaboracion y montaje.

0.1 OBJETO DEL PROYECTO :

Con este proyecto, que consiste en el diseno de un sistema capaz de generar las principales modulaciones de onda, concretamente diez casos, se pretende que los alumnos que estudien este tipo de fenomenos fisicos, puedan realizar practicas en el laboratorio visualizando en el osciloscopio cada una de estas modulaciones, pudiendo hacerse variaciones sobre amplitudes, frecuencias, fases, etc. llegando a resultados reales, contrastables con los obtenidos en sus clases teoricas.

En este estudio solo se aporta un cierto numero de las multiples posibilidades que este sistema permite alcanzar, dejando a la racionalizacion del alumno el conseguir su total desarrollo.

* 1. MODULACIONES ANALOGICAS CONTINUAS LINEALES :

Una definicion general de la modulacion lineal seria: La senal modulada es una funcion de la senal modulante f(t). Sea $\varphi[f(t)]$ la senal modulada; entonces, la modulacion es lineal si $\{ d/d[f(t)] \} \{ \varphi[f(t)] \}$ es independiente de f(t). De no ser asi, es una modulacion no lineal.

En el caso de las senales de modulacion de amplitud AM, las bandas laterales se rigen por el principio de superposicion. Asi pues, si $f_1(t)$ y $f_2(t)$ dan lugar a sendas bandas laterales φ_1 y φ_2 , la senal compuesta $f_1(t) + f_2(t)$ producira $\varphi_1 + \varphi_2$.No existen intermodulaciones o bandas laterales de producto cruzado, como se observaran en la modulacion de frecuencia FM. Por esta razon la AM es una modulacion lineal.

La modulacion lineal se presta a la manipulacion matematica y la generalizacion. Se puede encontrar el espectro de una senal modulada con la suma de dos senales modulantes calculando el espectro individual de cada senal para sumarlos posteriormente. Esto es muy util para calcular el ruido en sistemas de comunicacion. En los sistemas lineales de modulacion, el efecto del ruido presente en el canal puede calcularse suponiendo que la senal es cero.

1.1 MODULACION EN AMPLITUD [AM] :

En la modulacion de amplitud, la amplitud de la portadora varia proporcionalmente al mensaje modulador.

Supongamos que disponemos de una onda moduladora sinusoidal $fm(t) = Am\ \cos(Wmt + \beta m)$ y de una portadora $fc(t) = Ac\ \cos(Wct + \beta c)$; Para simplificar vamos a admitir que las fases iniciales de las dos ondas βm y βc son nulas. La expresion que se obtiene de la onda modulada $\varphi_{AM}(t)$, sabiendo que la amplitud de esta onda esta compuesta por la amplitud de la onda portadora Ac aumentada por una senal proporcional a la onda moduladora $fm(t) = Ka\ Am\ \cos(Wmt)$.

$$\varphi_{AM}(t) = [\ Ac + Ka\ fm(t)\ ]\ \cos(Wc\ t)$$

Observemos que para evitar que la onda modulada (la portadora) invierta su fase tiene que cumplirse que:

$$Ac >= Ka\ fm(t)$$

$$\varphi_{AM}(t) = [\ Ac + Ka\ Am\ \cos(Wm\ t)\ ]\ \cos\ Wc\ t$$

$$= Ac\ [\ 1 + Ka\ Am\ \cos(Wm\ t)\ /\ Ac\ ]\ \cos(Wc\ t)$$

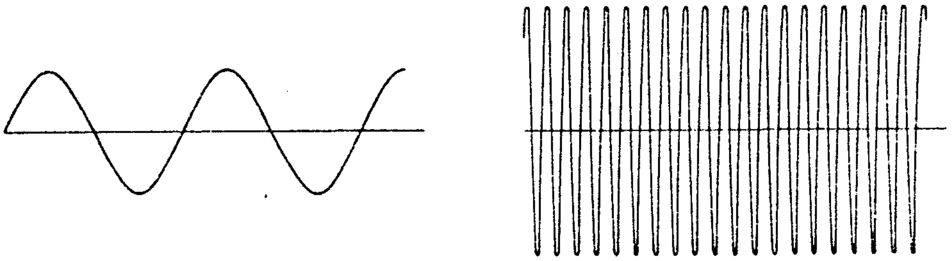
$$\varphi_{AM}(t) = Ac\ [\ 1 + m\ \cos(Wm\ t)\ ]\ \cos\ (Wc\ t)$$

Por definicion llamamos indice de modulacion m a:

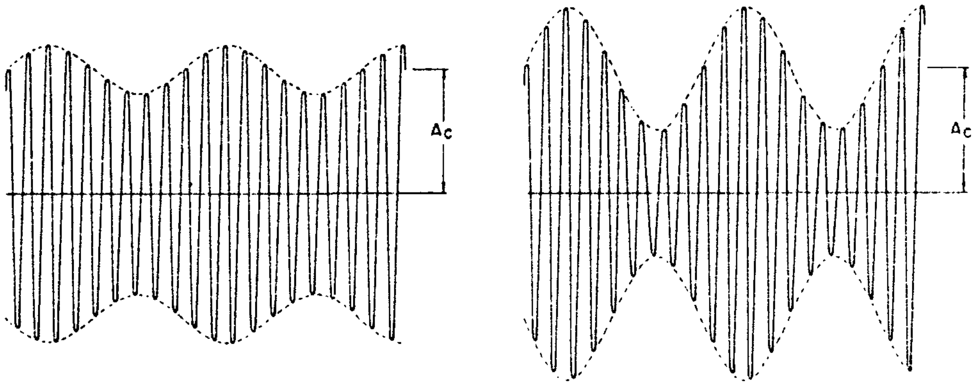
$$m = Ka\ Am\ /\ Ac$$

que con la condicion de que Ac > Ka Am hace que:

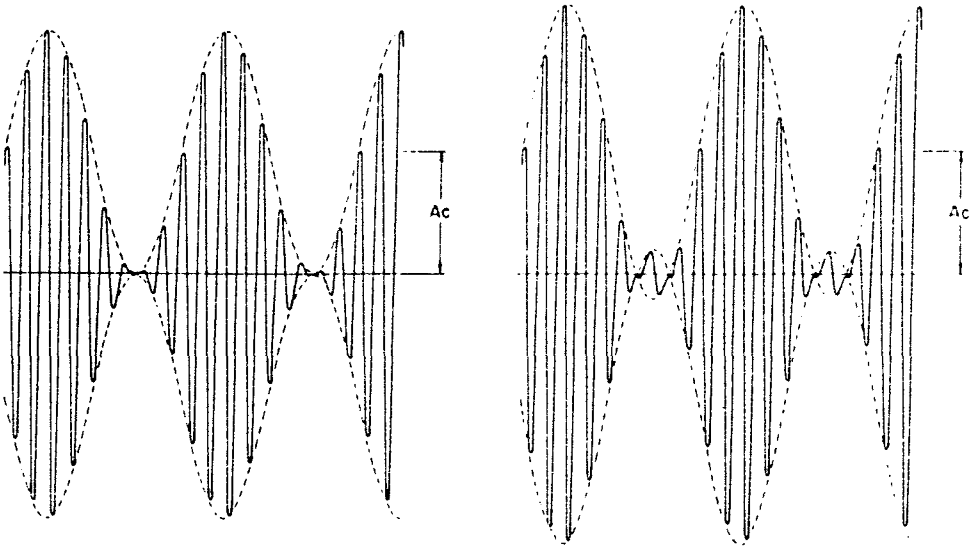
$$m = Ka\ Am\ /\ Ac \leq 1$$



A) ONDA MODULADORA $A_m \cos \omega_m t$ B) ONDA PORTADORA $A_c \cos \omega_c t$



C) 20% D) 50%



E) 100% F) m > 100%

Figura (1.1)

Frecuentemente el indice de modulacion se expresa de la siguiente manera:

Porcentaje de modulacion = m x 100 %

El indice de modulacion determina la variacion maxima de la amplitud de una onda de AM. Para mas claridad en la figura (1.1) se representan ondas moduladas en AM para diferentes indices de modulacion.

En la figura (1.1C), se representa un porcentaje de modulacion de un 20 %, es decir que la amplitud de la senal de AM es 1/5 de la amplitud de la portadora. Estas dos amplitudes se hacen iguales, cuando el porcentaje de modulacion es maximo (100%). La Fig.(1.1F) representa un porcentaje de modulacion superior al 100 %, en este caso hay sobremodulacion y la envolvente de la senal modulada no es proporcional a la onda moduladora dando lugar a un cambio de signo.

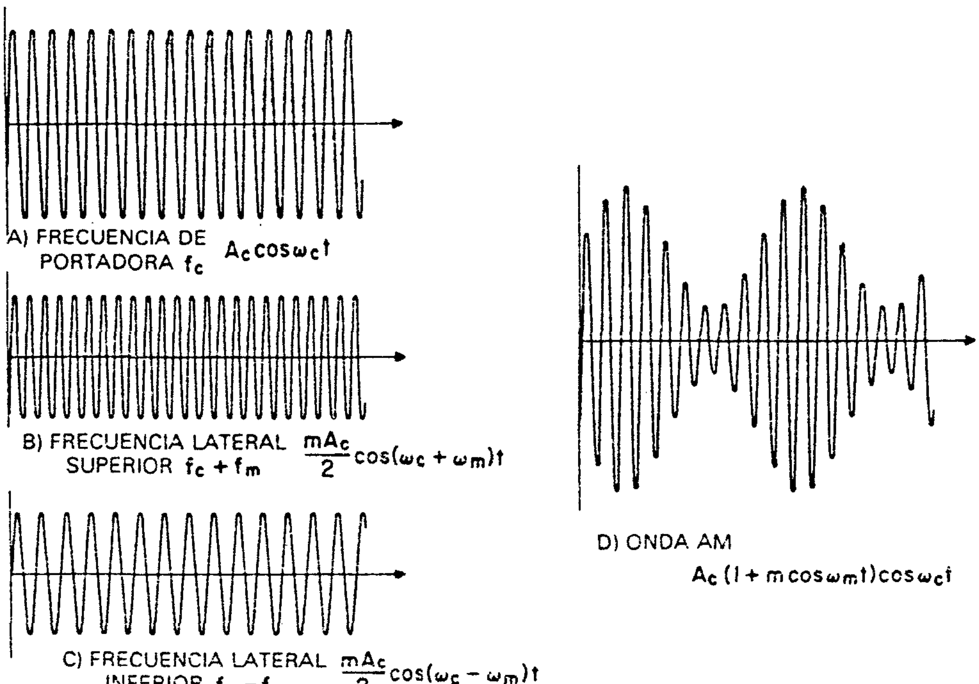


Figura (1.2)

La expresion de la onda AM puede desarrollarse de la forma siguiente:

$$\varphi_{AM}(t) = Ac\ [\ 1 + m \cos(Wm\ t)\ ]\ \cos(Wc\ t)$$

$$= Ac \cos(Wct) + m\ Ac \cos(Wmt) \cos(Wct)$$

$$= Ac \cos Wct + mAc\{\cos[(Wc+Wm)t] + \cos[(Wc-Wm)t]\}/2$$

Una onda AM se compone de tres ondas, la portadora y dos ondas cuyas frecuencias son (Wc + Wm) y (Wc - Wm). En la figura (1.2) podemos ver esta propiedad.

El ancho de banda de una onda AM es de 2fm, siendo fm la frecuencia moduladora maxima. Teoricamente para la transmision de una senal de audio el ancho de banda seria de 40 kHz, pero para la transmision en fonia es suficiente con 6 kHz, 10 kHz para una transmision musical, y 30 kHz para una transmision de audio de alta fidelidad.

Las altas frecuencias de audio, por ser poco numerosas, no afectan de forma particular a la calidad del sonido.

La potencia media Pt de una emision de AM, puede ser expresada en funcion de la potencia media de la portadora Pc, y de las potencias medias de las bandas laterales Pusb y Plsb.

Si una onda de AM se emite con una antena de resistencia de radiacion R, las potencias seran proporcionales al cuadrado de los valores eficaces:

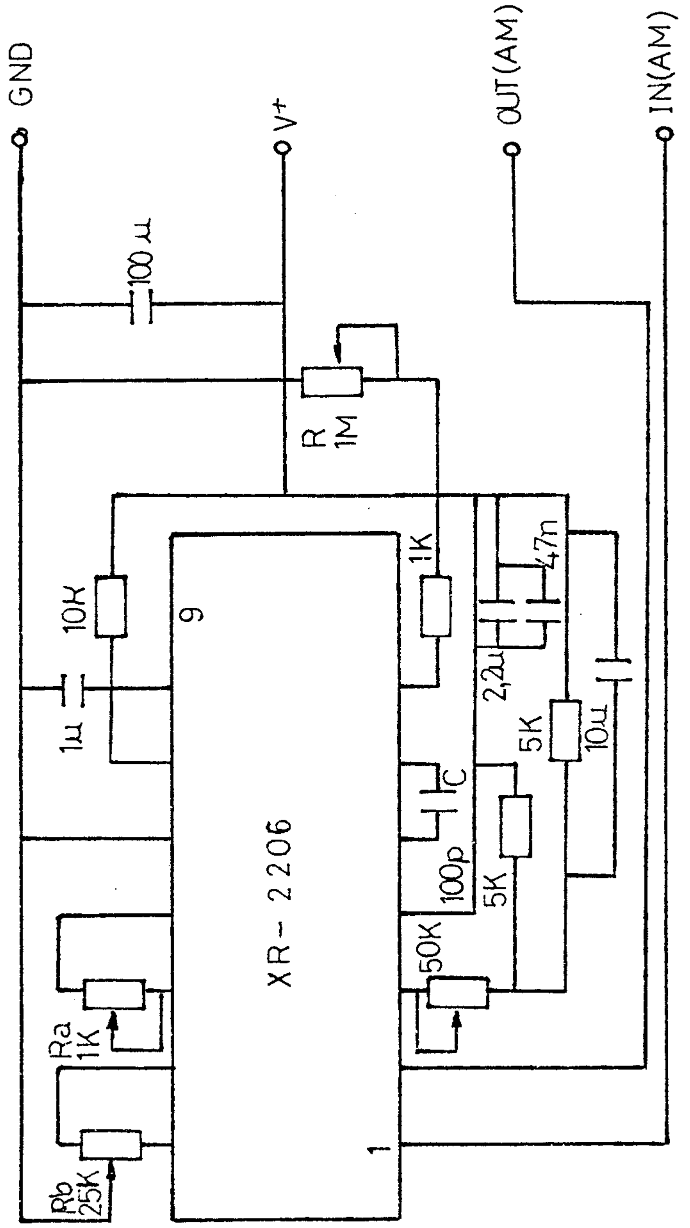
$$Pt = (Ac/\sqrt{2})^2 / R + (m\ Ac/2\sqrt{2})^2 / R + (m\ Ac/2\sqrt{2})^2 / R$$

como: $Pusb = Plsb = m^2 Pc / 4$

obtenemos: $Pt = Pc\ [\ 1 + m^2 / 2\ ]$

Un indice de modulacion maximo m=1, da lugar a una potencia en cada banda lateral de 1/6 de la potencia total emitida Pt. La potencia de la portadora de la senal de AM es de 2/3 de la potencia emitida.

1.1.1 CIRCUITO PROPUESTO : AM



1.1.2 DESARROLLO PRACTICO:

El circuito integrado XR-2206 esta compuesto por cuatro bloques funcionales: Un VCO, un multiplicador analogico generador de onda sinusoidal, un amplificador buffer y unos conmutadores de corriente. Estos conmutadores internos transfiren la corriente del oscilador a alguna de las dos resistencias exteriores de timing.

La frecuencia de operacion, fo, esta determinada por el condensador externo C (entre las patillas 5 y 6) y por el potenciometro R (en la patilla 7 u 8). La frecuencia esta dada por fo = 1 / RC Hz, luego puede ser ajustada variando R y C. Los valores de R recomendados para una estabilidad optima oscilan entre 4KΩ y 200KΩ. Y los valores recomendados para C, entre 100 pF y 100 uF.

Los valores de C y de R tomados en el circuito han sido:

R = 1KΩ + un potenciometro de 1MΩ

C = 0,1 nF

Luego:

fo (para R = 1KΩ) = 10 MHz.

fo (para R = 1MΩ) = 1 KHz.

La frecuencia de oscilacion es proporcional a la corriente total oscilante sacada de la patilla 7 u 8.

f = 320 It(mA) / C(uF) Hz.

Los terminales de timing (patillas 7 y 8) son puntos de baja impedancia, puestos internamente a 3 Voltios con respecto a la patilla 12. La frecuencia varia linealmente con It sobre un rango ancho de valores de corriente entre 1 uA y 3 mA.

La maxima amplitud de salida es inversamente proporcional a la resistencia externa Rc, conectada a la patilla 3. Para la salida de onda sinusoidal, que es la que utilizamos para nuestra aplicacion, la amplitud es aproximadamente de 60 mVpp. por KΩ de Rc.

La amplitud de la salida en este caso esta siendo modulada por la aplicacion de una senal de modulacion en la patilla 1. La impedancia interna de la patilla 1 es aproximadamente 100KΩ. La amplitud de salida varia linealmente con la tension aplicada a la patilla 1 para valores de ±4V.

El rango total de AM es de 55 dB.

El nivel de continua DC a la salida (patilla 2) es aproximadamente el mismo que en la patilla 3. En el circuito propuesto anteriomente tenemos la patilla 3 puesta a V+ / 2, y como el valor adoptado para V+ es de 12 V.,el nivel de continua DC sera de 6 V.

La distorsion de la portadora puede ser suprimida hasta el 0,5%, con los potenciometros Ra y Rb de ajuste. El potenciometro Ra ajusta la forma de onda sinusoidal y Rb produce el ajuste fino para la simetria. Los ajustes se hacen de la siguiente manera:

a) Poner Rb a la mitad y ajustar Ra para la minima distorsion.

b) Con Ra ajustada, ajustar Rb hasta reducir aun mas la distorsion.

NOTA:

Para visualizar correctamente en un osciloscopio la senal de AM, debemos hacer que la senal moduladora tenga un valor entre 1 Vpp y 2 Vpp.

El ajuste de offset debe estar sobre el nivel de continua, aunque variando este podemos cambiar el indice de modulacion de la senal de AM.
Ver figura (1.1).

1.2 MODULACION EN DOBLE BANDA LATERAL [DSB]:

El analisis del reparto de las potencias de una senal de AM nos indica que, como minimo, los 2/3 de la potencia emitida esta contenida en la portadora que no tiene informacion. Esto supone una perdida de energia evidente, que puede remediarse suprimiendo la portadora.

De la ecuacion:

$$\gamma_{AM}(t) = Ac\ cosWct + m\ Ac\{cos[(Wc+Wm)t] + cos[(Wc-Wm)]]\}/\ 2$$

Eliminamos la portadora y queda:

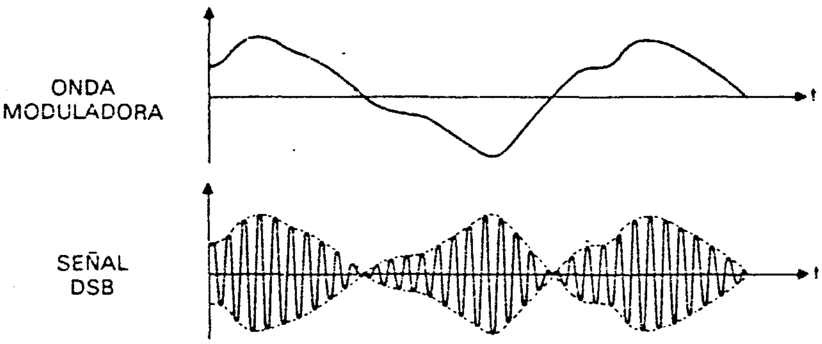
$$\gamma_{AM}(t) = m\ Ac\ cos(Wct)\ cos(Wmt)$$

$$\gamma_{AM}(t) = Ka\ Am\ cos(Wmt)\ cos(Wct)$$

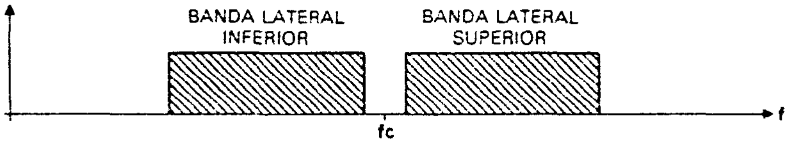
Esta senal contiene la informacion del mensaje que se quiere transmitir cuya amplitud y pulsacion son: Am y Wm. La portadora fc es una frecuencia fija que no contiene informacion, pero permite transmitir los parametros de la informacion que se detectaran luego en un receptor.

Una senal modulada en doble banda lateral (DBS), solamente transmite las bandas laterales superior e inferior de una emision en AM. La representacion en funcion del tiempo, de una senal de DSB es tal que todo cambio de signo de la onda moduladora anula la amplitud u origina un cambio de fase de la portadora. En la figura (1.3) se representa una onda de DSB en funcion del tiempo.

La modulacion en doble banda lateral se denomina a veces modulacion de amplitud con portadora suprimida, cuya sigla es DSB-SC.

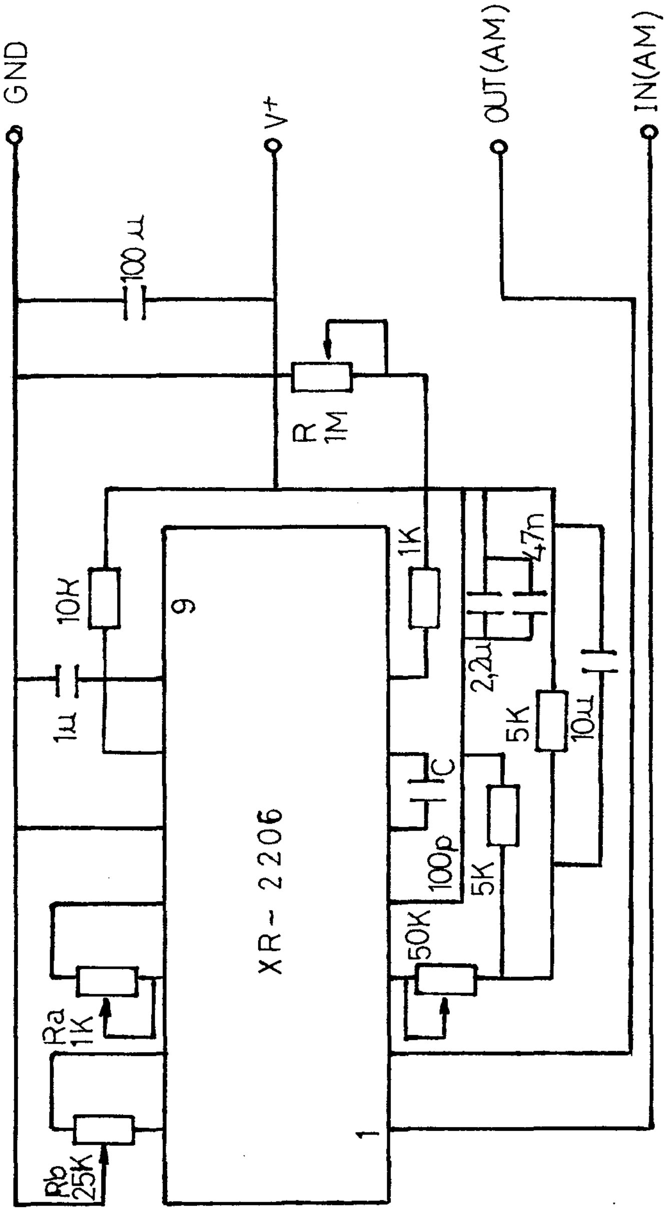


A) REPRESENTACION EN FUNCION DEL TIEMPO



B) ESPECTRO

1.2.1 CIRCUITO PROPUESTO : DSB



1.2.2 DESARROLLO PRACTICO:

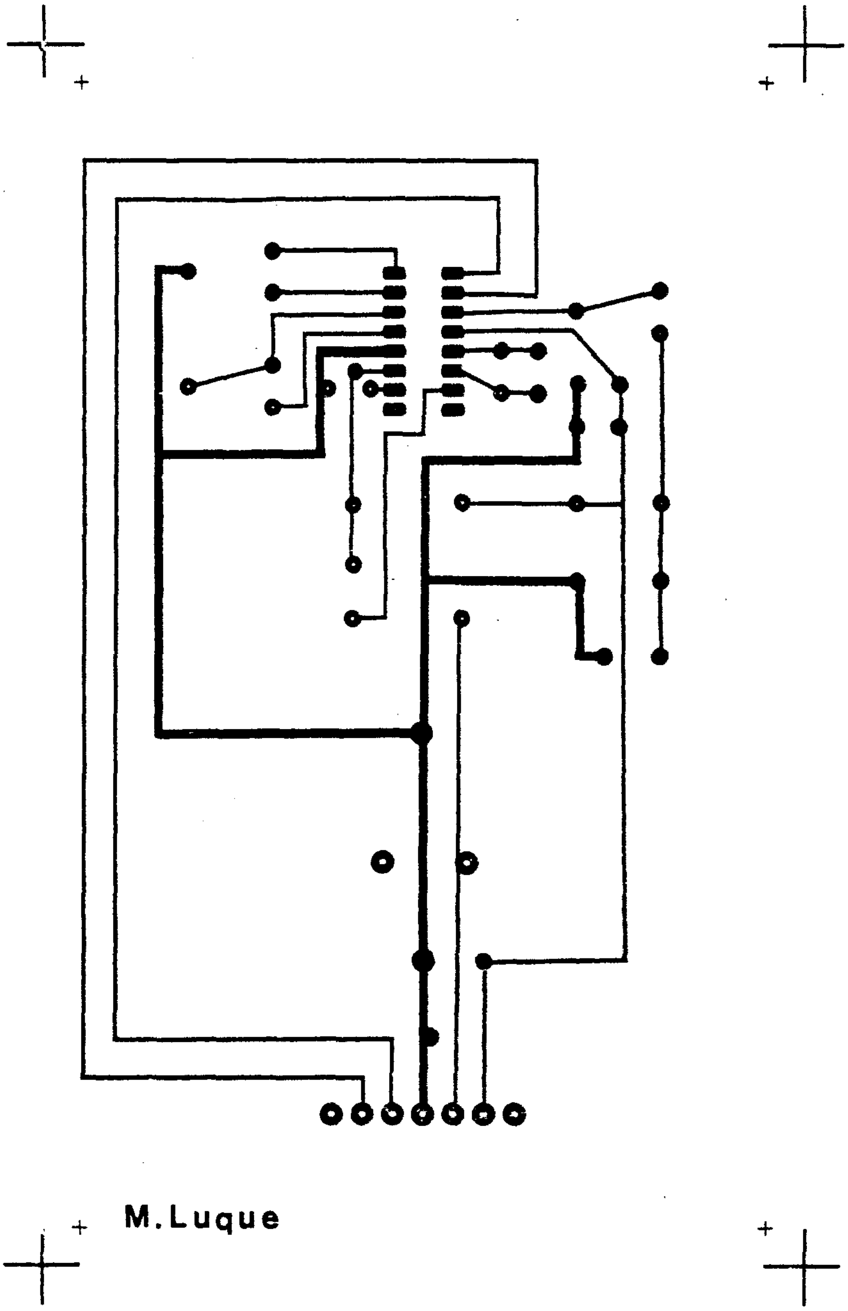
Como vemos, el circuito propuesto para la doble banda lateral (DSB) es similar al de la modulacion de amplitud (AM).

Por lo tanto son validos todos los comentarios propuestos anteriormente para el circuito de AM.

Solo tenemos que variar el nivel de offset de la senal moduladora, hasta el punto correcto para que se produzca la DSB.

Recordemos que la DSB es tal que todo cambio de signo de la onda moduladora anula la amplitud y origina un cambio de fase de la portadora.
Ver la figura (1.3).

1.3 MECANORMA AM Y DSB :



M.Luque

ELECTRICAL CHARACTERISTICS

Test Conditions: Test Circuit of Fig. 2, $V^+ = 12V$, $T_A = 25°C$, $C = 0.01\ \mu F$, $R_1 = 100\ K\Omega$, $R_2 = 10\ K\Omega$ $R_3 = 25\ K\Omega$ unless otherwise specified. S_1 open for triangle, closed for sinewave.

CHARACTERISTICS	XR-2206/XR-2206M			XR-2206C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Supply Voltage								
Single Supply	10		26	10		26	V	
Split Supply	±5		±13	±5		±13	V	
Supply Current		12	17		14	20	mA	$R_1 \geq 10\ K\Omega$
Oscillator Section								
Max. Operating Frequency	0.5	1		0.5	1		MHz	$C = 1000$ pF, $R_1 = 1\ K\Omega$
Lowest Practical Frequency		0.01			0.01		Hz	$C = 50\ \mu F$, $R_1 = 2\ M\Omega$
Frequency Accuracy		±1	±4		±2		% of f_o	$f_o = 1/R_1C$
Temperature Stability		±10	±50		±20		ppm/°C	$0°C \leq T_A \leq 75°C$, $R_1 = R_2 = 20\ K\Omega$
Supply Sensitivity		0.01	0.1		0.01		%/V	$V_{LOW} = 10V$, $V_{HIGH} = 20V$, $R_1 = R_2 = 20\ K\Omega$
Sweep Range	1000:1	2000:1			2000:1		$f_H = f_L$	f_H @ $R_1 = 1\ K\Omega$ f_L @ $R_1 = 2\ M\Omega$
Sweep Linearity								
10:1 Sweep		2			2		%	$f_L = 1$ kHz, $f_H = 10$ kHz
1000:1 Sweep		8			8		%	$f_L = 100$ Hz, $f_H = 100$ kHz
FM Distortion		0.1			0.1		%	±10% Deviation
Recommended Timing Components								
Timing Capacitor: C	0.001		100	0.001		100	µF	See Figure 5
Timing Resistors: R_1 & R_2	1		2000	1		2000	KΩ	
Triangle/Sinewave Output								See Note 1, Fig. 3
Triangle Amplitude		160			160		mV/KΩ	Fig. 2 S_1 Open
Sinewave Amplitude	40	60	80		60		mV/KΩ	Fig. 2 S_1 Closed
Max. Output Swing		6			6		Vpp	
Output Impedance		600			600		Ω	
Triangle Linearity		1			1		%	
Amplitude Stability		0.5			0.5		dB	For 1000:1 Sweep
Sinewave Amplitude Stability		-4800			-4800		ppm/°C	See Note 2
Sinewave Distortion								$R_1 = 30\ K\Omega$
Without Adjustment		2.5			2.5		%	See Figure 11
With Adjustment		0.4	1.0		0.5	1.5	%	See Figure 12
Amplitude Modulation								
Input Impedance	50	100		50	100		KΩ	
Modulation Range		100			100		%	
Carrier Suppression		55			55		dB	
Linearity		2			2		%	For 95% modulation
Square Wave Output								Measured at Pin 11
Amplitude		12			12		Vpp	
Rise Time		250			250		nsec	$C_L = 10$ pF
Fall Time		50			50		nsec	$C_L = 10$ pF
Saturation Voltage		0.2	0.4		0.2	0.6	V	$I_L = 2$ mA
Leakage Current		0.1	20		0.1	100	µA	$V_{11} = 26V$
FSK Keying Level (Pin 9)	0.8	1.4	2.4	0.8	1.4	2.4	V	See Section on Circuit Controls
Reference Bypass Voltage	2.9	3.1	3.3	2.5	3	3.5	V	Measured at Pin 10.

Note 1: Output Amplitude is directly proportional to the resistance R_3 on Pin 3. See Figure 3.
Note 2: For maximum amplitude stability R_3 should be a positive temperature coefficient resistor.

ELECTRICAL CHARACTERISTICS

Test Conditions: Test Circuit of Fig. 2, $V^+ = 12V$, $T_A = 25°C$, C = 0.01 µF, R_1 = 100 KΩ, R_2 = 10 KΩ R_3 = 25 KΩ unless otherwise specified. S_1 open for triangle, closed for sinewave.

CHARACTERISTICS	XR-2206/XR-2206M			XR-2206C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Supply Voltage								
Single Supply	10		26	10		26	V	
Split Supply	±5		±13	±5		±13	V	
Supply Current		12	17		14	20	mA	$R_1 \geq 10$ KΩ
Oscillator Section								
Max. Operating Frequency	0.5	1		0.5	1		MHz	C=1000 pF, R_1=1 KΩ
Lowest Practical Frequency		0.01			0.01		Hz	C=50 µF, R_1=2 MΩ
Frequency Accuracy		±1	±4		±2		% of f_o	$f_o = 1/R_1C$
Temperature Stability		±10	±50		±20		ppm/°C	$0°C \leq T_A \leq 75°C$, $R_1=R_2$=20 KΩ
Supply Sensitivity		0.01	0.1		0.01		%/V	V_{LOW} = 10V, V_{HIGH} = 20V, $R_1 = R_2$ = 20 KΩ
Sweep Range	1000:1	2000:1			2000:1		$f_H = f_L$	f_H @ R_1 = 1 KΩ f_L @ R_1 = 2 MΩ
Sweep Linearity								
10:1 Sweep		2			2		%	f_L = 1 kHz, f_H = 10 kHz
1000:1 Sweep		8			8		%	f_L = 100 Hz, f_H = 100 kHz
FM Distortion		0.1			0.1		%	±10% Deviation
Recommended Timing Components								
Timing Capacitor: C	0.001		100	0.001		100	µF	See Figure 5
Timing Resistors: R_1 & R_2	1		2000	1		2000	KΩ	
Triangle/Sinewave Output								See Note 1, Fig. 3
Triangle Amplitude		160			160		mV/KΩ	Fig. 2 S_1 Open
Sinewave Amplitude	40	60	80		60		mV/KΩ	Fig. 2 S_1 Closed
Max. Output Swing		6			6		Vpp	
Output Impedance		600			600		Ω	
Triangle Linearity		1			1		%	
Amplitude Stability		0.5			0.5		dB	For 1000:1 Sweep
Sinewave Amplitude Stability		–4800			–4800		ppm/°C	See Note 2
Sinewave Distortion								R_1 = 30 KΩ
Without Adjustment		2.5			2.5		%	See Figure 11
With Adjustment		0.4	1.0		0.5	1.5	%	See Figure 12
Amplitude Modulation								
Input Impedance	50	100		50	100		KΩ	
Modulation Range		100			100		%	
Carrier Suppression		55			55		dB	
Linearity		2			2		%	For 95% modulation
Square Wave Output								Measured at Pin 11
Amplitude		12			12		Vpp	
Rise Time		250			250		nsec	C_L = 10 pF
Fall Time		50			50		nsec	C_L = 10 pF
Saturation Voltage		0.2	0.4		0.2	0.6	V	I_L = 2 mA
Leakage Current		0.1	20		0.1	100	µA	V_{11}= 26V
FSK Keying Level (Pin 9)	0.8	1.4	2.4	0.8	1.4	2.4	V	See Section on Circuit Controls
Reference Bypass Voltage	2.9	3.1	3.3	2.5	3	3.5	V	Measured at Pin 10.

Note 1: Output Amplitude is directly proportional to the resistance R_3 on Pin 3. See Figure 3.
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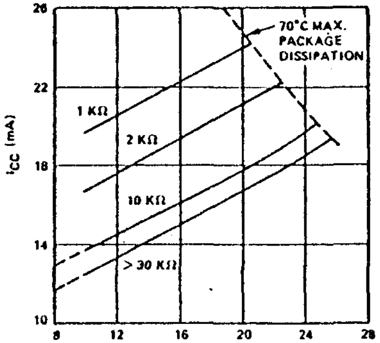


Figure 4. Supply Current vs Supply Voltage, Timing R

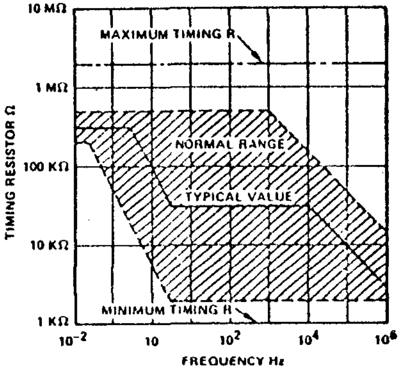


Figure 5. R vs Oscillation Frequency

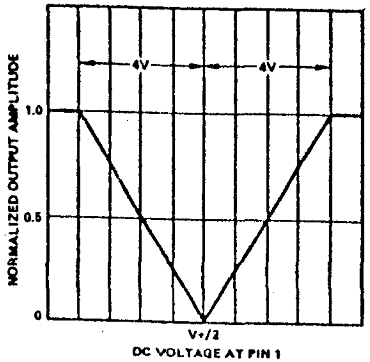


Figure 6. Normalized Output Amplitude vs DC Bias at AM Input (Pin 1).

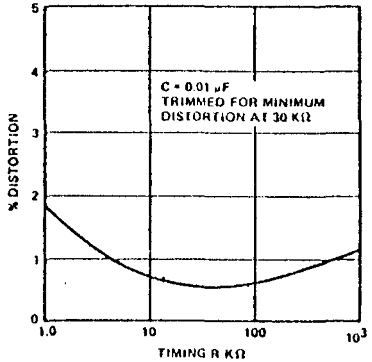


Figure 7. Trimmed Distortion vs Timing Resistor

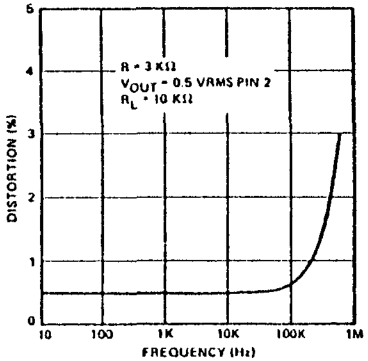


Figure 8. Signwave Distortion vs Operating Frequency With Timing Capacitors Varied

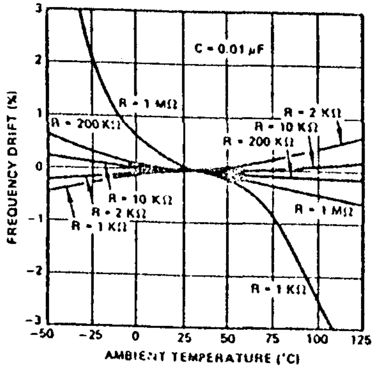


Figure 9. Frequency Drift vs Temperature

* 2. MODULACIONES ANALAGICAS CONTINUAS NO LINEALES:

La modulacion analogica continua no lineal (Angular o exponencial), a partir de una frecuencia de portadora fc y una senal moduladora fm, contiene otras componentes espectrales ademas de (fc + fm) y (fc - fm). En la modulacion de frecuencia FM y en la de la fase PM, el espectro es bastante mas complejo.

En la modulacion no lineal surgen terminos de modulacion cruzada. Por estas razones resulta interesante aproximarse a la modulacion no lineal por medio de un modelo lineal. El caso es analogo al del analisis de un sistema no lineal aproximable a otro lineal en un rango limitado de amplitudes de senal.

La FM se comporta aproximadamente lineal para un indice de modulacion pequeno.

2.1 MODULACION DE FRECUENCIA [FM] :

En este tipo de modulacion la frecuencia de la portadora varia linealmente en funcion del mensaje modulador $fm(t)$, siendo la frecuencia instantanea $fc+Kf.fm(t)$. La pulsacion varia en funcion del tiempo de acuerdo con la expresion siguiente:

$$Wi(t) = Wc + 2\pi\ Kf\ fm(t)$$

$Wi(t)$ representa la pulsacion instantanea, Wc la pulsacion de la portadora, y Kf es una constante.

La pulsacion de una onda sinusoidal es la velocidad angular de esta, por consiguiente la derivada del angulo θc respecto al tiempo.

$$Wi(t) = d\theta c(t)/dt = Wc + 2\pi\ Kf\ fm(t)$$

$$\theta c(t) = Wi(t)\ dt = Wc\ t + 2\pi\ Kf \int fm(t)\ dt$$

Luego la expresion matematica de la onda es:

$$\varphi_{FM}(t) = Ac \cos [\ Wc\ t + 2\pi\ \ Kf \int fm(t)\ dt\ ]$$

En el supuesto de un mensaje modulador del tipo $Am.\cos(Wm\ t)$:

$$\varphi_{FM}(t) = Ac \cos[\ Wc\ t + 2\pi\ Kf \int Am \cos(Wmt)\ dt\ ]$$

$$= Ac \cos\{\ Wc\ t + [\ 2\pi\ Kf\ Am\ sen(Wm\ t)\ ]\ /\ Wm\ ]\}$$

$$= Ac \cos\{\ Wc\ t + [\ Kf\ Am\ sen(Wm\ t)]\ /\ fm\ \}$$

Ver figura (2.1).

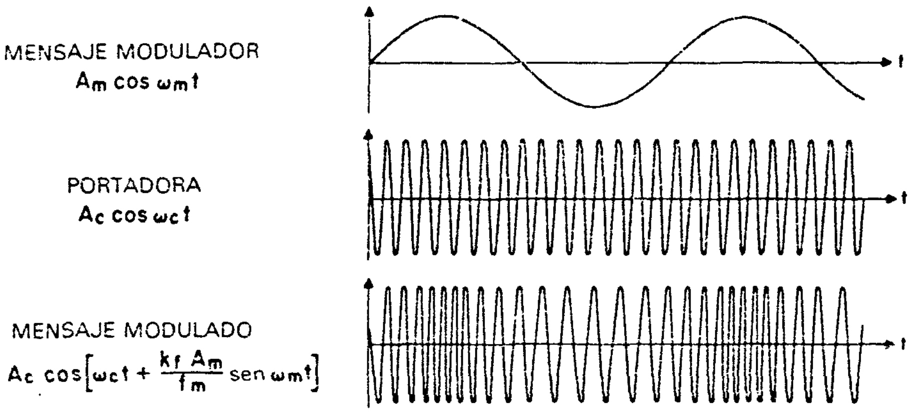


Figura (2.1)

Cuando el mensaje modulador es sinusoidal, la frecuencia de la onda modulada es $fc + Kf\ Am \cos(Wm\ t)$, y varia entre ($fc - Kf\ Am$) y ($Fc + Kf\ Am$). La desviacion maxima de frecuencia es $\Delta F = Kf\ Am$ y se denomina excursion o desviacion de frecuençia.

La relacion $\Delta f/fm$ se define como indice de modulacion mf de una senal de FM, cuya expresion es la siguiente:

$$\varphi_{FM}(t) = Ac \cos[\ Wc\ t + mf\ sen(Wm\ t)$$

$$mf = \Delta f\ /\ fm = Kf\ Am\ /\ Fm$$

$$\text{Siendo}\quad \Delta f = \Delta W\ /\ 2\pi$$

Una senal de FM cuyas frecuencias de portadora y moduladora tienen velocidades angulares Wc y Wm, poseen un numero infinito de componentes situados a $Wc \pm n\ Wm$ de la portadora, siendo n un numero entero (0,1,2,3,....). Las amplitudes correspondientes a estas frecuencias estan determinadas por los coeficientes Jn (mf), conocidos como funciones de Bessel.

La expresion de una senal de FM viene dada por:

$$
\begin{aligned}
e_{FM}(t) &= Ac \cos[\, Wc\ t + mf\ \mathrm{sen}(Wm\ t) \,] \\
&= Ac\ \Sigma\ Jn\ (mf) \cos(\, Wc + n\ Wm \,)\ t \\
&= Ac\ Jo\ (mf) \cos(Wc\ t) \\
&+ Ac\ J\ (mf)\ [\, \cos(Wc + Wm)t - \cos(Wc - Wm)t \,] \\
&+ Ac\ J\ (mf)\ [\, \cos(Wc + 2Wm)t + \cos(Wc - 2Wm)t \,] \\
&+ Ac\ J\ (mf)\ [\, \cos(Wc + 3Wm)t + \cos(Wc - 3Wm)t \,] \\
&+ \ldots\ldots\ldots\ldots
\end{aligned}
$$

La variacion de las funciones de Bessel en funcion del indice de modulacion se representa en la figura (2.2) Estas funciones son la solucion de la ecuacion :

$$mf^2\, d^2 f \ /\ dmf + mf\ df \ /\ dmf + (mf^2 - n^2)\ f = 0$$

En la practica se utilizan las tablas que representan las funciones de Bessel para una amplitud igual o superior a 0,01. La razon de elegir este valor, es que componentes espectrales, cuya amplitud es menor, pueden ser despreciados sin que esto afecte al funcionamiento general de la senal de FM.

Una senal de FM tiene a cada lado de la frecuencia portadora, un numero infinito de componentes espectrales a

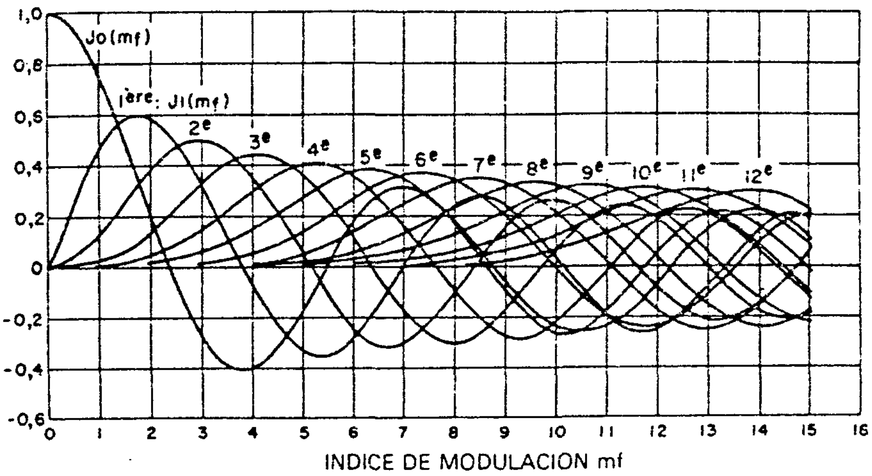


TABLA 2

COEFICIENTES DE BESSEL

J→ m↓	J_0	J_1	J_2	J_3	J_4	J_5	J_6	J_7	J_8	J_9	J_{10}	J_{11}	J_{12}	J_{13}	J_{14}	J_{15}	J_{16}
0,00	1,00	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,25	0,98	0,12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,5	0,94	0,24	0,03	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1,0	0,77	0,44	0,11	0,02	—	—	—	—	—	—	—	—	—	—	—	—	—
1,5	0,51	0,56	0,23	0,06	0,01	—	—	—	—	—	—	—	—	—	—	—	—
2,0	0,22	0,58	0,35	0,13	0,03	—	—	—	—	—	—	—	—	—	—	—	—
2,5	-0,05	0,50	0,45	0,22	0,07	0,02	—	—	—	—	—	—	—	—	—	—	—
3,0	-0,26	0,34	0,49	0,31	0,13	0,04	0,01	—	—	—	—	—	—	—	—	—	—
4,0	-0,40	-0,07	0,36	0,43	0,28	0,13	0,05	0,02	—	—	—	—	—	—	—	—	—
5,0	-0,18	-0,33	0,05	0,36	0,39	0,26	0,13	0,05	0,02	—	—	—	—	—	—	—	—
6,0	0,15	-0,28	-0,24	0,11	0,36	0,36	0,25	0,13	0,06	0,02	—	—	—	—	—	—	—
7,0	0,30	0,00	-0,30	-0,17	0,16	0,35	0,34	0,23	0,13	0,06	0,02	—	—	—	—	—	—
8,0	0,17	0,23	-0,11	-0,29	-0,10	0,19	0,34	0,32	0,22	0,13	0,06	0,03	—	—	—	—	—
9,0	-0,09	0,24	0,14	-0,18	-0,27	-0,06	0,20	0,33	0,30	0,21	0,12	0,06	0,03	0,01	—	—	—
10,0	-0,25	0,04	0,25	0,06	-0,22	-0,23	-0,01	0,22	0,31	0,29	0,20	0,12	0,06	0,03	0,01	—	—
12,0	0,05	-0,22	-0,08	0,20	0,18	-0,07	-0,24	-0,17	0,05	0,23	0,30	0,27	0,20	0,12	0,07	0,03	0,01
15,0	-0,01	0,21	0,04	-0,19	-0,12	0,13	0,21	0,03	-0,17	-0,22	-0,09	0,10	0,24	0,28	0,25	0,18	0,12

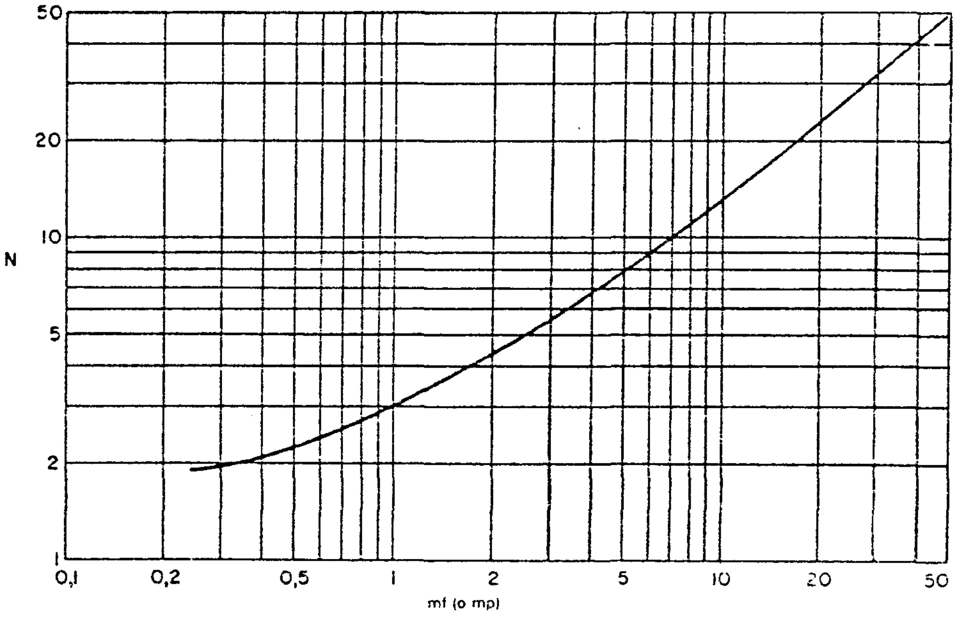


Figura (2.2)

las distancias: fm, 2fm, 3fm,... La separacion entre estas componentes sobre el eje de las frecuencias es fm.

Las componentes espectrales cuyas amplitudes de los coeficientes de Bessel son superiores a 0,01, no disminuyen necesariamente su amplitud cuando n aumenta. Para un determinado valor de n la amplitud de las componentes del espectro pueden ser todas despreciables. La figura (2.2) representa el numero de pares de componentes espectrales, de amplitud superior a 0,01 en funcion del valor del indice de modulacion.

En AM al aumentar el indice de modulacion, aumenta la potencia en las bandas laterales y la potencia total. En FM la potencia total permanece constante para cualquier indice de modulacion: en este caso con el indice de modulacion varia el ancho de banda. Observemos que el coeficiente de Bessel Jo(mf), corresponde a la frecuencia portadora y varia segun el indice de modulacion.

Para una misma desviacion de frecuencia, una frecuencia moduladora mas alta se traduce en un numero menor de componentes espectrales, es lo mismo que si la desviacion de frecuencia hubiese disminuido.

El ancho de banda de una senal de FM depende del indice de modulacion mf y de la frecuencia moduladora fm:

- Si mf << 1, el espectro de la senal de FM es similar al de una senal de AM, y se obtiene una modulacion de frecuencia en banda estrecha.

El ancho de banda W de la senal de FM es W = 2fm,donde fm representa la frecuencia moduladora maxima.

- Si 0,3 <= mf <= 20, el ancho de banda se determina, a partir del numero N de componentes espectrales, cuyas amplitudes de los coeficientes de Bessel son superiores a 0,01.

El numero N se obtiene de la tabla de la figura (2.2).

El ancho de banda W viene dado por:

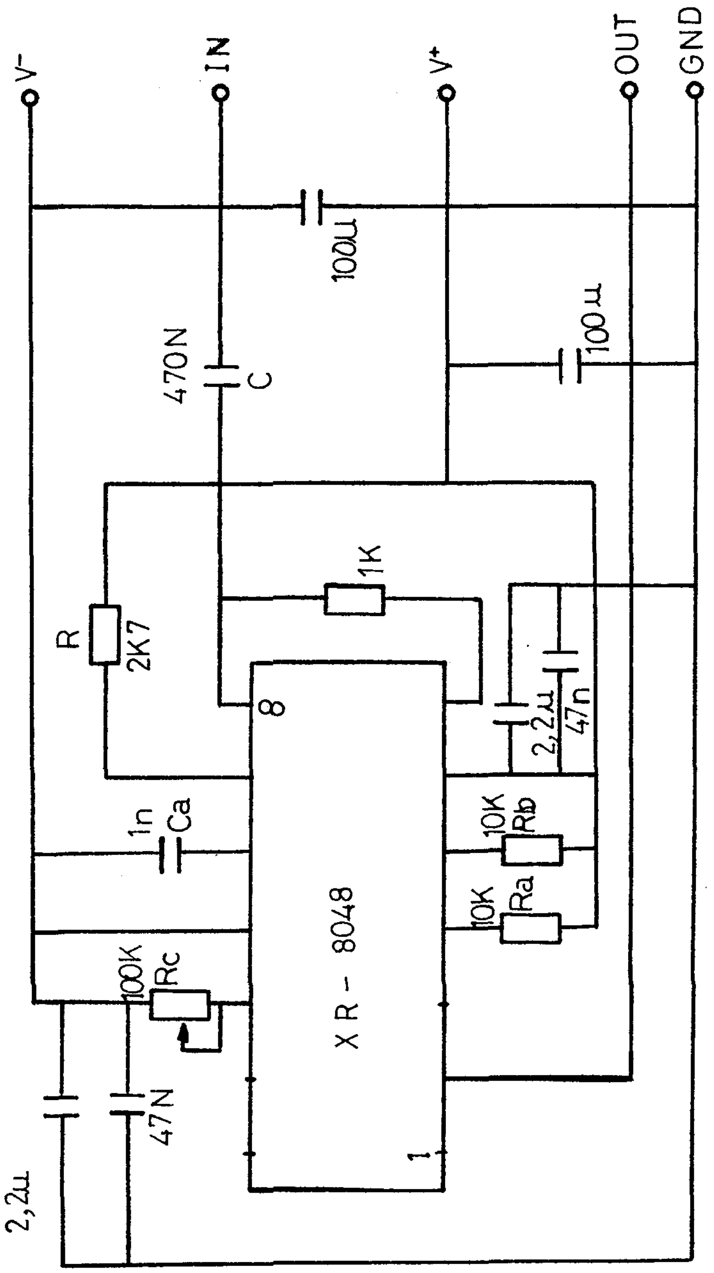
$$W = 2N\ fm$$

- Si mf > 20, para obtener el ancho de banda utilizaremos la formula aproximada:

$$W = 2\ [\Delta f + 2fm]$$

Se dice que las senales de FM estan moduladas en banda ancha, cuando su indice de modulacion es superior a 0,3.

2.1.1 CIRCUITO PROPUESTO : FM



2.1.2 DESARROLLO PRACTICO:

El circuito integrado que vamos a utilizar sera el 8038,que es un generador de formas de onda sinusoidal,triangular, pulsos y dientes de sierra. Su frecuencia de oscilacion puede variar entre 0,001 Hz a 1 MHz, y es altamente estable sobre un ancho rango de cambios de temperatura y alimentacion.

La frecuencia de este generador es una funcion directa de la tension DC aplicada a la patilla 8. Si en este punto aplicamos una senal moduladora, a la salida tendremos una portadora modulada en frecuencia (FM).

La senal moduladora la acoplamos al circuito (patilla 8) mediante un condensador, y una resistencia entre las patillas 7 y 8. Como la impedancia de entrada del I.C. es $Zi = R + 8K\Omega$:

Haciendo $R = 1K\Omega$ y sabiendo que la impedancia exterior tiene que ser mucho menor que Zi, queda que: $Zi = 9K\Omega$.

Luego $Ze << Zi$, por ejemplo: $Ze = 350\ \Omega$

$$Ze = 1 / (jWC) = 350\Omega \qquad W = 2\pi f$$

Para una frecuencia de 1KHz:

$$C = 1 / (350 \times 2\pi \times 10^3) \simeq 0.47\ uF.$$

Variando la Rc podemos ajustar al minimo la distorsion de la senal de salida, pudiendo alcanzar una reduccion aproximada al 0.5 %.

Existe un ancho rango de combinaciones entre R y C para conseguir que la frecuencia de portadora oscile a un determinado valor. Pero existen ciertas magnitudes para que su funcionamiento sea mas optimo. Corrientes menores de 0,1 uA son indeseables porque el circuito tiende a producir errores significativos a temperaturas altas. Para corrientes mayores de 5 mA, las betas de los transistores y los voltajes de saturacion contribuyen a grandes errores. Un funcionamiento optimo se obtiene para cambios de corrientes entre 1 uA y 1 mA.

Como la Vcc es de ±12V y queremos estar dentro del rango optimo de corrientes:

$$I = Vcc / (5R)$$

Entonces: $R = Vcc / (5I) = 24V / (5x0,5\ mA) \simeq 10K\Omega$.

La duracion de cada ciclo de la senal de salida puede ajustarse independientemente uno del otro, variando las resistencia Ra y Rb.Pero en este caso nos interesa que la onda de salida sea simetrica por lo que hacemos:

$$Ra = Rb = R$$

La frecuencia viene dada por:

$$f = 3 / (5\ Ra\ C\ [1 + Rb / (2Ra - Rb)])$$

Como Ra = Rb = R, la frecuencia queda:

$$f = 0,33 / (RC)$$

Habiamos calculado que R = 10KΩ. Y como queremos que la frecuencia sea aproximadamente de 30 KHz. C valdra:

$$C = 0{,}33 / 30 \times 10^3 = 1nF$$

Una practica que proponemos es calcular el valor de la constante Kf, y averiguar si la modulacion es banda ancha o banda estrecha.

Para medir el Kf de la senal modulada, hacemos lo siguiente:

a) fm(t) = 0, con lo cual la ecuacion:

$$Wi = Wc + 2\pi\ Kf\ fm(t)$$

Queda: $$Wi = Wc$$

$$fc = 1 / Tc = 28.571\ Hz.$$

(La frecuencia es algo distinta a la calculada anteriormente, debido a la tolerancia de los componentes).

$$Wc \simeq 180 \times 10^3\ Rad/seg.$$

b) Hacemos que fm(t) sea una senal cuadrada de 2 Vpp, con una tension de offset de 0V. Luego su valor estara cambiando entre +1V y -1V.

Medimos Wi (en el osciloscopio) para el ciclo de fm(t)=1V.

$$Wi = 2\pi\ fi = 2\pi\ 21.739 \simeq 137 \times 10^3\ Rad/seg.$$

Sustituyendo en la ecuacion :

$$Kf = (Wi - Wc) / 2\pi = -6{,}843$$

Kf es negativa porque la modulacion es de tipo inverso.

Para averiguar si la senal es de banda ancha o banda estrecha, aplicamos (por ejemplo) una senal:

$$Am \cos Wmt = 4 \cos(2\pi \times 10\ t)$$

Entoces: $mf = Kf\ Am / fm = 27{,}37$

Al ser $mf \gg 1$ la modulacion de FM es de banda ancha.

NOTA :

La senal moduladora debe tener como maximo 4Vpp, para que en la modulacion no se produzcan cortes.

La amplitud maxima de salida es de 5Vpp.

El nivel de tension de offset de la senal moduladora lo podemos variar sin que esto influya en el resultado de la modulacion.

2.2 MODULACION DE FASE [PM] :

En la modulacion de fase, la fase de la portadora varia proporcionalmente con la senal moduladora. La fase de la senal modulada sera pues de la forma:

$$\theta(t) = Wc\ t + Kp\ fm(t)$$

Kp es una constante de proporcion, Wc la pulsacion de la portadora y fm(t) el mensaje modulador. La senal modulada se representa de la forma siguiente:

$$\varphi_{PM}(t) = Ac \cos[\ Wc\ t + Kp\ fm(t)\ ]$$

La amplitud de la senal modulada es constante e igual a Ac; en cambio su frecuencia es variable. La pulsacion instantanea de la senal es:

$$Wi(t) = d\theta(t)\ /\ dt = Wc + Kp\ dfm(t)\ /\ dt$$

Suponiendo que el mensaje modulador sea sinusoidal Am.cos(Wm t) :

$$\theta(t) = Wc\ t + Kp\ Am \cos(Wm\ t)$$

$$Wi(t) = Wc - Kp\ Am\ Wm\ \mathrm{sen}(Wm\ t)$$

$$\varphi_{FM}(t) = Ac \cos[\ Wc\ t + Kp\ Am \cos(Wm\ t)\ ]$$

El indice de modulacion es $mp = Kp\ Am$ Luego:

$$\varphi_{FM}(t) = Ac \cos[\ Wc\ t + mp \cos(Wm\ t)\ ]$$

La representacion en funcion del tiempo de esta senal se muestra en la figura (2.3).

El espectro de la onda modulada en PM tambien se

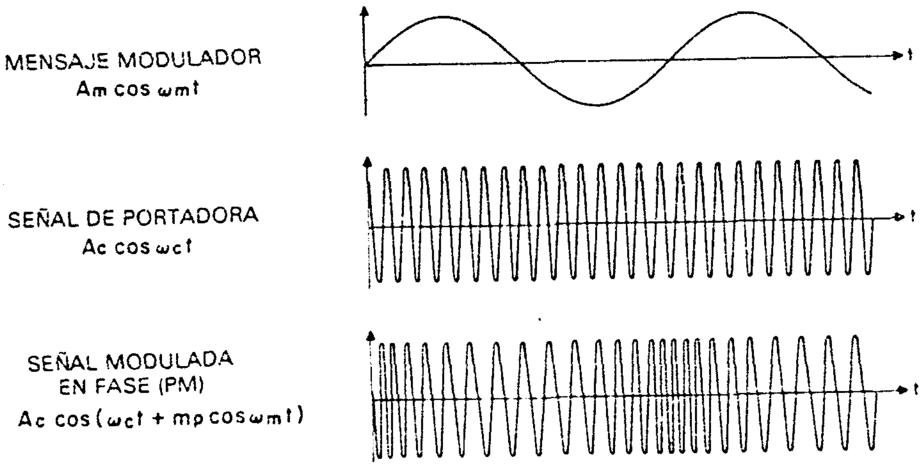


Figura (2.3)

obtiene por las funciones de Bessel Jn(mp). Siendo la diferencia fundamental con el espectro de FM es que la variacion de la frecuencia moduladora no modifica la distribucion espectral, sino que se modifica por la variacion de la amplitud de la senal moduladora.

En FM el indice de modulacion era:

$$mf = Kf\ Am\ /\ fm$$

y el angulo de fase de la senal modulada era proporcional a la integral del mensaje modulador. En el caso de la PM el indice de modulacion es:

$$mp = Kp\ Am$$

siendo el angulo de fase de la senal modulada proporcional al mensaje modulador. El indice de modulacion mp representa la desviacion de fase maxima o excursion o desviacion de fase.

Para evitar toda ambiguedad en la demodulacion, la desviacion de fase se limita a 180° ya que los angulos que se difieren en 360° no podrian distinguirse. Luego el indice de modulacion quedaria:

$$mp = Kp\ Am <= \pi$$

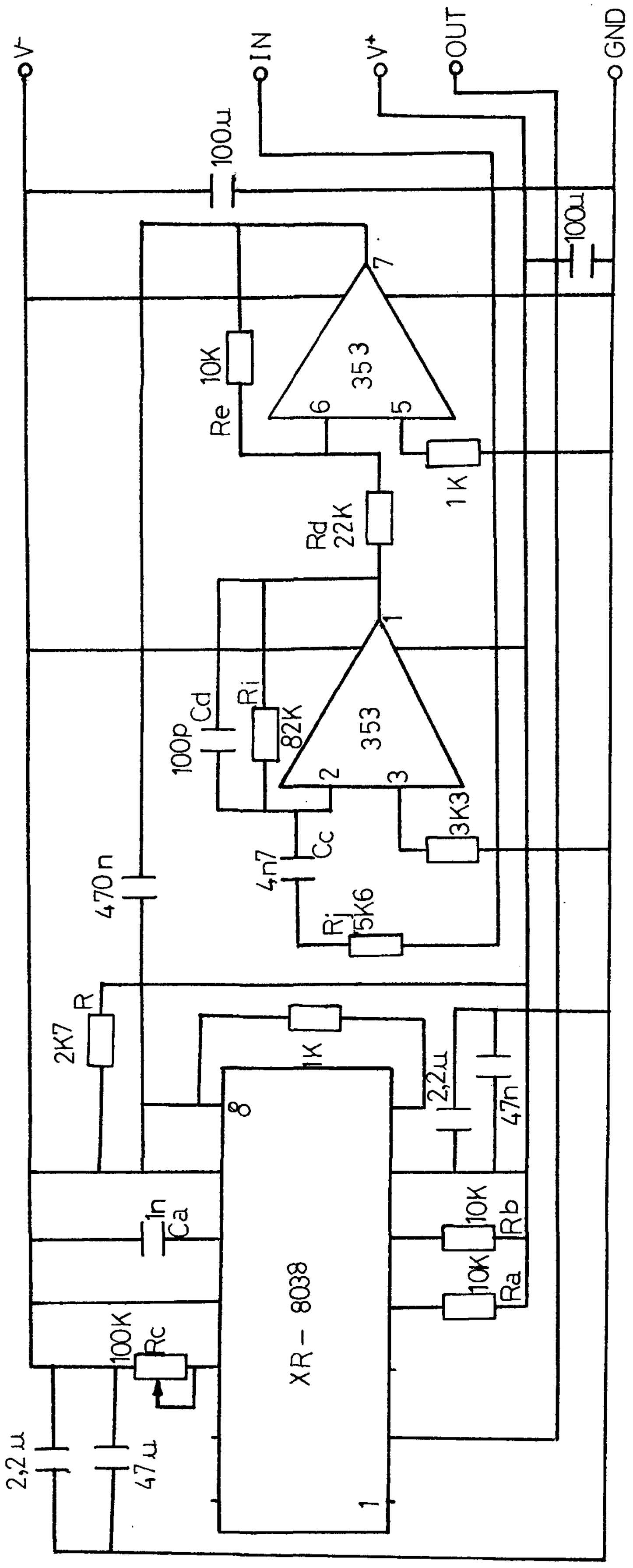
En el caso de que el indice de modulacion mp sea inferior a 0,3, la modulacion es casi lineal y se denomina modulacion de fase en banda estrecha.

La condicion de que mp <= π da lugar a que el numero de componentes espectrales sea reducido.

La tabla de la figura (2.2) nos indica que el numero maximo de componentes espectrales a cada lado de la portadora es 6. Representando por fm la frecuencia maxima del mensaje modulador, el ancho de banda maximo W ocupado por la senal de PM es 12 fm.

$$W <= 12\ fm$$

2.2.1 CIRCUITO PROPUESTO : PM



2.2.2 DESARROLLO PRACTICO :

Como sabemos las ecuaciones de la PM y la FM son respectivamente:

$$\varphi_{PM} = Ac \cos[\, Wc\ t + Kp\ fm(t)\ ]$$

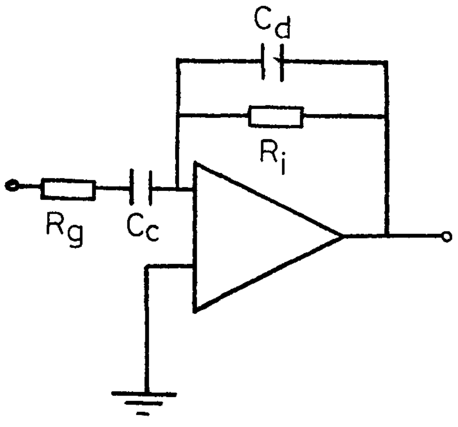
$$\varphi_{FM} = Ac \cos[Wc\ t + Kf \int fm(t)\ dt\ ]$$

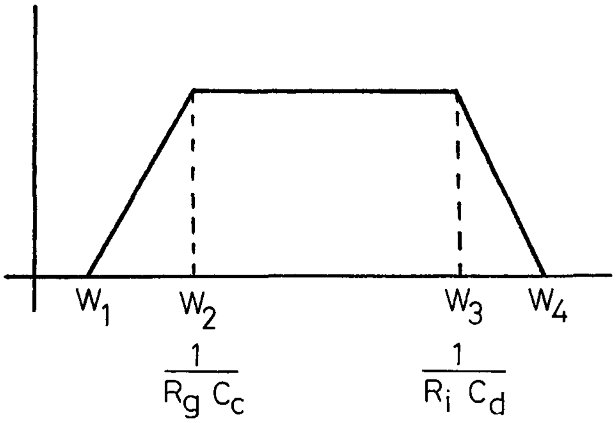
Podemos apreciar que la unica diferencia existente entre estas dos modulaciones, es que el valor de la FM varia con respecto a la integral de la frecuencia moduladora fm, mientras que en PM lo hace con respecto a fm.

Por lo que si derivamos previamente la senal fm y luego la modulamos en FM tendremos un modulador de fase PM.

Hemos elegido el amplificador operacional LF351 por sus elevadas caracteristicas, teniendo un alto SLEW RATE de 13 V/us, para desarrollar el circuito derivador.

Escogemos la configuracion siguiente:





Por las experiencias realizadas hemos llegado a la conclusion de que esta configuracion es la que mejores resultados nos ofrece.

El circuito funciona como un derivador hasta la pulsacion 1 / (Rg Cc), como amplificador entre 1 / (Rg Cc) y 1 / (Ri Cd), y como integrador desde 1 / (Ri Cd hasta W_4.

Su transmitancia se escribe:

$H(p) = -Ri\ Cc\ p\ /\ [\ (Rg\ Cc\ p + 1)\ (Ri\ Cd\ p + 1)\ ]$

Entonces calculando Rg, Ri, Cc y Cd:

Queremos que $f_1 \simeq 400$ Hz.

Luego $W_1 = 2\pi\ (400\ Hz.) = 800\pi$ Rad/Seg.

Y fijando Cc = 4,7 nF

$$Ri = 1\ /\ (W_1 Cc) \simeq 82K\Omega$$

f_2 debe ser 6 KHz. Con lo que $W = 12\pi \times 10^3$ Rad/seg.

$$Rg = 1\ /\ (W_2 Cc) \simeq 5{,}6\ K\Omega$$

Y f_3 debe ser 20 KHz.

Luego $W_3 = 2\pi\ 20 \times 10^3 = 125 \times 10^3$ Rad/seg.

$$Cd = 1\ /\ (W_3 Ri) \simeq 100\ pF$$

Este derivador tiene ganancia positiva, con lo cual la senal derivada tiene un valor demasiado alto. Para alcanzar un voltaje mas adecuado para excitar el modulador de FM, ponemos otro amplificador operacional que nos disminuya e invierta la senal, porque el derivador previamente tambien nos la habia invertido.

Queremos que la senal de salida del amplificador sea la mitad de la de entrada, luego que tenga una ganancia $G = 1/2$.

Como $G = Re / Rd = 10K\Omega / 22K\Omega \simeq 1/2$.

Una vez completado el diferenciador, el resto del circuito es igual al utilizado en FM, con lo cual todo lo comentado anteriormente para ese circuito es valido para este.

Una practica que proponemos es calcular Kp y observar si la modulacion es de banda ancha o banda estrecha.

Para calcular Kp hacemos que fm(t) sea una senal triangular:

a) Para el ciclo de subida de la senal triangular $fm(t) = (Vb / tb)\ t$.

Si hacemos que Vb = 4V. y tb = 0,5 mSeg.

$$fm(t) = 8 \times 10^3 t$$

(Wc la medimos poniendo la entrada del modulador a masa, dandonos $Wc \simeq 182 \times 10^3$ Rad/seg.).

Y Ahora medimos Wi en el osciloscopio:

$Ti = 55 \times 10^{-6}$ Luego $Wi \simeq 113 \times 10^3$ Rad/seg.

Sustituyendo en la formula:

$$Wi = Wc + Kp\ dfm(t) / dt$$

Y despejando:

$Kp = [(113 - 182) \times 10^3] / (8 \times 10^3) = - 8,625$

El signo negativo es porque la modulacion es de tipo inverso.

Entonces: $mp = Kp\ Am = 34,5$

b) Para el ciclo de bajada de la senal triangular $fm(t) = - 8 \times 10^3\ t + 4$. Siendo Vb y Tb de valores iguales a los del caso anterior:

$$dfm(t) / dt = - 8 \times 10^3$$

Como Wc es la misma, medimos Wi:

$Ti = 25 \times 10^{-6}$ Luego $Wi = 251 \times 10^3$ Rad/seg.

Sustituyendo:

$Kp = [(251 - 182) \times 10^3] / -(8 \times 10^3) = - 8,625$

Entonces: $mp = Kp\ Am = 34,5$

Comprobamos que Kp vale igual para el ciclo de bajada que para el ciclo de subida, y por lo tanto tambien mp.

Como mp >> 1 esta modulacion en fase es de banda ancha.

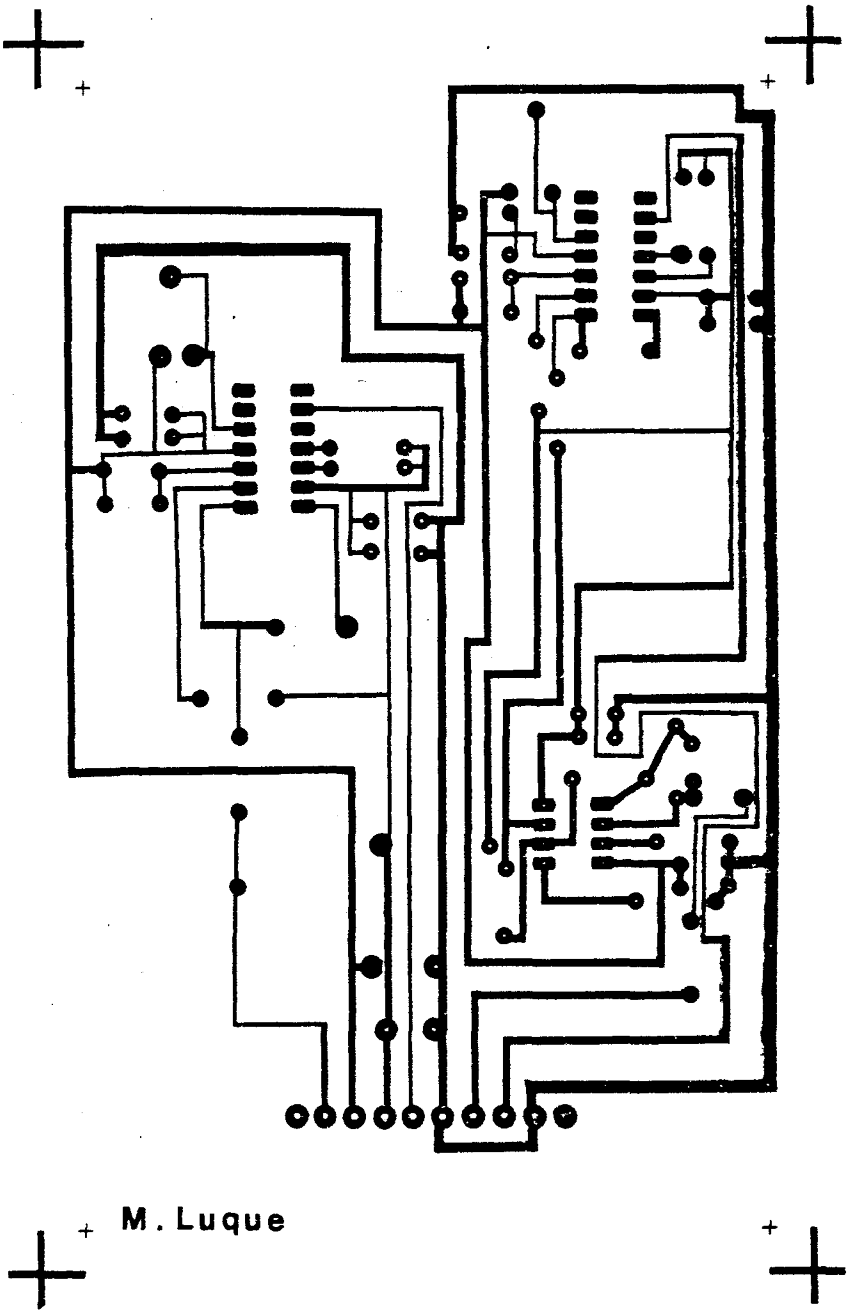
NOTA:

La senal moduladora debe tener como maximo una amplitud de 4 Vpp para que no se produzcan cortes en la modulacion.

La amplitud maxima a la salida del circuito es de 5 Vpp.

El nivel de tension de offset de la senal moduladora puede ser variado sin influir en la senal modulada.

2.3 MECANORMA FM Y PM :



XR-8038

Precision Waveform Generator

GENERAL DESCRIPTION

The XR-8038 is a precision waveform generator IC capable of producing sine, square, triangular, sawtooth and pulse waveforms with a minimum number of external components and adjustments. Its operating frequency can be selected over nine decades of frequency, from 0.001 Hz to 1 MHz, by the choice of external R-C components. The frequency of oscillation is highly stable over a wide range of temperature and supply voltage changes. The frequency control, sweep and modulation can be accomplished with an external control voltage, without effecting the quality of the output waveforms. Each of the three basic waveforms, i.e. sinewave, triangle and square wave outputs are available simultaneously, from independent output terminals.

The XR-8038 monolithic waveform generator uses advanced processing technology and Schottky-barrier diodes to enhance its frequency performance. It can be readily interfaced with a monolithic phase-detector circuit, such as the XR-2208, to form stable phase-locked loop circuits.

FEATURES

Direct Replacement for Intersil 8038
Low Frequency Drift—50 ppm/°C Max.
Simultaneous Sine, Triangle and Square-Wave Outputs
Low Distortion –THD ≃ 1%
High FM and Triangle Linearity
Wide Frequency Range – 0.001 Hz to 1 MHz
Variable Duty-Cycle – 2% to 98%

APPLICATIONS

Precision Waveform Generation Sine, Triangle, Square, Pulse
Sweep and FM Generation
Tone Generation
Instrumentation and Test Equipment Design
Precision PLL Design

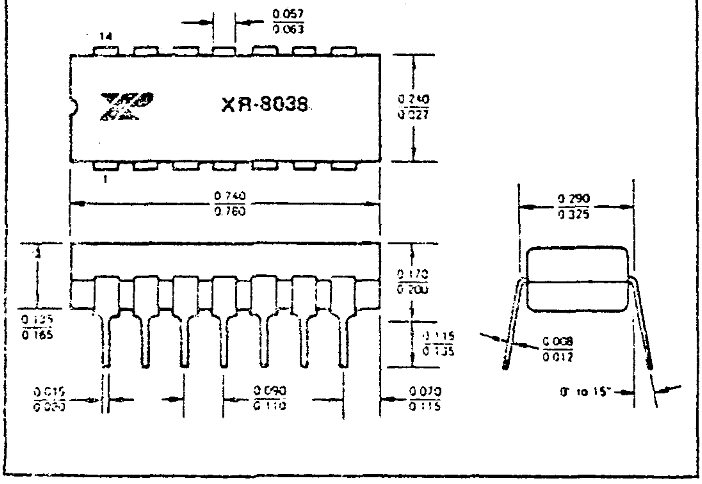
ABSOLUTE MAXIMUM RATINGS

Power Supply	36V
Power Dissipation (package limitation)	
Ceramic package	750 mW
Derate above +25°C	6.0 mW/°C
Plastic package	625 mW
Derate above +25°C	5 mW/°C
Storage Temperature Range	–65°C to +150°C

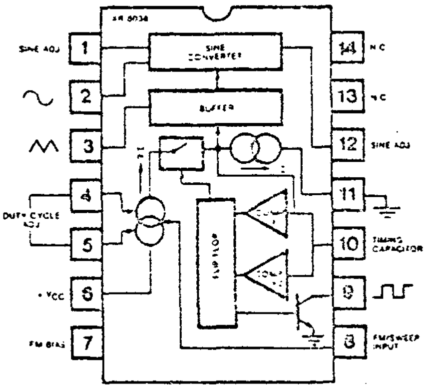
AVAILABLE TYPES

Part Number	Package	Operating Temperature
XR-8038M	Ceramic	–55°C to +125°C
XR-8038N	Ceramic	0°C to +75°C
XR-8038P	Plastic	0°C to +75°C
XR-8038CN	Ceramic	0°C to +75°C
XR-8038CP	Plastic	0°C to +75°C

PACKAGE INFORMATION



FUNCTIONAL BLOCK DIAGRAM

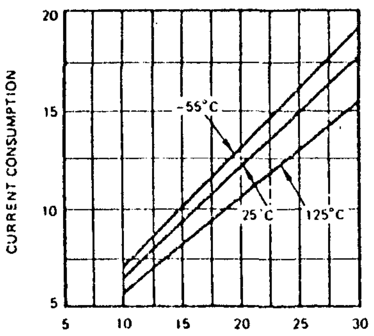


ELECTRICAL CHARACTERISTICS

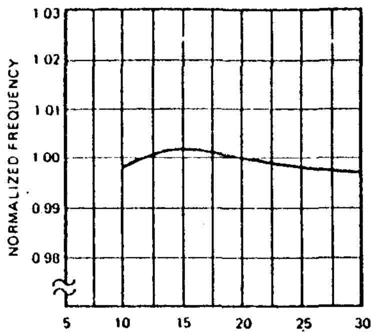
Test Conditions: V_S = ±5V to ±15V, T_A = 25°C, R_L = 1 MΩ, R_A = R_B = 10kΩ, C_1 = 3300 pF, S_1 closed, unless otherwise specified. See Test Circuit of Figure 1.

CHARACTERISTICS	XR-8038M/XR-8038			XR-8038C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
GENERAL CHARACTERISTICS								
Supply Voltage, V_S								
Single Supply	10		30	10		30	V	
Dual Supplies	±5		±15	±5		±15	V	
Supply Current		12	15		12	20	mA	V_S = ±10V. See Note 1.
FREQUENCY CHARACTERISTICS (Measured at Pin 9)								
Range of Adjustment								
Max. Operating Frequency		1			1		MHz	R_A = R_B = 500Ω, C_1 = 0, R_L = 15 kΩ
Lowest Practical Frequency		0.001			0.001		Hz	R_A = R_B = 1 MΩ, C_1 = 500 μF
Max. FM Sweep Frequency		100			100		kHz	
FM Sweep Range		1000:1			1000:1			S_1 Open. See Notes 2 and 3.
FM Linearity		0.1			0.2		%	S_1 Open. See Note 3.
Range of Timing Resistors	0.5		1000	0.5		1000	kΩ	Values of R_A and R_B.
Temperature Stability								
XR-8038M		20	50	–	–	–	ppm/°C	
XR-8038		50	100	–	–	–	ppm/°C	
XR-8038C	–	–	–		50		ppm/°C	
Power Supply Stability		0.05			0.05		%/V	See Note 4.
OUTPUT CHARACTERISTICS								
Square-Wave								Measured at Pin 9.
Amplitude	0.9	0.98		0.9	0.98		x V_s	R_L = 100 kΩ
Saturation Voltage		0.2	0.4		0.2	0.5	V	I_{sink} = 2 mA
Rise Time		100			100		nsec	R_L = 4.7 kΩ
Fall Time		40			40		nsec	R_L = 4.7 kΩ
Duty Cycle Adj.	2		98	2		98	%	
Triangle/Sawtooth/Ramp								Measured at Pin 3.
Amplitude	0.3	0.33		0.3	0.33		x V_s	R_L = 100 kΩ
Linearity		0.05			0.1		%	
Output Impedance		200			200			I_{out} = 5 mA
Sine-Wave Amplitude	0.2	0.22		0.2	0.22		x V_s	R_L = 100 kΩ
Distortion								
Unadjusted		0.7	1.5		0.8	3	%	R_L = 1 MΩ. See Note 5.
Adjusted		0.5			0.5		%	R_L = 1 MΩ

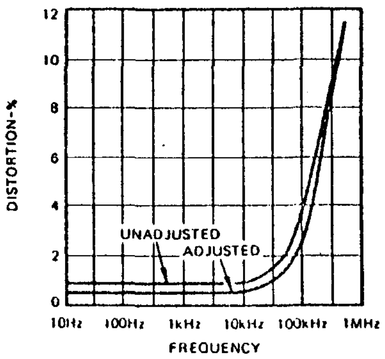
CHARACTERISTIC CURVES



Supply Voltage
Power Dissipation vs. Supply Voltage

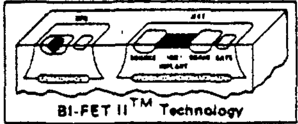


Supply Voltage
Frequency Drift vs. Power Supply



Sinewave THD vs. Frequency

National Semiconductor



BI-FET II™ Technology

LF353 Wide Bandwidth Dual JFET Input Operational Amplifier

General Description

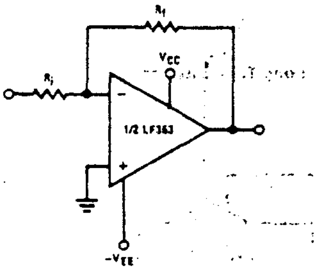
These devices are low cost, high speed, dual JFET input operational amplifiers with an internally trimmed input offset voltage (BI-FET II™ technology). They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF353 is pin compatible with the standard LM1558 allowing designers to immediately upgrade the overall performance of existing LM1558 and LM358 designs.

These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices also exhibit low noise and offset voltage drift.

Features

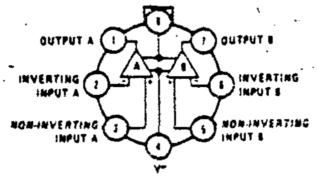
■ Internally trimmed offset voltage	10 mV
■ Low input bias current	50 pA
■ Low input noise voltage	16 nV/√Hz
■ Low input noise current	0.01 pA/√Hz
■ Wide gain bandwidth	4 MHz
■ High slew rate	13 V/μs
■ Low supply current	3.6 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20 V_{p-p}$, BW = 20 Hz-20 kHz	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01%	2 μs

Typical Connection



Connection Diagrams

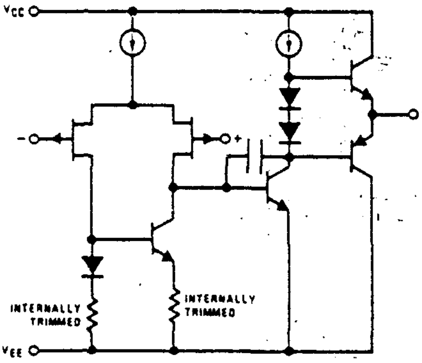
LF353H Metal Can Package (Top View)



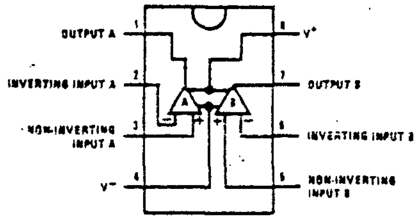
Order Number LF353H
See NS Package H08C

Simplified Schematic

1/2 Dual



LF353N Dual-In-Line Package (Top View)



Order Number LF353N
See NS Package N08A

Absolute Maximum Ratings

Supply Voltage	±18V	Input Voltage Range (Note 2)	±15V
Power Dissipation (Note 1)	500 mW	Output Short Circuit Duration	Continuous
Operating Temperature Range	0°C to +70°C	Storage Temperature Range	−65°C to +150°C
T_j(MAX)	115°C	Lead Temperature (Soldering, 10 seconds)	300°C
Differential Input Voltage	±30V		

DC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353			UNITS
			MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 10k\Omega$, $T_A = 25°C$		5	10	mV
		Over Temperature			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10k\Omega$		10		μV/°C
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 4, 5)		25	100	pA
		$T_j \leq 70°C$			4	nA
I_B	Input Bias Current	$T_j = 25°C$, (Notes 4, 5)		50	200	pA
		$T_j \leq 70°C$			8	nA
R_{IN}	Input Resistance	$T_j = 25°C$		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm15V$, $T_A = 25°C$ $V_O = \pm10V$, $R_L = 2k\Omega$	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	$V_S = \pm15V$, $R_L = 10k\Omega$	±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm15V$	±11	+15 −12		V V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10k\Omega$	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	70	100		dB
I_S	Supply Current			3.6	6.5	mA

AC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353			UNITS
			MIN	TYP	MAX	
	Amplifier to Amplifier Coupling	$T_A = 25°C$, f = 1 Hz–20 kHz (Input Referred)		−120		dB
SR	Slew Rate	$V_S = \pm15V$, $T_A = 25°C$		13		V/μs
GBW	Gain Bandwidth Product	$V_S = \pm15V$, $T_A = 25°C$		4		MHz
e_n	Equivalent Input Noise Voltage	$T_A = 25°C$, $R_S = 100\Omega$, f = 1000 Hz		16		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	$T_j = 25°C$, f = 1000 Hz		0.01		$pA/\sqrt{Hz}$

Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 160°C/W junction to ambient for the N package, and 150°C/W junction to ambient for the H package.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

Note 3: The power dissipation limit, however, cannot be exceeded.

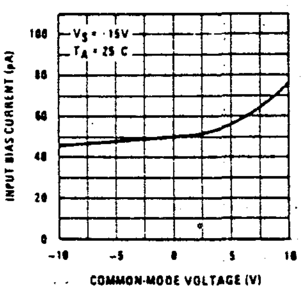
Note 4: These specifications apply for $V_S = \pm15V$ and $0°C \leq T_A \leq +70°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to the limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \theta_{jA} P_D$ where θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

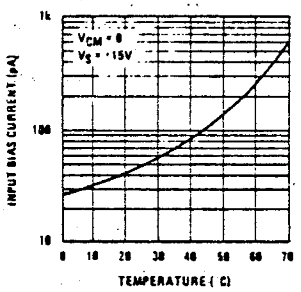
Note 6.: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

Typical Performance Characteristics

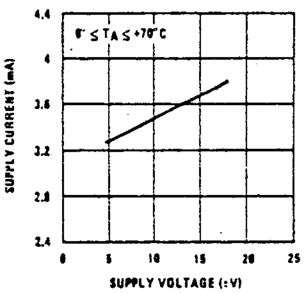
Input Bias Current



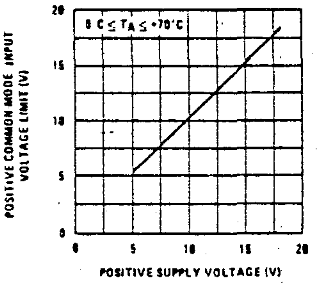
Input Bias Current



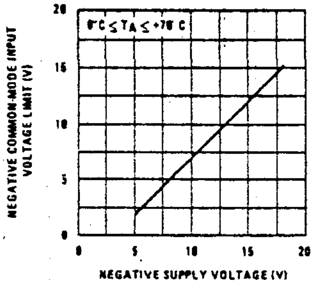
Supply Current



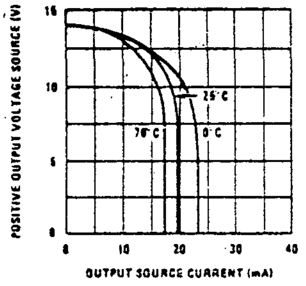
Positive Common-Mode Input Voltage Limit



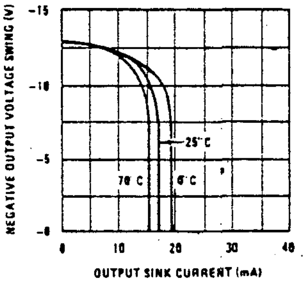
Negative Common-Mode Input Voltage Limit



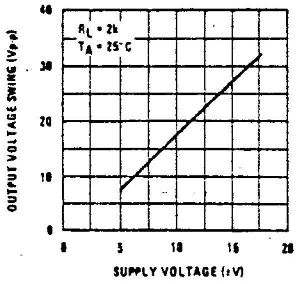
Positive Current Limit



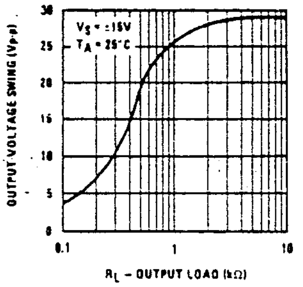
Negative Current Limit



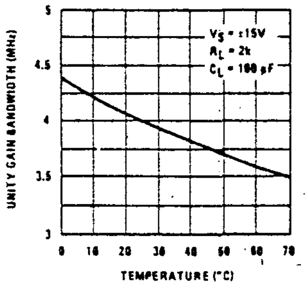
Voltage Swing



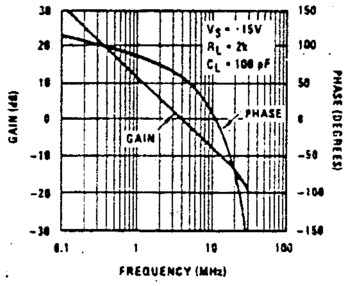
Output Voltage Swing



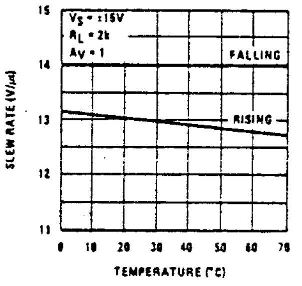
Gain Bandwidth



Bode Plot

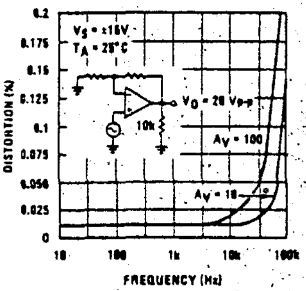


Slew Rate

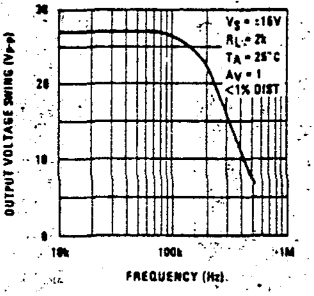


Typical Performance Characteristics (Continued)

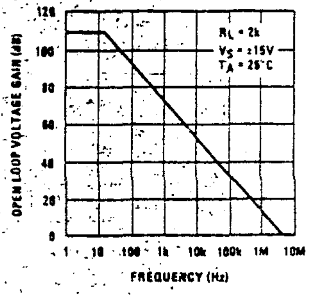
Distortion vs Frequency



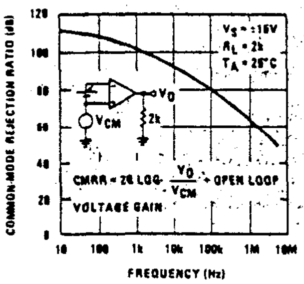
Undistorted Output Voltage Swing



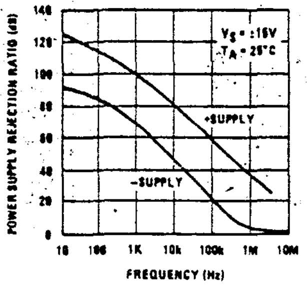
Open Loop Frequency Response



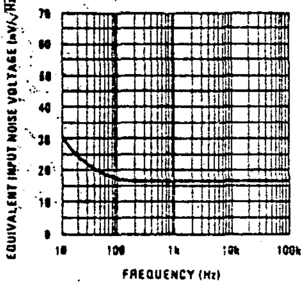
Common-Mode Rejection Ratio



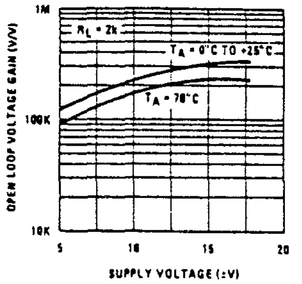
Power Supply Rejection Ratio



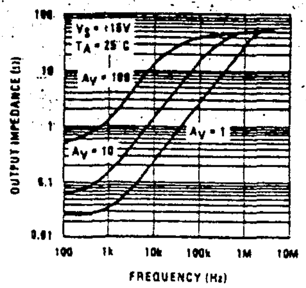
Equivalent Input Noise Voltage



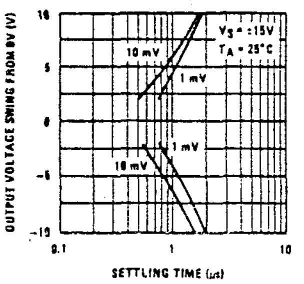
Open Loop Voltage Gain (V/V)



Output Impedance



Inverter Settling Time



Application Hints (Continued)

high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

The amplifiers will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

Each amplifier is individually biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The amplifiers will drive a 2 kΩ load resistance to ±10V over the full temperature range of 0°C to +70°C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

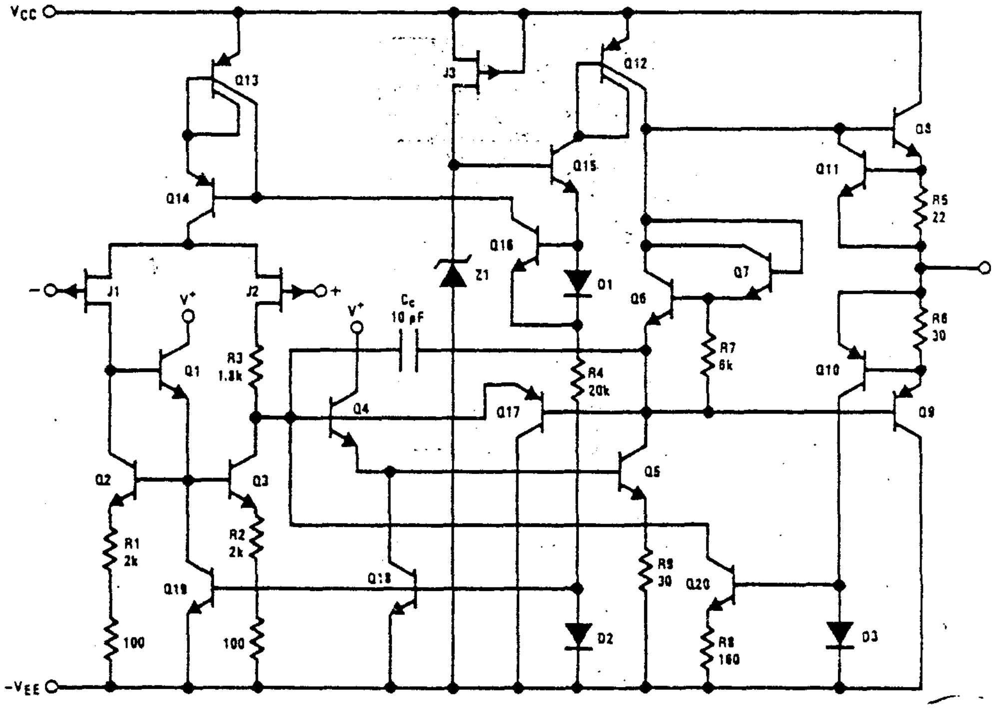
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

Detailed Schematic



* 3. MODULACIONES ANALOGICAS POR IMPULSOS :

El Teorema del muestreo proporciona las bases teoricas para las tecnicas de modulacion por impulsos. Una senal de banda limitada, sin componentes espectrales de frecuencia superior a fm Hz, queda completamente especificada mediante sus valores en intervalos uniformente espaciados de 1/2fm segundos. En lugar de transmitir la senal en forma continua solo es necesario trasmitirla en un numero finito de instantes (2fm por segundo).

Un tren de impulsos rectangulares puede considerarse como una senal portadora, se puede variar la amplitud, la posicion o la duracion de los impulsos proporcionalmente a los mensajes.

A continuacion vamos a estudiar estos tres tipos de modulacion:

-Modulacion por amplitud del pulso PAM.

-Modulacion por duracion del pulso PDM.

-Modulacion por posicion del pulso PPM.

3.1. MODULACION DE PULSOS EN AMPLITUD [PAM] :

En este tipo de modulacion, la amplitud de los pulsos varia proporcionalmente al mensaje modulador. Figura (3.1).

Si hiciesemos un muestreo de forma ideal (muestreo instantaneo), con impulsos, las muestras se localizarian a intervalos 1/2fm segundos. Y el espectro de la senal muestreada fs(t) estaria dado por la repeticion periodica del espectro de f(t), es decir, de F(W). Figura (3.1e).
Se puede recuperar f(t) de la senal muestreada al transmitir fs(t) a traves de un filtro de paso bajo con frecuencia de corte fm. El espectro de fs(t) es Fs(W) dado por la ecuacion:

$$Fs(W) = 1/T \Sigma F(W - nWo)$$

$$\text{Donde} \quad Wo = 2\pi / T \qquad T = 1/2fm$$

Para el caso de la figura (3.1):

$T = 1/2fm$ (intervalo de Nyquist) y $Wo = 2Wm$

Por lo tanto:

$$Fs(W) = 1/T \Sigma F(W - 2n\ Wm) \qquad T = \pi/Wm$$

En la figura (3.1e) se puede apreciar que el espectro de la senal, muestreada en forma ideal, ocupa todo el ancho de banda (de $-\infty$ a $+\infty$), es decir contiene componentes de todas las frecuencias. Sin embargo en la practica no se puede efectuar tal muestreo ideal pues no es posible

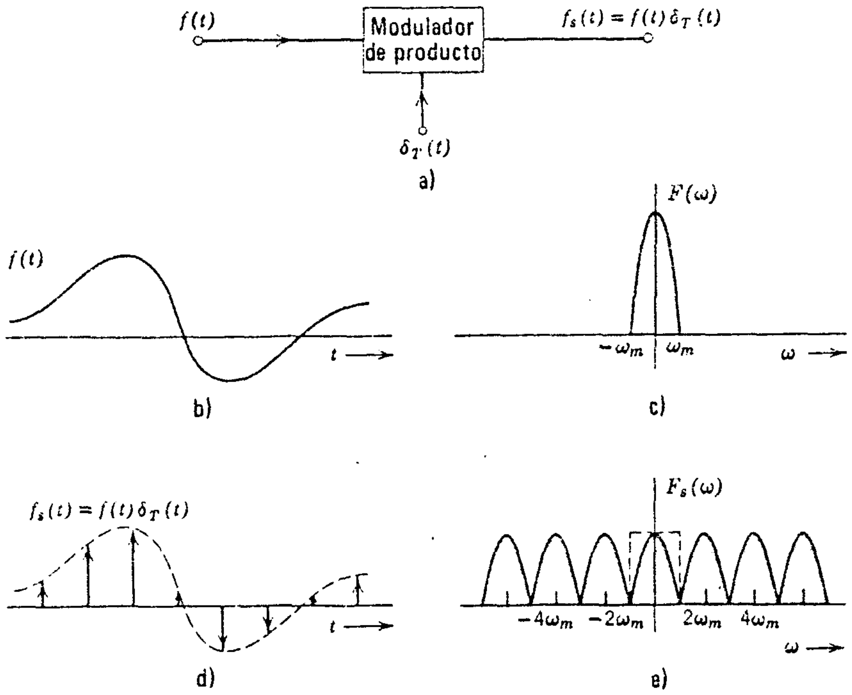


Figura (3.1) Muestreo instantaneo.

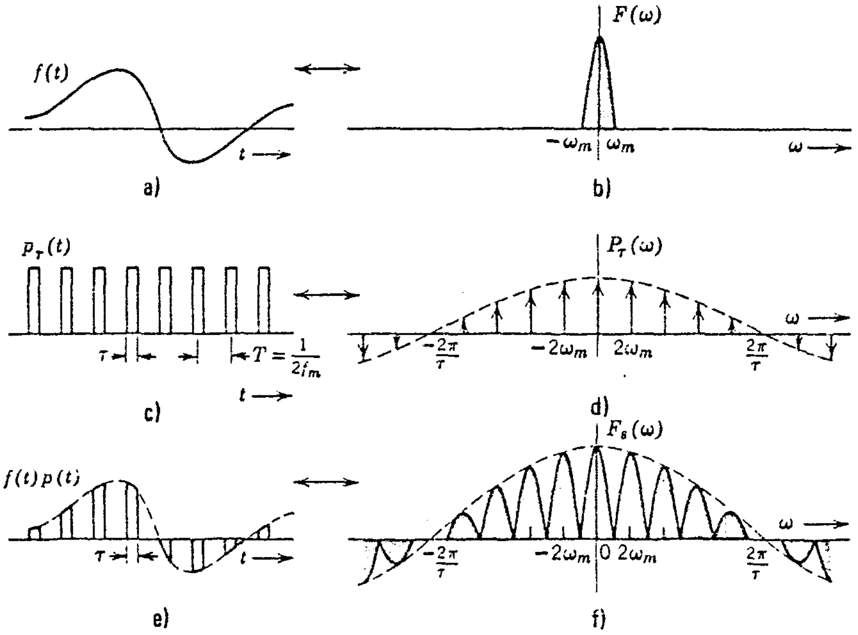


Figura (3.2) Muestreo natural.

generar verdaderos impulsos. Por lo tanto el muestreo se realiza por medio de pulsos muy angostos de duracion finita, con lo cual dicho muestreo no es instantaneo sino que ocurre en intervalos de tiempo finitos.

Haciendo el muestreo con pulsos rectangulares periodicos de segundos de duracion, repetidos cada T segundos . Y llamando a este tren de pulsos $p_\tau(t)$. Figura (3.2c). Tomamos el intervalo de muestreo T como el intervalo de Nyquist, 1/2fm segundos.

La senal muestreada fs(t) es el producto de f(t) y $p_\tau(t)$; entonces , Fs(W), (espectro de fs(t)) se obtiene de la convolucion de F(W) con $P_\tau(W)$. Cuyo resultado lo podemos apreciar de forma grafica en la figura (3.2f).

Con el muestreo no ideal se produce un espectro similar al del muestreo ideal de f(t), pero con amplitud decreciente .

Sin embargo analiticamente podemos obtener el mismo resultado :

$$fs(t) = f(t)\, p_\tau(t)$$

Entonces: $$Fs(W) = 1/2\pi\ F(\omega) * P_\tau(\omega)$$

Luego como: $T = 1/2fm = \pi/Wm$ y $Wo = 2\pi/T = 2Wm$

$$P_\tau(W) = 2A_\tau Wm\ \Sigma\ Sa\ (n_\tau\ Wm)\ \delta\ (W - 2n\ Wm)$$

Sustituyendo:

$$Fs(W) = A_\tau Wm/\pi\ F(W) * \Sigma\ Sa(n_\tau Wm)\ \delta\ (W - 2nWm)$$

$$Fs(W) = A_{\tau}/T\ \Sigma\ Sa(n_{\tau} Wm)\ F(W) * \delta(W - 2nWm)$$

$$Fs(W) = A_{\tau}/T\ \Sigma\ Sa(n_{\tau} Wm)\ F(W)\ F(W - 2nWm)$$

Esta ecuacion obtenida representa el espectro de F(W) repetido cada 2Wm radianes por segundo con una variacion de amplitud dada por $Sa(n_{\tau}Wm)$. Figura (3.2F).

Por lo tanto, el muestreo no ideal de f(t) resulta, en una repeticion de sus espectro cuyas amplitudes van disminuyendo. La senal original puede ser recuperada de la senal muestreada fs(t) usando un filtro de paso bajo con frecuencia de corte Wm.

El ancho de banda necesario para transmitir una senal muestreada de forma ideal (modulacion por impulsos) es infinito, mientras que el necesario para la modulacion por pulsos es finito, pues el espectro Fs(W) decrece en funcion de la frecuencia y el contenido de energia es despreciable en frecuencias superiores.

Segun se va aumentando la duracion de los pulsos, el espectro decae mas rapidamente y se reduce el ancho de banda para transmitir. Luego como conclusion, la modulacion por pulsos (muestreo no ideal) es mejor que la modulacion por impulsos (muestreo ideal). Pero, la ventaja obtenida en el dominio de la fracuencia se pierde en el dominio del tiempo; porque en la modulacion por pulsos se precisa un mayor intervalo de tiempo para transmitir la senal muestreada que en la modulacion por impulsos. Como los pulsos tienen una duracion finita, solo es posible transmitir simultaneamente un numero finito de senales bajo la base de tiempo compartido (multicanalizacion por division de tiempo) mientras que, en el caso de la modulacion por impulsos, es posible transmitir cualquier numero de senales.

La senal muestreada puede ser expresada como el producto de f(t) y un tren uniforme de pulsos:

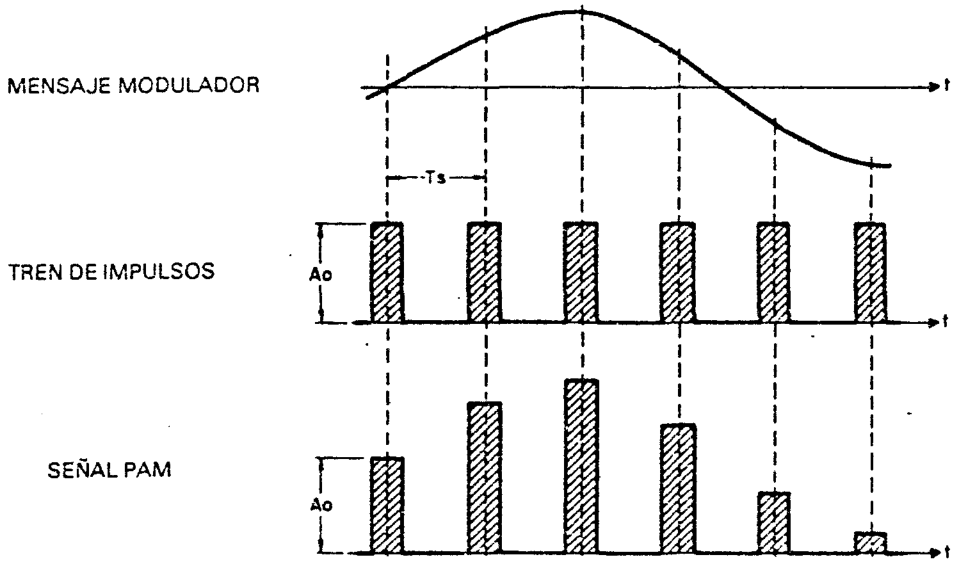
$$fs(t) = f(t)\ q_{\tau}(t)$$

$$fs(t) = f(t)\ \Sigma\ q\ (t-nT)$$

Donde q(t) representa los pulsos basicos de muestreo. Este muestreo es el llamado "muestreo natural".

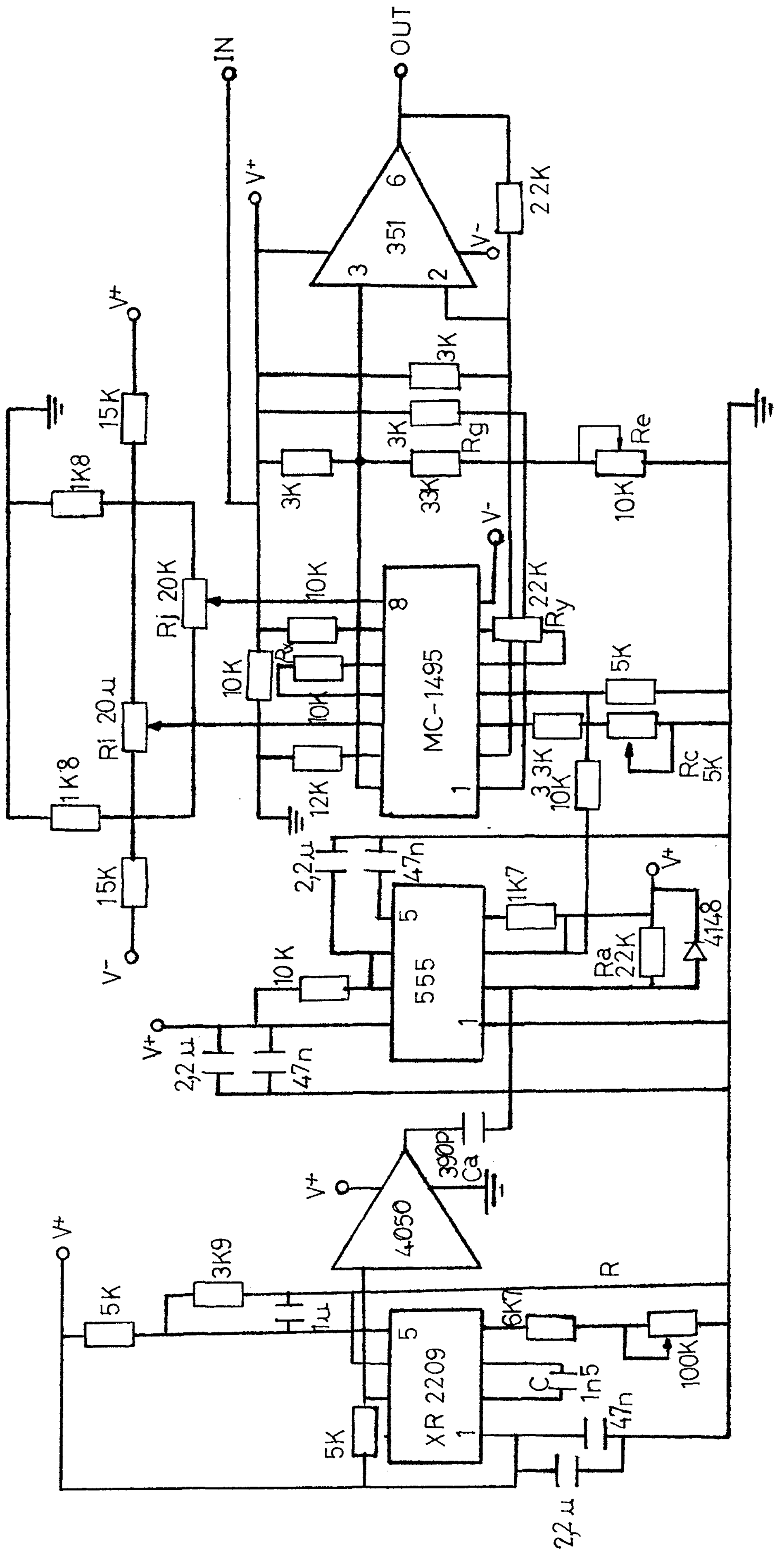
Si se desea que las muestras de una senal de banda limitada lleve la informacion completa de la senal, entonces la rapidez de muestreo nunca debe ser menor que 2fm muestras por segundo. Esta es la rapidez minima de muestreo, llamada rapidez de Nyquist.

Es obvio que la rapidez de Nyquist da como resultado una repeticion del espectro de la senal, sin sobreposiciones y sin intervalo alguno entre ciclos sucesivos.



$$A = Ka\ f(nI)$$

3.1.1 CIRCUITO PROPUESTO : PAM



4.1.2 DESARROLLO PRACTICO:

Para el diseno de esta modulacion hemos utilizado cinco circuitos integrados, que son: El oscilador XR-2209, el buffer 4050, el timer NE-555, el multiplicador analogico MC-1495 y el amplificador operacional LF-351.

El XR-2209 es un oscilador que nos proporciona la senal de clock que necesitamos. Hemos fijado que esta senal tenga una frecuencia variable (mediante el potenciometro R) entre 5 KHz y 100 KHz.

El XR-2209 va acoplado a el NE-555 mediante el buffer 4050.

El NE-555 lo hemos montado como monoestable, para convertir la senal cuadrada del XR-2209 en pulsos rectangulares de una duracion aproximada a unos 10 uSeg. Para conseguir que el monoestable se dispare en pulsos tan estrechos, tuvimos que derivar la senal del XR-2209 previamente a la entrada en el NE-555. (El derivador esta formado por el condensador Ca y la resistencia Ra).

Luego hasta aqui hemos explicado como conseguir el tren de pulsos que modularemos en amplitud, proporcionalmente a la senal moduladora. El resto del circuito esta formado por el multiplicador analogico MC-1495 con un amplificador operacional a su salida (el LF-351), utilizado para cambiar el nivel de tension de offset. En los parrafos siguientes comentamos el funcionamiento de este conjunto multiplicador.

El ancho de banda se determina principalmente por las resistencias de carga, las capacidades de salida del multiplicador y el amplificador operacional utilizado. Si se desea un gran ancho de banda debemos poner una resistencia de carga de bajo valor y un amplificador operacional de gran ancho de banda.

Los maximos voltajes de entrada deben ser tal, que:

$Vx\ (max) < I_{13}\ Ry = 1\ mA \times 22\ K\Omega = 22\ Vpp$

$Vy\ (max) < I_3\ Ry = 1\ mA \times 22\ K\Omega = 22\ Vpp$

$I_{13} = I_3 = 1\ mA$

Si se excede de ese valor un lado del amplificador de entrada se cortara y provocara una respuesta no lineal.

El rango maximo de voltaje de salida depende de los componentes elegidos y de las tensiones de entrada, pero varia segun la relacion:

$$Vo = -\ K\ Vx'\ Vy'$$

Siendo Vx' e Vy' las tensiones a las entradas de los divisores de tension de las patillas 4 y 9.

$$Vx' = 2\ Vx$$

$$Vy' = Vy$$

Luego: $Vo = -\ 2K\ Vx\ Vy$

El potenciometro Rc, es para ajustar el valor del factor de escala K.

Hemos seleccionado Rx Ry, de forma que aseguremos que los transistores de entrada siempre esten en activo.

El voltaje en la base de los transistores Q5, Q6, Q7 y Q8 (ver hojas de datos), debe ser aproximadamente 0,7 V menor que el voltaje de la patilla 1 (que hemos fijado en 9 V con la resistencia Rg = 3KΩ). Luego para que esos transistores se mantengan en activo el voltaje en la patilla 2 y 14, debe estar aproximadamente a la mitad, entre el voltaje de la patilla 1 y de +V, o sea aproximadamente unos 10,5 V.

Para conseguir un buen ajuste del multiplicador, anulando los offset y estableciendo el factor de escala al valor deseado, debemos hacer lo siguiente:

1. Offset de la entrada X:

a) Conectar el generador (en 1 Kz y 5 Vpp de onda sinusoidal) a la entrada Y en la patilla 4.

b) Conectar la entrada X (patilla 9) a masa.

c) Ajustar el potenciometro Ri para obtener una AC nula a la salida.

2. Offset a la entrada Y:

a) Conectar el generador (en 1Kz y 5Vpp de onda sinusoidal) a la entrada X, en la patilla 9.

b) Conectar la entrada Y (patilla 4) a masa.

c) Ajustar Rj para obtener una Ac nula a la salida.

3. Offset de salida.

a) Conectar ambas entradas X e Y a masa.

b) Ajustar Re, hasta que el voltaje Vo de salida, sea cero voltios DC.

4. Factor de escala.

a) Aplicar 10V. DC a ambas entradas X e Y.

b) Ajustar Rc hasta encontrar el valor deseado.

Proponemos como practica calcular el valor de la constante Ka. Procederemos de la siguiente forma:

En la entrada del modulador introducimos una senal cuadrada de 4 Vpp, situada justo sobre el nivel de 0V de DC. Entonces:

$$f(nT) = 4 \text{ Vpp.}$$

Midiendo la amplitud a la salida: $A = 2$ Vpp.

Como $A = Ka\, f(nT)$

Despejando: $Ka = 4 \text{ Vpp} / 2 \text{ Vpp} = 2$

Esta constante se puede variar con el potenciometro Ri.

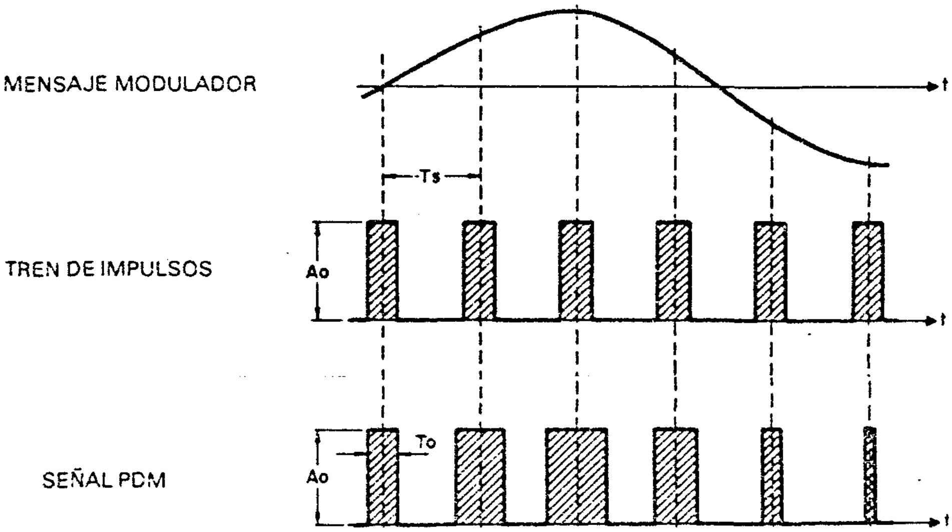
3.2 MODULACION POR DURACION DEL PULSO [PDM]:

En la modulacion anteriormente explicada la PAM, la informacion iba en la amplitud de los pulsos pero la duracion y la posicion de los pulsos era constante.

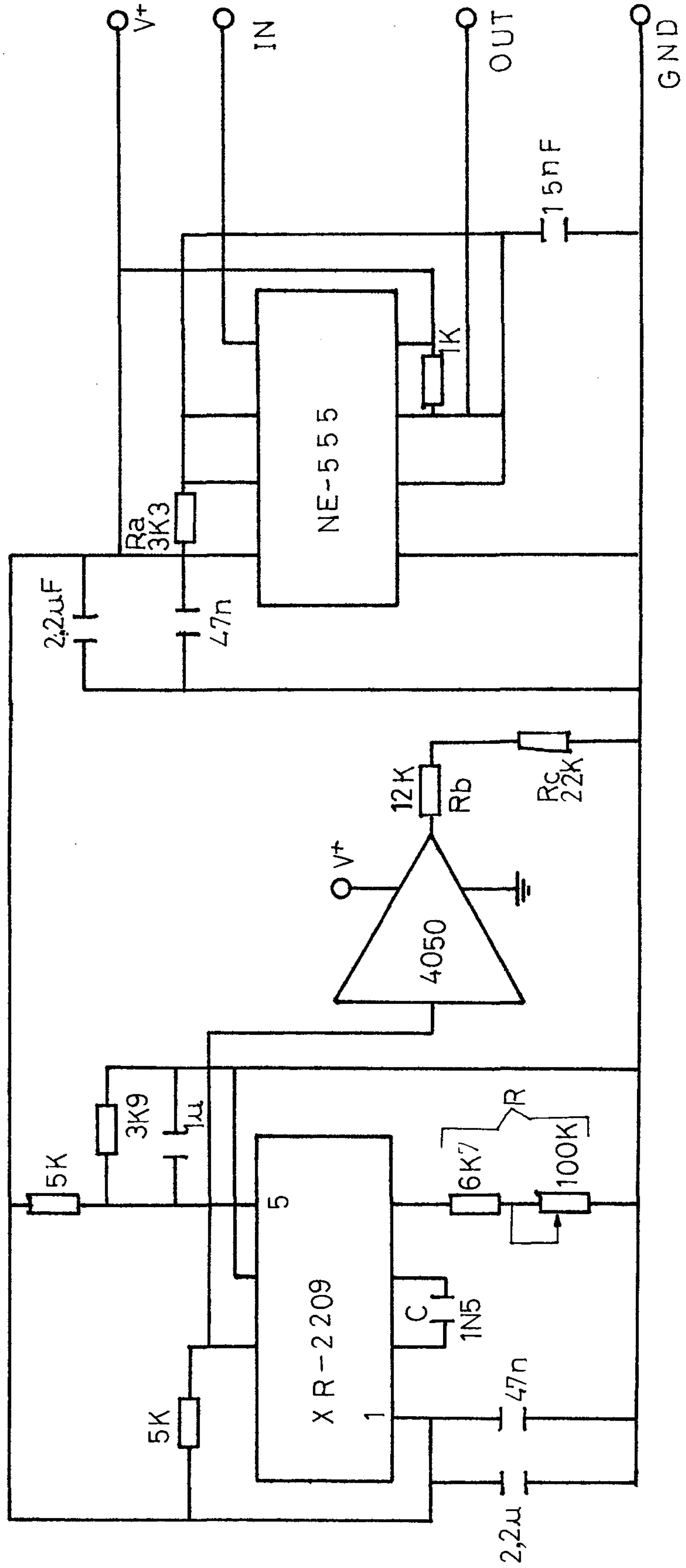
Tambien podriamos hacer que en lugar de variar la amplitud proporcionalmente a la senal moduladora, varie la duracion del pulso, dejando constantes la amplitud y su posicion. Esta es la llamada modulacion por duracion del pulso PDM, donde la duracion de los pulsos varia proporcionalmente al mensaje modulador.

Lo mas frecuente es conservar un pulso de referencia fijo de duracion To, al principio, al final, o en medio de los pulsos modulados en duracion.

$$D = K_d\, f(nT)$$



3.2.1 CIRCUITO PROPUESTO: PDM



3.2.2 DESARROLLO PRACTICO:

En el diseno de esta modulacion vamos a utilizar dos circuitos integrados, el XR-2209 que nos servira como reloj (al igual que en la modulacion PAM) y el NE-555.

Como anteriormente vimos el XR-2209 es un oscilador de frecuencia variable, cuyo rango esta entre 0,01 Hz y 1MHz, pero que nosotros hemos limitado a 5 KHz y 100 KHz. La frecuencia es inversamente proporcional al producto de R y C:

$$fo = 1 / (R\ C)$$

Los valores elegidos han sido:

$$C = 1{,}5\ nF.$$

$$R = 6K7\Omega + \text{Potenc. de } 100\ K\Omega$$

Que estan dentro del rango recomendado por el fabricante.

El otro I.C. que necesitamos es el NE-555, que sera el que nos produzca la modulacion.

La frecuencia de oscilacion depende de la senal de "Clock", si la entrada del ciruito esta puesta a masa. Y cuando introduzcamos una senal moduladora ademas dependera de esta.

La senal de "Clock" procedente del XR-2209 tiene una amplitud de 12 Vpp, lo cual es muy alto, porque el NE-555 en su entrada de trigger (patilla 2) solo admite 2/3 de Vcc.

Al ser Vcc = 12 V, hemos puesto un divisor de tension en la entrada, formado por dos resistencias de valores:

Rb = 12KΩ y Rc = 22KΩ

Entre la salida del XR-2209 y el divisor de tension a la entrada de trigger del NE-555, hemos puesto un buffer (el 4050), para asegurar que la senal de clock llega en perfectas condiciones a el NE-555.

Como practica, proponemos calcular Kd. Para ello procederemos de la manera siguiente:

a) Ajustamos el XR-2209 para una frecuencia de oscilacion de 10 KHz.

b) Ponemos a la entrada una onda cuadrada de 10 Vpp y 1 KHz de frecuencia, situandola sobre el nivel de 0V de DC. Ahora podemos apreciar como varia la duracion de los pulsos cuando el nivel de entrada es de 0V y cuando es de 10 V. Luego midiendo estas duraciones en el osciloscopio, vemos que para 0V es de 60×10^{-6} Seg. y para 10 V es de 90×10^{-6} Seg.

Entonces, para f(nT) = 10 V.

$$Kd = f(nT) / D = 10 \text{ V} / (90 \times 10^{-6} \text{ Seg}) \simeq 111 \times 10^{3}$$

NOTA:

La tension de la onda moduladora no debe sobrepasar los 10 Vpp.

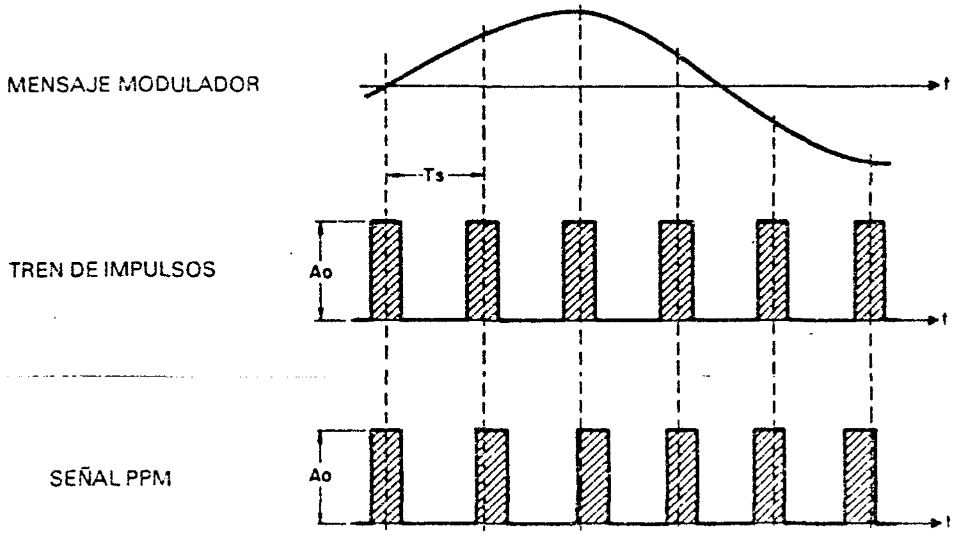
La senal moduladora debe estar situada sobre el nivel de OV de DC.

3.2 MODULACION POR POSICION DEL PULSO [PPM]:

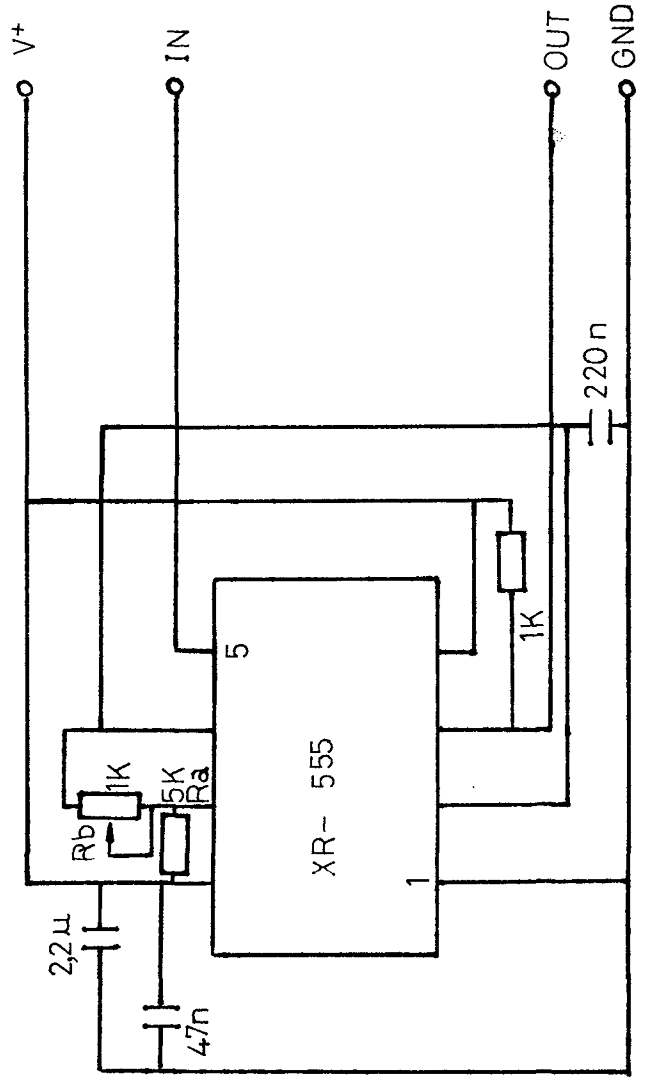
En los casos anteriores de modulaciones por pulsos habiamos hecho que variara, primero la amplitud para la modulacion PAM y luego la duracion de los pulsos para la modulacion PDM.

En este tercer tipo de modulacion por pulsos, se emiten pulsos iguales en intervalos de tiempo diferentes, el ritmo de repeticion de los pulsos varia, siendo el tiempo de adelanto o retardo proporcional al mensaje modulador.

$$P = Kp\ f(nT)$$



3.3.1 CIRCUITO PROPUESTO : PPM



3.3.2 DESARROLLO PRACTICO:

El I.C. elegido para disenar el circuito de la modulacion PPM, ha sido al igual que para la PDM, el XR-555.

El circuito es muy sencillo, en el la frecuencia de oscilacion, con la entrada puesta a masa, depende del condensador C y de la resistencia Ra. Y al introducirle una senal moduladora tambien dependera de esta.

Variando la resistencia Rb, podemos rectificar el ancho de los pulsos.

La patilla 4 (de reset) la tenemos puesta fija a +V para impedir disparos erroneos.

Proponemos como practica el calcular la constante Kp. Para ello realizamos lo siguiente:

a) Ponemos la entrada del circuito a masa, haciendo f(nT) = 0V. Y obtendremos una serie de pulsos con periodo:

$$Ta = 1,5 \times 10^{-4} \text{ Seg.}$$

b) Ponemos una tension DC de 3 V a la entrada. Y a la salida obtenemos una serie de pulsos de periodo:

$$Tb = 1,8 \times 10^{-4} \text{ Seg.}$$

Luego la posicion de los pulsos ha cambiado con la amplitud de la senal de entrada. Este cambio de posicion lo medimos en segundos, y es:

$P = Tb - Ta = (1{,}8 \times 10^{-4}) - (1{,}5 \times 10^{-4}) = 30$ uSeg.

Como: $P = Kp\ f(nT)$

entonces despejando Kp.

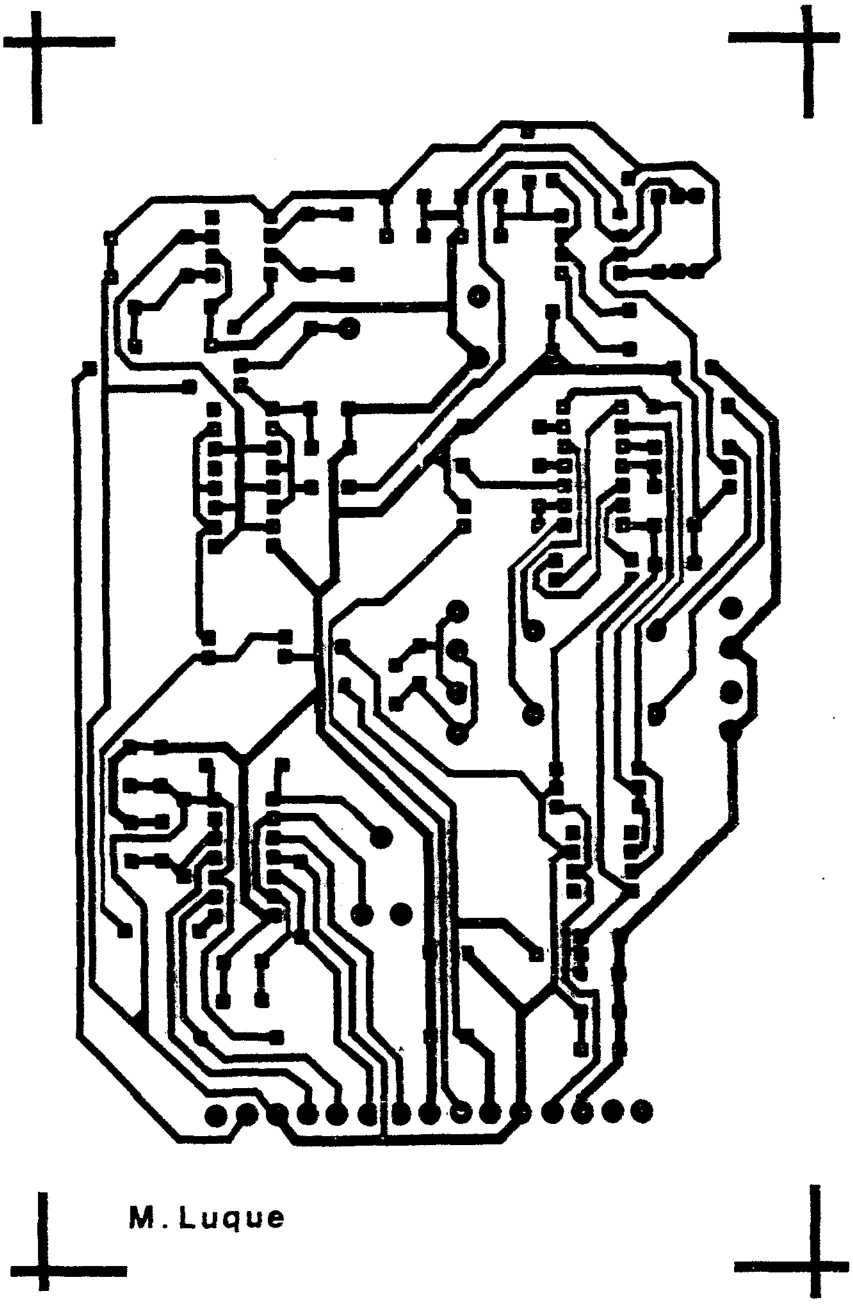
$Kp = f(nT) / P = 3$ Volt. / 30 uSeg. = 0,1

NOTA :

La senal moduladora no debe sobrepasar los 3 Vpp.

La amplitud maxima de la senal modulada es de 12 Vpp.

3.4 MECANORMA PAM, PDM, PPM :



M.Luque

XR-2209

Precision Oscillator

GENERAL DESCRIPTION

The XR-2209 is a monolithic variable frequency oscillator circuit featuring excellent temperature stability and a wide linear sweep range. The circuit provides simultaneous triangle and squarewave outputs over a frequency range of 0.01 Hz to 1 MHz. The frequency is set by an external RC product. It is ideally suited for frequency modulation, voltage to frequency or current to frequency conversion, sweep or tone generation as well as for phase-locked loop applications when used in conjunction with a phase comparator such as the XR-2208.

The circuit is comprised of three functional blocks: a variable frequency oscillator which generates the basic periodic waveforms and two buffer amplifiers for the triangle and the squarewave outputs.

The oscillator frequency is set by an external capacitor, C, and the timing resistor R. With no sweep signal applied, the frequency of oscillation is equal to 1/RC. The XR-2209 has a typical drift specification of 20 ppm/°C. Its frequency can be linearly swept over a 1000:1 range with an external control signal.

FEATURES

- Excellent Temperature Stability (20 ppm/°C)
- Linear Frequency Sweep
- Wide Sweep Range (1000:1 Min)
- Wide Supply Voltage Range (±4V to ±13V)
- Low Supply Sensitivity (0.15%/V)
- Wide Frequency Range (0.01 Hz to 1 MHz)
- Simultaneous Triangle and Squarewave Outputs

APPLICATIONS

- Voltage and Current-to-Frequency Conversion
- Stable Phase-Locked Loop
- Waveform Generation
- FM and Sweep Generation

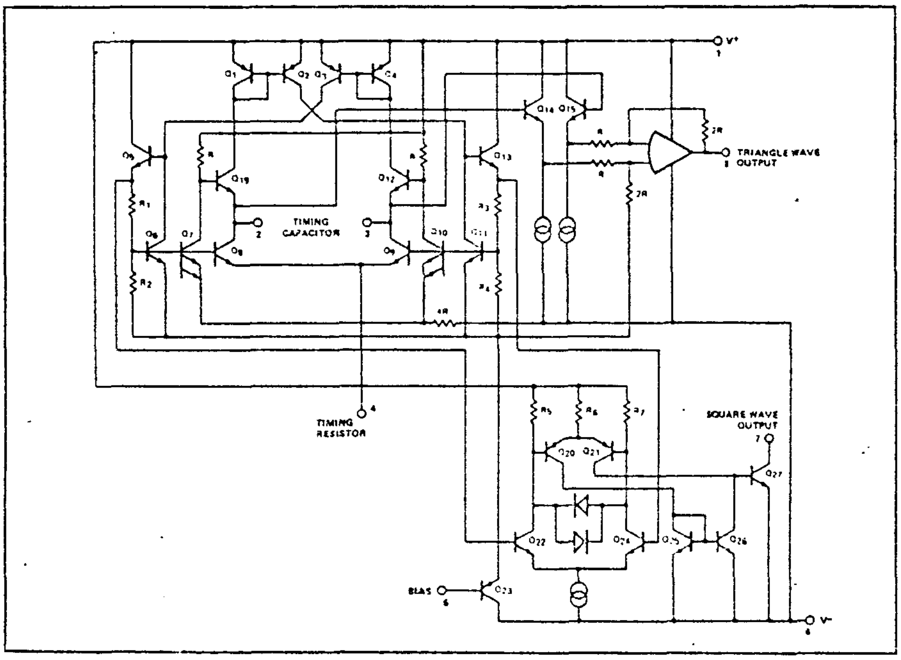
ABSOLUTE MAXIMUM RATINGS

Power Supply	26 volts
Power Dissipation (package limitation)	
Ceramic package	385 mW
Plastic Package	300 mW
Derate above +25°C	2.5 mW/°C
Temperature Range	
Operating	
XR-2209M	−55°C to +125°C
XR-2209C	0°C to +75°C
Storage	−65°C to +150°C

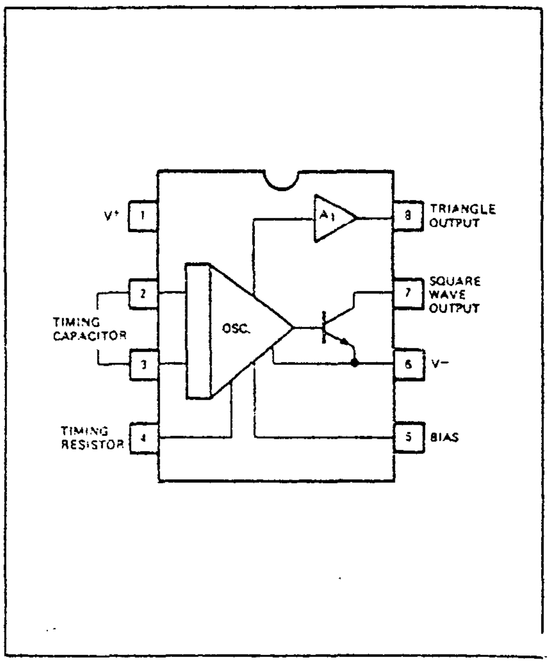
AVAILABLE TYPES

Part Number	Package	Operating Temperature
XR-2209M	Ceramic	−55°C to +125°C
XR-2209CN	Ceramic	0°C to +75°C
XR-2209CP	Plastic	0°C to +75°C

EQUIVALENT SCHEMATIC DIAGRAM



FUNCTIONAL BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS – PRELIMINARY

Test Conditions: Test Circuit of Figure 1, $V^+ = V^- = 6V$, $T_A = +25°C$, C = 5000 pF, R = 20 KΩ, R_L = 4.7 KΩ.
S_1 and S_2 closed unless otherwise specified.

PARAMETERS	XR-2209M			XR-2209C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
GENERAL CHARACTERISTICS								
Supply Voltage								
Single Supply	8		26	8		26	V	See Figure 2
Split Supplies	±4		±13	±4		±13	V	See Figure 1
Supply Current								
Single Supply		5	7		5	8	mA	Measured at pin 1, S_1, S_2 open See Figure 2
Split Supplies								
Positive		5	7		5	8	mA	Measured at pin 1, S_1, S_2 open
Negative		4	6		4	7	mA	Measured at pin 4, S_1, S_2 open
OSCILLATOR SECTION – FREQUENCY CHARACTERISTICS								
Upper Frequency Limit	0.5	1.0		0.5	1.0		MHz	C = 500 pF, R = 2 KΩ
Lowest Practical Frequency		0.01			0.01		Hz	C = 50 μF, R = 2 MΩ
Frequency Accuracy		±1	±3		±1	±5	% of f_o	
Frequency Stability								
Temperature		20	50		30		ppm/°C	$0° < T_A < 75°C$
Power Supply		0.15			0.15		%/V	
Sweep Range	1000:1	3000:1			1000:1		f_H/f_L	R = 1.5 KΩ for f_{H1} R = 2 MΩ for f_L
Sweep Linearity							%	C = 5000 pF
10:1 Sweep		1	2		1.5			f_H = 10 kHz, f_L = 1 kHz
1000:1 Sweep		5			5			f_H = 100 kHz, f_L = 100Hz
FM Distortion		0.1			0.1		%	±10% FM Deviation
Recommended Range of Timing Resistors	1.5		2000	1.5		2000	KΩ	See Characteristic Curves
Impedance at Timing Pin		75			75		Ω	Measured at pin 4
OUTPUT CHARACTERISTICS								
Triangle Output								Measured at pin 8
Amplitude	4	6		4	6		Vpp	
Impedance		10			10		Ω	
Linearity		0.1			0.1		%	10% to 90% of swing
Squarewave Output								Measured at pin 7, S_2 closed
Amplitude	11	12		11	12		Vpp	
Saturation Voltage		0.2	0.4		0.2	0.4	V	Referenced to pin 6
Rise Time		200			200		nsec	$C_L \leq 10$ pF, R_L = 4.7 KΩ
Fall Time		20			20		nsec	$C_L \leq 10$ pF

CHARACTERISTIC CURVES

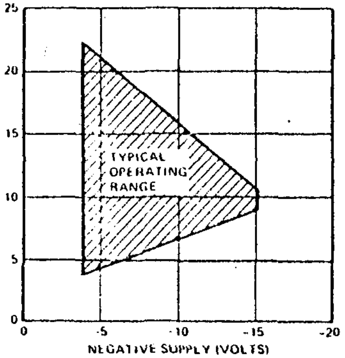


Figure 3. Typical Operating Range For Split Supply Voltage

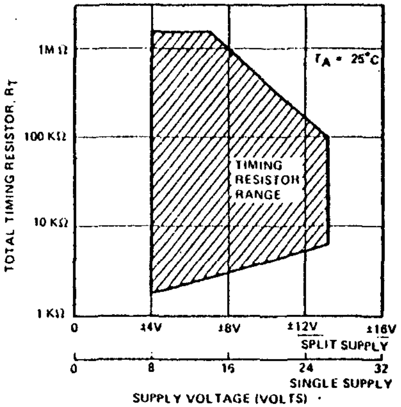


Figure 4. Recommended Timing Resistor Value vs. Power Supply Voltage*

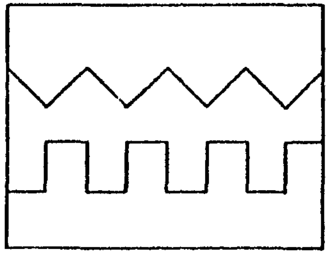


Figure 5: Output Waveforms
Top: Triangle Output (Pin 8)
Bottom: Squarewave Output (Pin 7)

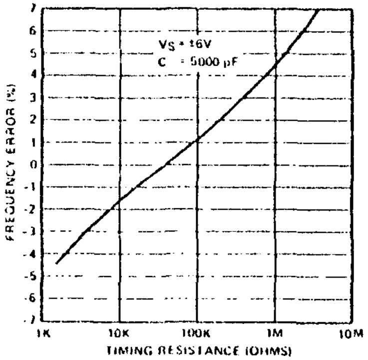


Figure 6. Frequency Accuracy vs. Timing Resistance

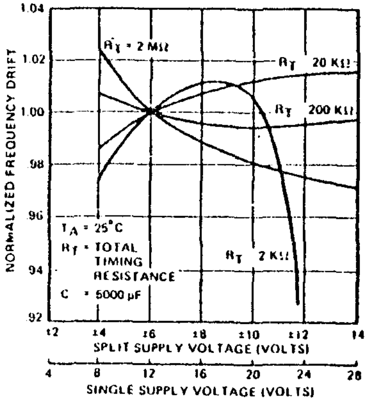


Figure 7. Frequency Drift vs. Supply Voltage

*Note: R_T = Timing Resistor at Pin 4

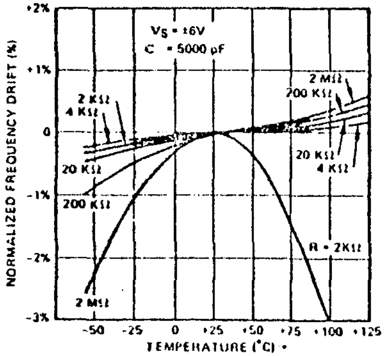


Figure 8. Normalized Frequency Drift With Temperature

National Semiconductor

CD4049M/CD4049C Hex Inverting Buffer
CD4050BM/CD4050BC Hex Non-Inverting Buffer

General Description

These hex buffers are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. These devices feature logic level conversion using only one supply voltage (V_{DD}). The input signal high level (V_{IH}) can exceed the V_{DD} supply voltage when these devices are used for logic level conversions. These devices are intended for use as hex buffers, CMOS to DTL/TTL converters, or as CMOS current drivers, and at $V_{DD} = 5.0V$, they can drive directly two DTL/TTL loads over the full operating temperature range.

Features

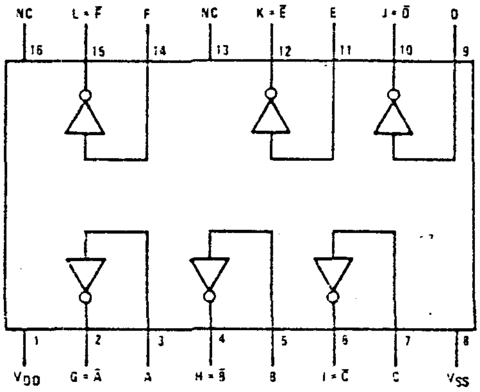
- Wide supply voltage range 3.0V to 15V
- Direct drive to 2 TTL loads at 5.0V over full temperature range
- High source and sink current capability
- Special input protection permits input voltages greater than V_{DD}

Applications

- CMOS hex inverter/buffer
- CMOS to DTL/TTL hex converter
- CMOS current "sink" or "source" driver
- CMOS high-to-low logic level converter

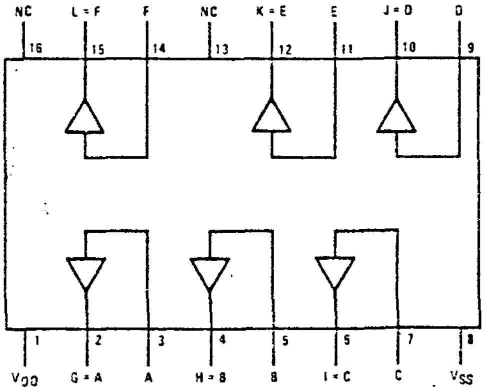
Connection Diagrams

CD4049M/CD4049C
Dual-In-Line and Flat Package



TOP VIEW

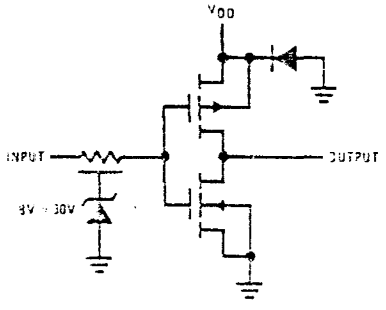
CD4050BM/CD4050BC
Dual-In-Line and Flat Package



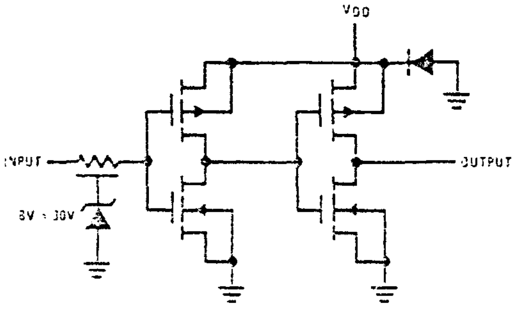
TOP VIEW

Schematic Diagrams

CD4049M/CD4049C
1 of 6 Identical Units



CD4050BM/CD4050BC
1 of 6 Identical Units



Absolute Maximum Ratings

(Notes 1 and 2)

V_{DD} Supply Voltage	−0.5V to +18V
V_{IN} Input Voltage	−0.5V to +18V
V_{OUT} Voltage at Any Output Pin	−0.5V to V_{DD} + 0.5V
T_S Storage Temperature Range	−65°C to +150°C
P_D Package Dissipation	500 mW
T_L Lead Temperature (Soldering, 10 seconds)	300°C

Recommended Operating Conditions

(Note 2)

V_{DD} Supply Voltage	3V to 15V
V_{IN} Input Voltage	0V to 15V
V_{OUT} Voltage at Any Output Pin	0 to V_{DD}
T_A Operating Temperature Range	
CD4049M, CD4050BM	−55°C to +125°C
CD4049C, CD4050BC	−40°C to +85°C

DC Electrical Characteristics CD4049M/CD4050BM (Note 2)

PARAMETER	CONDITIONS	−55°C		25°C			125°C		UNITS
		MIN	MAX	MIN	TYP	MAX	MIN	MAX	
I_{DD} Quiescent Device Current	V_{DD} = 5V		1.0		0.01	1.0		30	μA
	V_{DD} = 10V		2.0		0.01	2.0		60	μA
	V_{DD} = 15V		4.0		0.03	4.0		120	μA
V_{OL} Low Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0, $\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V		0.05		0	0.05		0.05	V
	V_{DD} = 10V		0.05		0	0.05		0.05	V
	V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH} High Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0, $\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V	4.95		4.95	5		4.95		V
	V_{DD} = 10V	9.95		9.95	10		9.95		V
	V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL} Low Level Input Voltage (CD4050BM Only)	$\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V, V_O = 0.5V		1.5		2.25	1.5		1.5	V
	V_{DD} = 10V, V_O = 1V		3.0		4.5	3.0		3.0	V
	V_{DD} = 15V, V_O = 1.5V		4.0		6.75	4.0		4.0	V
V_{IL} Low Level Input Voltage (CD4049M Only)	$\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V, V_O = 4.5V		1.0		1.5	1.0		1.0	V
	V_{DD} = 10V, V_O = 9V		2.0		2.5	2.0		2.0	V
	V_{DD} = 15V, V_O = 13.5V		3.0		3.5	3.0		3.0	V
V_{IH} High Level Input Voltage (CD4050BM Only)	$\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V, V_O = 4.5V	3.5		3.5	2.75		3.5		V
	V_{DD} = 10V, V_O = 9V	7.0		7.0	5.5		7.0		V
	V_{DD} = 15V, V_O = 13.5V	11.0		11.0	8.25		11.0		V
V_{IH} High Level Input Voltage (CD4049M Only)	$\lvert I_O \rvert < 1\ \mu A$								
	V_{DD} = 5V, V_O = 0.5V	4.0		4.0	3.5		4.0		V
	V_{DD} = 10V, V_O = 1V	8.0		8.0	7.5		8.0		V
	V_{DD} = 15V, V_O = 1.5V	12.0		12.0	11.5		12.0		V
I_{OL} Low Level Output Current (Note 3)	V_{IH} = V_{DD}, V_{IL} = 0V								
	V_{DD} = 5V, V_O = 0.4V	5.6		4.6	5		3.2		mA
	V_{DD} = 10V, V_O = 0.5V	12		9.8	12		6.8		mA
	V_{DD} = 15V, V_O = 1.5V	35		29	40		20		mA
I_{OH} High Level Output Current (Note 3)	V_{IH} = V_{DD}, V_{IL} = 0V								
	V_{DD} = 5V, V_O = 4.6V	−1.3		−1.1	−1.6		−0.72		mA
	V_{DD} = 10V, V_O = 9.5V	−2.6		−2.2	−3.6		−1.5		mA
	V_{DD} = 15V, V_O = 13.5V	−8.0		−7.2	−12		−5.0		mA
I_{IN} Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.1		-10^{-5}	−0.1		−1.0	μA
	V_{DD} = 15V, V_{IN} = 15V		0.1		10^{-5}	0.1		1.0	μA

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed; they are not meant to imply that the devices should be operated at these limits. The table of "Recommended Operating Conditions" and "Electrical Characteristics" provides conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

Note 3: These are *peak* output current capabilities. Continuous output current is rated at 12 mA maximum. The output current should not be allowed to exceed this value for extended periods of time.

DC Electrical Characteristics CD4049C/CD4050BC (Note 2)

PARAMETER		CONDITIONS	−40°C		25°C			85°C		UNITS
			MIN	MAX	MIN	TYP	MAX	MIN	MAX	
I_{DD}	Quiescent Device Current	V_{DD} = 5V		4		0.03	4.0		30	µA
		V_{DD} = 10V		8		0.05	8.0		60	µA
		V_{DD} = 15V		16		0.07	16.0		120	µA
V_{OL}	Low Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V, $\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V, $\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V	4.95		4.95	5		4.95		V
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL}	Low Level Input Voltage (CD4050BC Only)	$\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V, V_O = 0.5V		1.5		2.25	1.5		1.5	V
		V_{DD} = 10V, V_O = 1V		3.0		4.5	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V		4.0		6.75	4.0		4.0	V
V_{IL}	Low Level Input Voltage (CD4049C Only)	$\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V, V_O = 4.5V		1.0		1.5	1.0		1.0	V
		V_{DD} = 10V, V_O = 9V		2.0		2.5	2.0		2.0	V
		V_{DD} = 15V, V_O = 13.5V		3.0		3.5	3.0		3.0	V
V_{IH}	High Level Input Voltage (CD4050BC Only)	$\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V, V_O = 4.5V	3.5		3.5	2.75		3.5		V
		V_{DD} = 10V, V_O = 9V	7.0		7.0	5.5		7.0		V
		V_{DD} = 15V, V_O = 13.5V	11.0		11.0	8.25		11.0		V
V_{IH}	High Level Input Voltage (CD4049C Only)	$\lvert I_O\rvert < 1\,\mu A$								
		V_{DD} = 5V, V_O = 0.5V	4.0		4.0	3.5		4.0		V
		V_{DD} = 10V, V_O = 1V	8.0		8.0	7.5		8.0		V
		V_{DD} = 15V, V_O = 1.5V	12.0		12.0	11.5		12.0		V
I_{OL}	Low Level Output Current (Note 3)	V_{IH} = V_{DD}, V_{IL} = 0V								
		V_{DD} = 5V, V_O = 0.4V	4.6		4.0	5		3.2		mA
		V_{DD} = 10V, V_O = 0.5V	9.8		8.5	12		6.8		mA
		V_{DD} = 15V, V_O = 1.5V	29		25	40		20		mA
I_{OH}	High Level Output Current (Note 3)	V_{IH} = V_{DD}, V_{IL} = 0V								
		V_{DD} = 5V, V_O = 4.6V	−1.0		−0.9	−1.6		−0.72		mA
		V_{DD} = 10V, V_O = 9.5V	−2.1		−1.9	−3.6		−1.5		mA
		V_{DD} = 15V, V_O = 13.5V	−7.1		−6.2	−12		−5		mA
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V	−0.3		−0.3	-10^{-5}			−1.0	µA
		V_{DD} = 15V, V_{IN} = 15V	0.3		0.3	10^{-5}			1.0	µA

AC Electrical Characteristics CD4049M/CD4049C

$T_A = 25^\circ C$, $C_L = 50\ pF$, $R_L = 200k$, $t_r = t_f = 20\ ns$, unless otherwise specified.

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
t_{PHL}	Propagation Delay Time High-to-Low Level	$V_{DD} = 5V$		30	65	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{PLH}	Propagation Delay Time Low-to-High Level	$V_{DD} = 5V$		45	85	ns
		$V_{DD} = 10V$		25	45	ns
		$V_{DD} = 15V$		20	35	ns
t_{THL}	Transition Time High-to-Low Level	$V_{DD} = 5V$		30	60	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{TLH}	Transition Time Low-to-High Level	$V_{DD} = 5V$		60	120	ns
		$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	ns
C_{IN}	Input Capacitance	Any Input		15	22.5	pF

AC Electrical Characteristics CD4050BM/CD4050BC

$T_A = 25^\circ C$, $C_L = 50\ pF$, $R_L = 200k$, $t_r = t_f = 20\ ns$, unless otherwise specified.

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
t_{PHL}	Propagation Delay Time High-to-Low Level	$V_{DD} = 5V$		60	110	ns
		$V_{DD} = 10V$		25	55	ns
		$V_{DD} = 15V$		20	30	ns
t_{PLH}	Propagation Delay Time Low-to-High Level	$V_{DD} = 5V$		60	120	ns
		$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	ns
t_{THL}	Transition Time High-to-Low Level	$V_{DD} = 5V$		30	60	ns
		$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	ns
t_{TLH}	Transition Time Low-to-High Level	$V_{DD} = 5V$		60	120	ns
		$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	ns
C_{IN}	Input Capacitance	Any Input		5	7.5	pF

XR-555

Timing Circuit

GENERAL DESCRIPTION

The XR-555 monolithic timing circuit is a highly stable controller capable of producing accurate timing pulses. It is a direct, pin-for-pin replacement for the SE/NE 555 timer. The circuit contains independent control terminals for triggering or resetting if desired, as shown in the functional block diagram of Figure 1.

In the monostable mode of operation, the time delay is controlled by one external resistor and one capacitor. For astable operation as an oscillator, the free-running frequency and the duty cycle are accurately controlled with two external resistors and one capacitor (as shown in Figure 2).

The XR-555 may be triggered or reset on falling waveforms. Its output can source or sink up to 200 mA or drive TTL circuits.

FEATURES

- Direct Replacement for SE/NE 555
- Timing from Microseconds Thru Hours
- Operates in Both Monostable and Astable Modes
- High Current Drive Capability (200 mA)
- TTL and DTL Compatible Outputs
- Adjustable Duty Cycle
- Temperature Stability of 0.005%/°C

ABSOLUTE MAXIMUM RATINGS

Power Supply	18 volts
Power Dissipation (package limitation)	
Ceramic Package	385 mW
Plastic Package	300 mW
Derate above +25°C	2.5 mW/°C
Storage Temperature	−65°C to +125°C

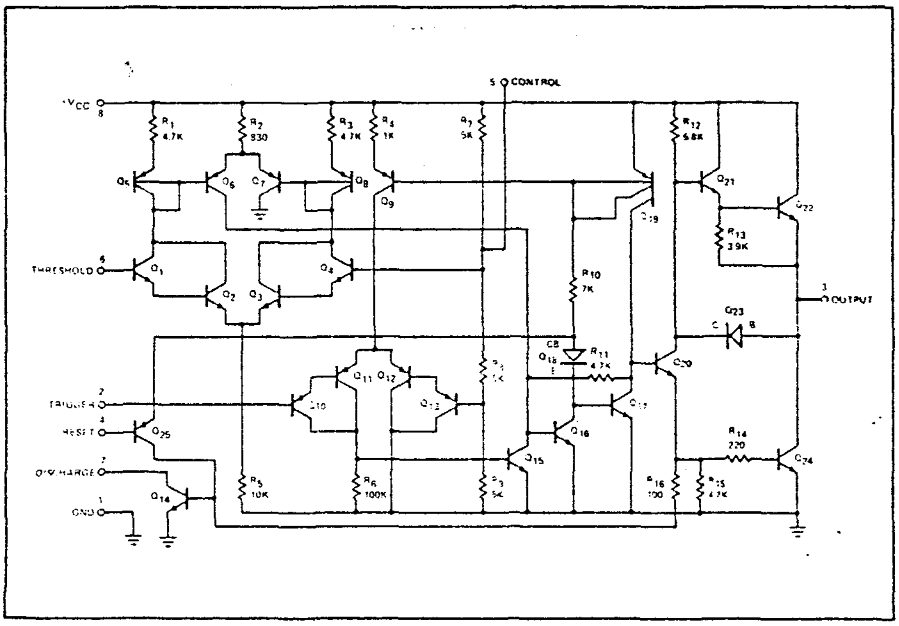
APPLICATIONS

- Precision Timing
- Pulse Generation
- Sequential Timing
- Pulse Shaping
- Clock Generation
- Missing Pulse Detection
- Pulse-Width Modulation
- Frequency Division
- Pulse-Position Modulation
- Appliance Timing

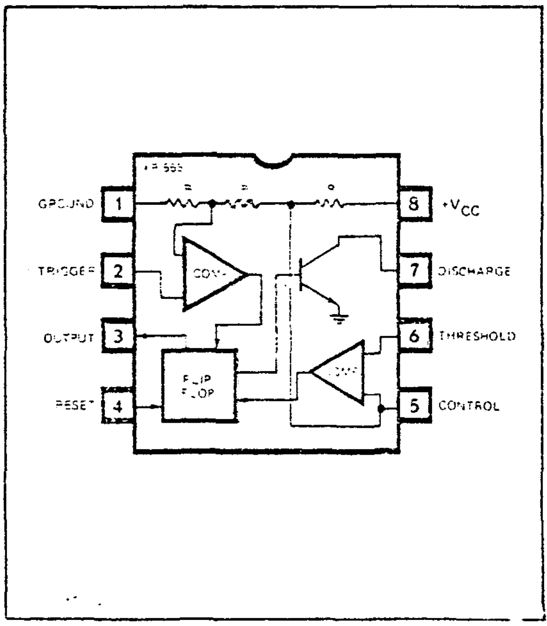
AVAILABLE TYPES

Part Number	Package	Operating Temperature
XR-555M	Ceramic	−55°C to +125°C
XR-555CM	Ceramic	0°C to +75°C
XR-555CP	Plastic	0°C to +75°C

EQUIVALENT SCHEMATIC DIAGRAM



FUNCTIONAL BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

Test Conditions: (T_A = 25°C, V_{CC} = +5V to +15V, unless otherwise specified.)

PARAMETER	XR-555M			XR-555C			UNITS	CONDITION
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Supply Voltage	4.5		18	4.5		16	V	
Supply Current								Low State Output (Note 1)
		3	5		3	6	mA	V_{CC} = 5V, R_L = ∞
		10	12		10	15	mA	V_{CC} = 15V, R_L = ∞
Timing Error (Monostable)								R_A, R_B = 1 KΩ to 100 KΩ
Initial Accuracy		0.5	2.0		1.0	3.0	%	Note 2, C = 0.1 μF
Drift with Temperature		30	100		50		ppm/°C	0°C ≤ T_A ≤ 75°C
Drift with Supply Voltage		0.05	0.2		0.1	0.5	%/V	
Timing Error (Astable)								R_A, R_B = 1 KΩ to 100 KΩ
Initial Accuracy (Note 2)		1.5			2.25		%	C = 0.1 μF
Drift with Temperature		90			150		ppm/°C	V_{CC} = 15V
Drift with Supply Voltage		0.15			0.3		%/V	
Threshold Voltage	9.4	10.0	10.6	8.8	10.0	11.2	V	V_{CC} = 15V
	2.7	3.33	4.0	2.4	3.33	4.2	V	V_{CC} = 5V
Trigger Voltage	1.45	1.67	1.9		1.67		V	V_{CC} = 5V
	4.8	5.0	5.2		5.0		V	V_{CC} = 15V
Trigger Current		0.5	0.9		0.5	2.0	μA	
Reset Voltage	0.4	0.7	1.0	0.4	0.7	1.0	V	Trigger Input High
Reset Current		0.4	1.0		0.4	1.5	mA	
Threshold Current		0.1	0.25		0.1	0.25	μA	(Note 3)
Control Voltage Level	2.7	3.33	4.0	2.4	3.33	4.2	V	V_{CC} = 5V
	9.4	10.0	10.6	8.8	10.0	11.2	V	V_{CC} = 15V
Output Voltage Drop (Low)								V_{CC} = 5V
		0.10	0.25		0.3		V	I_{sink} = 8.0 mA
		0.05	0.2		0.25	0.35	V	I_{sink} = 5.0 mA
								V_{CC} = 15V
		0.1	0.15		0.1	0.25	V	I_{sink} = 10 mA
		0.4	0.5		0.4	0.75	V	I_{sink} = 50 mA
		2.0	2.2		2.0	2.5	V	I_{sink} = 100 mA
		2.5			2.5		V	I_{sink} = 200 mA
Output Voltage Drop (High)								I_{source} = 100 mA
	3.0	3.3		2.75	3.3		V	V_{CC} = 5V
	13	13.3		12.75	13.3		V	V_{CC} = 15V
								I_{source} = 200 mA
		12.5			12.5		V	V_{CC} = 15V
Turn Off Time (Note 4)		0.5	2.0		0.5		μs	V_{RESET} High
Rise Time of Output		100	200		100	300	nsec	
Fall Time of Output		100	200		100	300	nsec	
Discharge Transistor Leakage		20	100		20	100	nA	

Note 1: Supply current when output is high is typically 1.0 mA less.

Note 2: Tested at V_{CC} = 5V and V_{CC} = 15V.

Note 3: This will determine the maximum value of $R_A + R_B$ for 15V operation. The maximum total R = 20 megohms and for 5V operation, the maximum R_T = 3.4 megohms.

Note 4: Time measured from a positive-going input pulse from 0 to 0.8xV_{CC} into the threshold to the drop from high to low of the output. Trigger is tied to threshold.

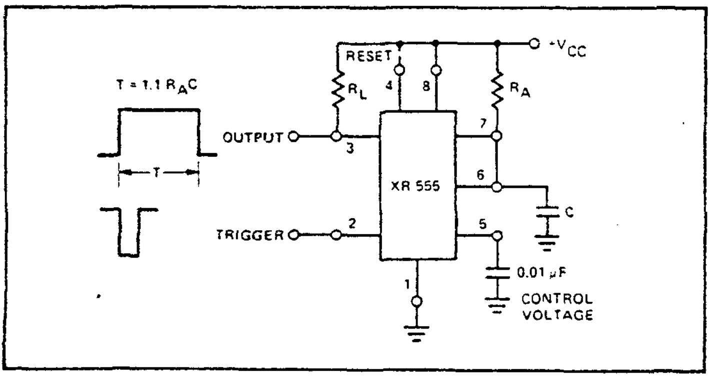


Figure 1. Monostable (One-Shot) Circuit.

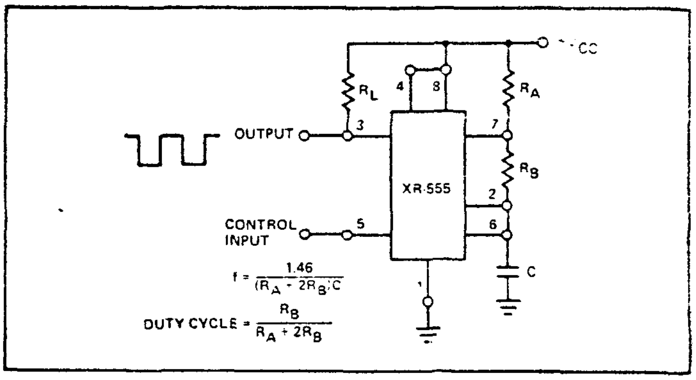


Figure 2. Astable (Free-Running) Circuit.

µA556

DUAL TIMING CIRCUIT

FAIRCHILD LINEAR INTEGRATED CIRCUITS

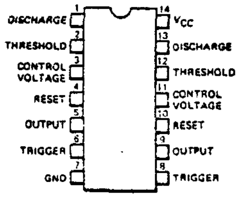
GENERAL DESCRIPTION – The µA556 Timing Circuits are very stable controllers for producing accurate time delays or oscillations. In the time delay mode, the delay time is precisely controlled by one external resistor and one capacitor; in the oscillator mode, the frequency and duty cycle are both accurately controlled with two external resistors and one capacitor. By applying a trigger signal, the timing cycle is started and an internal flip-flop is set, immunizing the circuit from any further trigger signals. To interrupt the timing cycle a reset signal is applied, ending the time-out.

The output, which is capable of sinking or sourcing 200 mA, is compatible with TTL circuits and can drive relays or indicator lamps.

The µA556 Dual Timing Circuit is a pair of 555s for use in sequential timing or applications requiring multiple timers.

- MICROSECONDS THROUGH HOURS TIMING CONTROL
- ASTABLE OR MONOSTABLE OPERATING MODES
- ADJUSTABLE DUTY CYCLE
- 200 mA SINK OR SOURCE OUTPUT CURRENT CAPABILITY
- TTL OUTPUT DRIVE CAPABILITY
- TEMPERATURE STABILITY OF 0.005% PER °C
- NORMALLY ON OR NORMALLY OFF OUTPUT

CONNECTION DIAGRAM
14-PIN DIP
(TOP VIEW)
PACKAGE OUTLINES 6A 9A
PACKAGE CODES D P



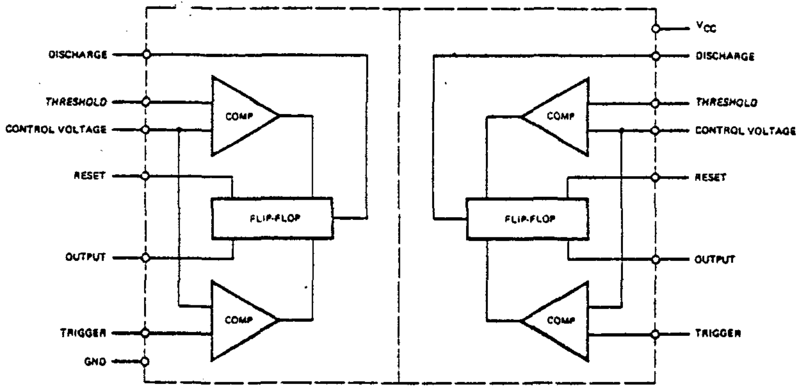
ORDER INFORMATION

TYPE	PART NO.
µA556	µA556DC
µA556	µA556DM
µA556	µA556PC

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	+18 V
Power Dissipation	600 mW
Operating Temperature Ranges	
µA556 DC/PC	0°C to +70°C
µA556DM	−55°C to +125°C
Storage Temperature Range	−65°C to +150°C
Pin Temperature (Soldering)	
(10 s) Plastic DIP (9A)	260°C
(60 s) Ceramic DIP (6A)	300°C

BLOCK DIAGRAM



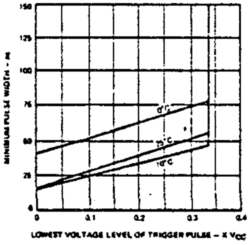
ELECTRICAL CHARACTERISTICS: $T_A = 25°C$, $V_{CC} = +5.0$ V to +15 V, unless otherwise specified

CHARACTERISTICS	TEST CONDITIONS	μA556DM			μA556DC/PC			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Supply Voltage		4.5		18	4.5		16	V
Supply Current (Total)	$V_{CC} = 5.0$ V, $R_L = \infty$		6.0	10		6.0	12	mA
	$V_{CC} = 15$ V, $R_L = \infty$ LOW State (Note 1)		20	22		20	28	mA
Timing Error (Monostable)								
Initial Accuracy	$R_A = 2$ kΩ to 100 kΩ		0.5	1.5		0.75		%
Drift with Temperature	C = 0.1 μF (Note 2)		30	100		50		ppm/°C
Drift with Supply Voltage			0.05	0.2		0.1		%V
Timing Error (Astable)								
Initial Accuracy	R_A, $R_B = 2$ kΩ to 100 kΩ		1.5			2.25		%
Drift with Temperature	C = 0.1 μF (Note 2)		90			150		ppm/°C
Drift with Supply Voltage			0.15			0.3		%V
Threshold Voltage			2/3			2/3		X V_{CC}
Threshold Current	Note 3		30	100		30	100	nA
Trigger Voltage	$V_{CC} = 15$ V	4.8	5.0	5.2		5.0		V
	$V_{CC} = 5.0$ V	1.45	1.67	1.9		1.67		V
Trigger Current			0.5			0.5		μA
Reset Voltage		0.4	0.7	1.0	0.4	0.7	1.0	V
Reset Current			0.1			0.1		mA
Control Voltage Level	$V_{CC} = 15$ V	9.6	10	10.4	9.0	10	11	V
	$V_{CC} = 5.0$ V	2.9	3.33	3.8	2.6	3.33	4.0	V
Output Voltage (LOW)	$V_{CC} = 15$ V							
	$I_{SINK} = 10$ mA		0.1	0.15		0.1	0.25	V
	$I_{SINK} = 50$ mA		0.4	0.5		0.4	0.75	V
	$I_{SINK} = 100$ mA		2.0	2.25		2.0	2.75	V
	$I_{SINK} = 200$ mA		2.5			2.5		V
	$V_{CC} = 5.0$ V							
	$I_{SINK} = 8.0$ mA		0.1	0.25				V
	$I_{SINK} = 5.0$ mA					0.25	0.35	V
Output Voltage (HIGH)	$I_{SOURCE} = 200$ mA							
	$V_{CC} = 15$ V		12.5			12.5		V
	$I_{SOURCE} = 100$ mA							
	$V_{CC} = 15$ V	13.0	13.3		12.75	13.3		V
	$V_{CC} = 5.0$V	3.0	3.3		2.75	3.3		V
Rise Time of Output			100			100		ns
Fall Time of Output			100			100		ns
Discharge Leakage Current			20	100		20	100	nA
Matching Characteristics (Note 4)								
Initial Timing Accuracy			0.05	0.1		0.1	0.2	%
Timing Drift with Temperature			±10			±10		ppm/°C
Drift with Supply Voltage			0.1	0.2		0.2	0.5	%V

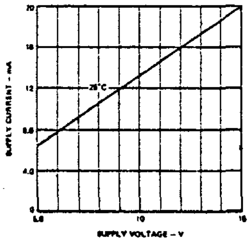
NOTES:
1. Supply current when output is HIGH is typically 1.0 mA less.
2. Tested at $V_{CC} = 5$ V and $V_{CC} = 15$ V.
3. This will determine the maximum value of $R_A + R_B$ for 15 V operation. The maximum total R = 20 MΩ.
4. Matching characteristics refer to the difference between performance characteristics of each timer section.

TYPICAL PERFORMANCE CURVES

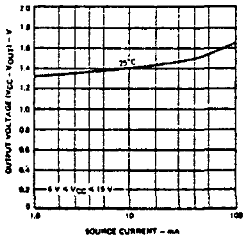
MINIMUM PULSE WIDTH REQUIRED FOR TRIGGERING



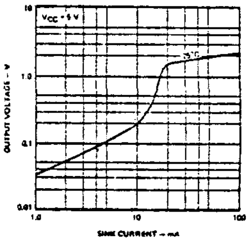
TOTAL SUPPLY CURRENT AS A FUNCTION OF SUPPLY VOLTAGE



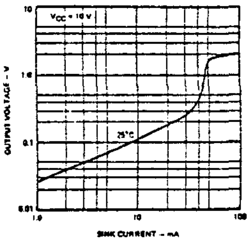
HIGH OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT SOURCE CURRENT



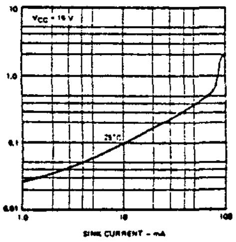
LOW OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT SINK CURRENT



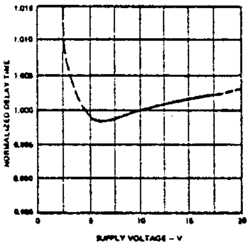
LOW OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT SINK CURRENT



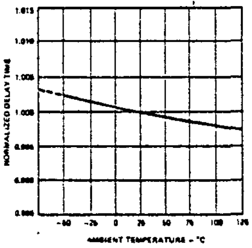
LOW OUTPUT VOLTAGE AS A FUNCTION OF OUTPUT SINK CURRENT



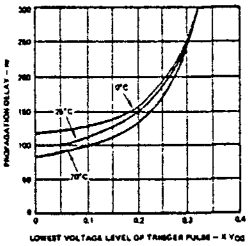
DELAY TIME AS A FUNCTION OF SUPPLY VOLTAGE



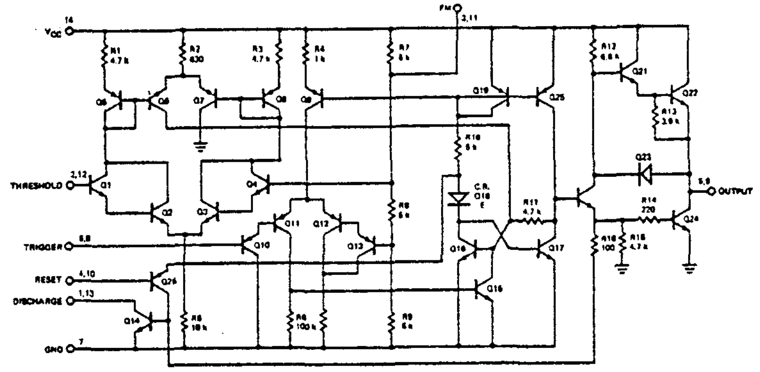
DELAY TIME AS A FUNCTION OF AMBIENT TEMPERATURE



PROPAGATION DELAY AS A FUNCTION OF VOLTAGE LEVEL OF TRIGGER PULSE



EQUIVALENT CIRCUIT (One Half of µA556)



TYPICAL APPLICATIONS

MONOSTABLE OPERATION

In the monostable mode, the timer functions as a one-shot. Referring to Figure 1 the external capacitor is initially held discharged by a transistor inside the timer.

When a negative trigger pulse is applied to lead 6, the flip-flop is set, releasing the short circuit across the external capacitor and drives the output HIGH. The voltage across the capacitor, increases exponentially with the time constant $\tau = R1C1$. When the voltage across the capacitor equals 2/3 V_{CC}, the comparator resets the flip-flop which then discharges the capacitor rapidly and drives the output to its LOW state. Figure 2 shows the actual waveforms generated in this mode of operation.

The circuit triggers on a negative-going input signal when the level reaches 1/3 V_{CC}. Once triggered, the circuit remains in this state until the set time has elapsed, even if it is triggered again during this interval. The duration of the output HIGH state is given by $t = 1.1\ R1C1$ and is easily determined by Figure 3. Notice that since the charge rate and the threshold level of the comparator are both directly proportional to supply voltage, the timing interval is independent of supply. Applying a negative pulse simultaneously to the Reset terminal (lead 4) and the Trigger terminal (lead 6) during the timing cycle discharges the external capacitor and causes the cycle to start over. The timing cycle now starts on the positive edge of the reset pulse. During the time the reset pulse is applied, the output is driven to its LOW state.

When Reset is not used, it should be tied high to avoid any possibility of false triggering.

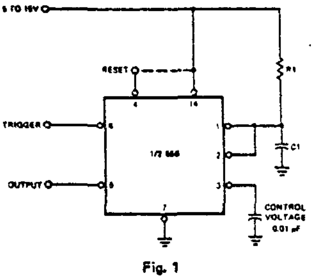
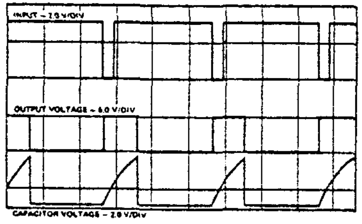


Fig. 1



R1 = 9.1 kΩ, C1 = 0.01 µF, R_L = 1.0 kΩ

Fig. 2

TIME DELAY AS A FUNCTION OF R1 AND C1

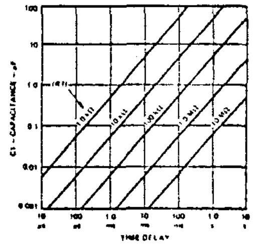


Fig. 3

ORDERING INFORMATION

Device	Temperature Range	Package
MC1495L	0°C to +70°C	Ceramic DIP
MC1595L	−55°C to +125°C	Ceramic DIP

MC1495L
MC1595L

Specifications and Applications Information

WIDEBAND MONOLITHIC FOUR-QUADRANT MULTIPLIER

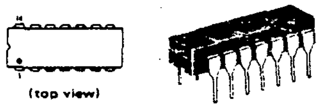
. . . designed for uses where the output is a linear product of two input voltages. Maximum versatility is assured by allowing the user to select the level shift method. Typical applications include: multiply, divide*, square root*, mean square*, phase detector, frequency doubler, balanced modulator/demodulator, electronic gain control.

*When used with an operational amplifier.

- Wide Bandwidth
- Excellent Linearity – 1% max Error on X-Input, 2% max Error on Y-Input – MC1595L
- Excellent Linearity – 2% max Error on X-Input, 4% max Error on Y-Input – MC1495L
- Adjustable Scale Factor, K
- Excellent Temperature Stability
- Wide Input Voltage Range – ± 10 Volts
- ± 15 Volt Operation

LINEAR FOUR-QUADRANT MULTIPLIER INTEGRATED CIRCUIT

MONOLITHIC SILICON
EPITAXIAL PASSIVATED



CERAMIC PACKAGE
CASE 632
TO-116

FIGURE 1 – FOUR-QUADRANT MULTIPLIER TRANSFER CHARACTERISTIC

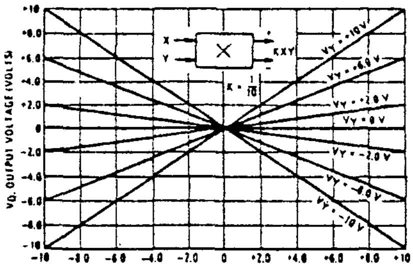


FIGURE 2 – TRANSCONDUCTANCE BANDWIDTH

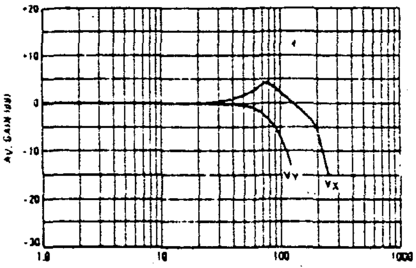
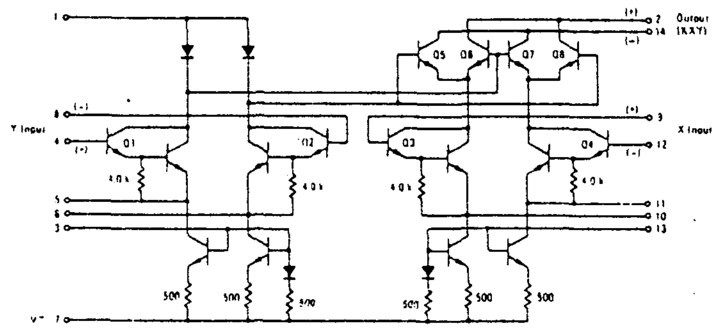


FIGURE 3 – CIRCUIT SCHEMATIC



ELECTRICAL CHARACTERISTICS (V^+ = +32V, V^- = –15 V, T_A = +25°C, $I_3 = I_{13}$ = 1 mA, $R_X = R_Y$ = 15 kΩ, R_L = 11 kΩ unless otherwise noted)

Characteristic		Figure	Symbol	Min	Typ	Max	Unit
Linearity:							
Output Error in Percent of Full Scale:		5					%
T_A = +25°C							
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)	MC1495		E_{RX}	–	±1.0	±2.0	
	MC1595			–	±0.5	±1.0	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)	MC1495		E_{RY}	–	±2.0	±4.0	
	MC1595			–	±1.0	±2.0	
T_A = 0 to +70°C	MC1495						
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)			E_{RX}	–	±1.5	–	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)			E_{RY}	–	±3.0	–	
T_A = -55°C to +125°C	MC1595						
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)			E_{RX}	–	±0.75	–	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)			E_{RY}	–	±1.50	–	
Squaring Mode Error:							
Accuracy in Percent of Full Scale After Offset and Scale Factor Adjustment		5	E_{SQ}				%
T_A = +25°C	MC1495			–	±0.75	–	
	MC1595			–	±0.5	–	
T_A = 0 to +70°C	MC1495			–	±1.0	–	
T_A = -55°C to +125°C	MC1595				±0.75		
Scale Factor (Adjustable)							
$(K = \frac{2R_L}{I_3 R_X R_Y})$		–	K	-	0.1	–	–
Input Resistance	MC1495	7	R_{INX}	–	20	–	MegOhms
(f = 20 Hz)	MC1595			–	35	–	
	MC1495		R_{INY}	-	20	–	
	MC1595			-	35	–	
Differential Output Resistance (f = 20 Hz)		8	R_o	–	300	–	k Ohms
Input Bias Current							
$I_{bx} = \frac{(I_9 + I_{12})}{2}, I_{by} = \frac{(I_4 + I_8)}{2}$	MC1495	6	I_{bx}	-	2.0	12	µA
	MC1595			–	2.0	8.0	
	MC1495		I_{by}	–	2.0	12	
	MC1595			–	2.0	8.0	
Input Offset Current							
$\lvert I_9 - I_{12} \rvert$	MC1495	6	$\lvert I_{iox} \rvert$	–	0.4	2.0	µA
	MC1595			–	0.2	1.0	
$\lvert I_4 - I_8 \rvert$	MC1495		$\lvert I_{ioy} \rvert$	–	0.4	2.0	
	MC1595			–	0.2	1.0	
Average Temperature Coefficient of Input Offset Current		6	$\lvert TC_{Iio} \rvert$				nA/°C
(T_A = 0 to +70°C)	MC1495			–	2.0	–	
(T_A = -55°C to +125°C)	MC1595			–	2.0	–	
Output Offset Current		6	$\lvert I_{oo} \rvert$				µA
$\lvert I_{14} - I_2 \rvert$	MC1495			–	20	100	
	MC1595			-	10	50	
Average Temperature Coefficient of Output Offset Current		6	$\lvert TC_{Ioo} \rvert$				nA/°C
(T_A = 0 to +70°C)	MC1495			–	1.0	-	
(T_A = -55°C to +125°C)	MC1595			-	1.0	–	
Frequency Response							
3.0 dB Bandwidth, R_L = 11 kΩ		9,10	BW_{3dB}	–	3.0	–	MHz
3.0 dB Bandwidth, R_L = 50 Ω (Transconductance Bandwidth)			T_{BW3dB}	–	80	–	MHz
3° Relative Phase Shift Between V_X and V_Y			f_ϕ	–	750	-	kHz
1% Absolute Error Due to Input-Output Phase Shift			f_θ	–	30	–	kHz
Common Mode Input Swing		11	CMV				Vdc
(Either Input)	MC1495			±10.5	±12	–	
	MC1595			±11.5	±13	–	
Common Mode Gain		11	A_{CM}				dB
(Either Input)	MC1495			-40	-50	–	
	MC1595			-50	-60	–	
Common Mode Quiescent		12	V_{o1}	–	21	–	Vdc
Output Voltage			V_{o2}	–	21	–	
Differential Output Voltage Swing Capability		9	V_o	–	±14	–	V_{peak}
Power Supply Sensitivity		12	S^+	–	5.0	–	mV/V
			S^-	–	10	–	
Power Supply Current		12	I_7	–	6.0	7.0	mA
DC Power Dissipation		12	P_D	–	135	170	mW

TYPICAL CHARACTERISTICS

FIGURE 15 – LINEARITY versus TEMPERATURE

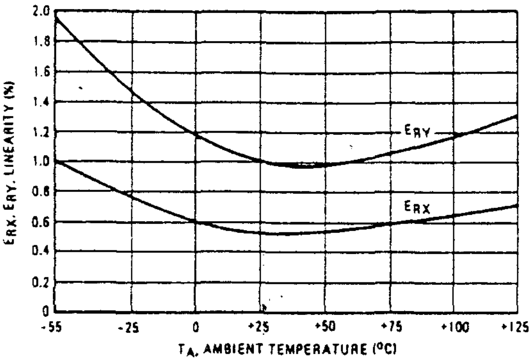


FIGURE 16 – SCALE FACTOR versus TEMPERATURE

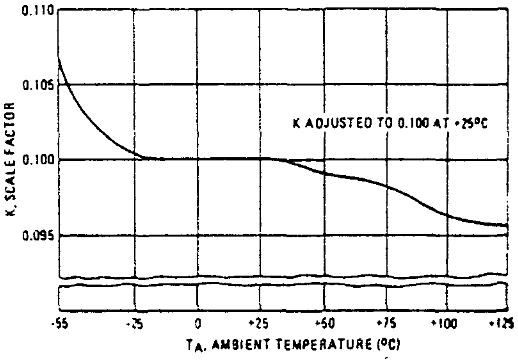


FIGURE 17 – ERROR CONTRIBUTED BY INPUT DIFFERENTIAL AMPLIFIER

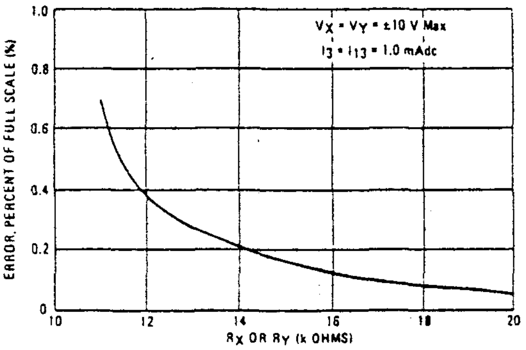


FIGURE 18 – ERROR CONTRIBUTED BY INPUT DIFFERENTIAL AMPLIFIER

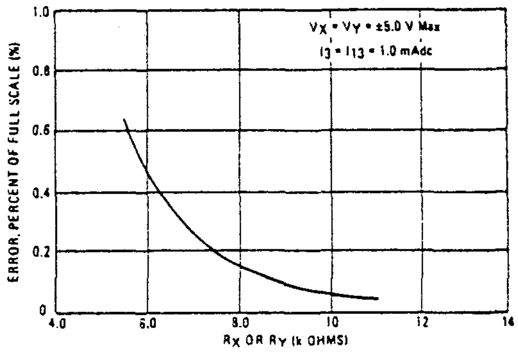
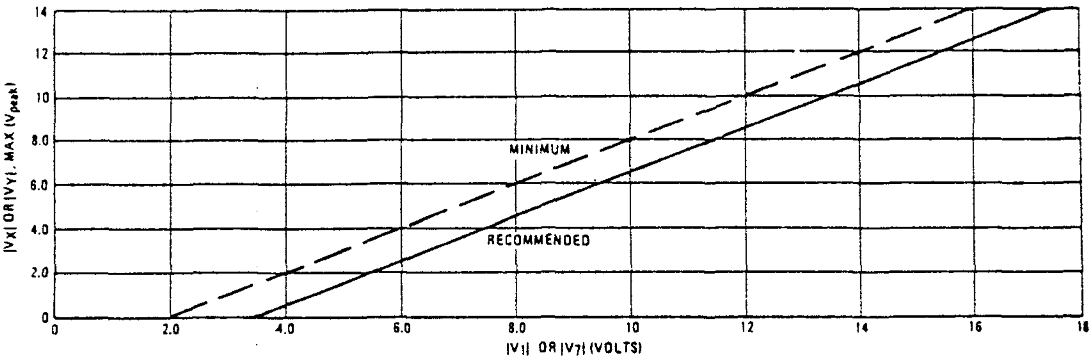


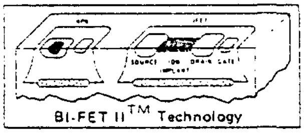
FIGURE 19 – MAXIMUM ALLOWABLE INPUT VOLTAGE versus VOLTAGE AT PIN 1 OR PIN 7



MAXIMUM RATINGS (T_A = +25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Applied Voltage (V_2-V_1, $V_{14}-V_1$, V_1-V_9, V_1-V_{12}, V_1-V_4, V_1-V_8, $V_{12}-V_7$, V_9-V_7, V_8-V_7, V_4-V_7)	ΔV	30	Vdc
Differential Input Signal	$V_{12}-V_9$ V_4-V_8	$\pm(6+I_{13}R_X)$ $\pm(6+I_3R_Y)$	Vdc Vdc
Maximum Bias Current	I_3 I_{13}	10 10	mA
Power Dissipation (Package Limitation) Ceramic Package Derate above T_A = +25°C	P_D	750 5.0	mW mW/°C
Operating Temperature Range MC1495 MC1595	T_A	0 to +70 -55 to +125	°C °C
Storage Temperature Range	T_{stg}	-65 to +150	°C

National Semiconductor


BI-FET II^{TM} Technology

LF351 Wide Bandwidth JFET Input Operational Amplifier

General Description

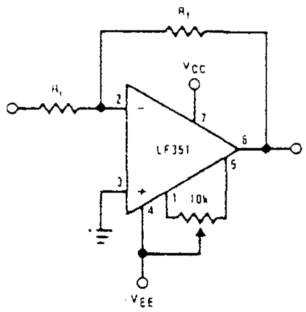
The LF351 is a low cost high speed JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF351 is pin compatible with the standard LM741 and uses the same offset voltage adjustment circuitry. This feature allows designers to immediately upgrade the overall performance of existing LM741 designs.

The LF351 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift, but for applications where these requirements are critical, the LF356 is recommended. If maximum supply current is important, however, the LF351 is the better choice.

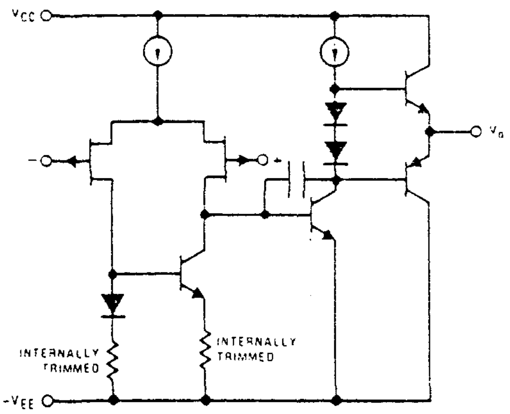
Features

■ Internally trimmed offset voltage	10 mV
■ Low input bias current	50 pA
■ Low input noise voltage	16 nV/√Hz
■ Low input noise current	0.01 pA/√Hz
■ Wide gain bandwidth	4 MHz
■ High slew rate	13 V/μs
■ Low supply current	1.8 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20\ Vp\text{-}p$, BW = 20 Hz-20 kHz	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01%	2 μs

Typical Connection

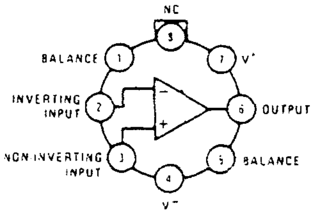


Simplified Schematic



Connection Diagrams (Top Views)

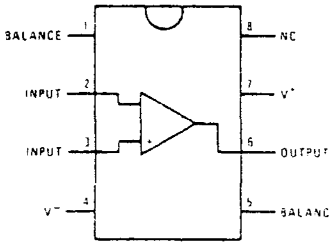
Metal Can Package



Note: Pin 4 connected to case

Order Number LF351H
See NS Package H08C

Dual-In-Line Package



TOP VIEW

Order Number LF351N
See NS Package N08A

Absolute Maximum Ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500mW
Operating Temperature Range	0°C to +70°C
$T_{j(MAX)}$	115°C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±15V
Output Short Circuit Duration	Continuous
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

DC Electrical Characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF351			UNITS
			MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 10k\Omega$, $T_A = 25°C$		5	10	mV
		Over Temperature			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10k\Omega$		10		μV/°C
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 3, 4)		25	100	pA
		$T_j \leq 70°C$			4	nA
I_B	Input Bias Current	$T_j = 25°C$, (Notes 3, 4)		50	200	pA
		$T_j \leq 70°C$			8	nA
R_{IN}	Input Resistance	$T_j = 25°C$		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm15V$, $T_A = 25°C$ $V_O = \pm10V$, $R_L = 2k\Omega$	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	$V_S = \pm15V$, $R_L = 10k\Omega$	±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm15V$	±11	+15 −12		V V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10k\Omega$	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 5)	70	100		dB
I_S	Supply Current			1.8	3.4	mA

AC Electrical Characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF351			UNITS
			MIN	TYP	MAX	
SR	Slew Rate	$V_S = \pm15V$, $T_A = 25°C$		13		V/μs
GBW	Gain Bandwidth Product	$V_S = \pm15V$, $T_A = 25°C$		4		MHz
e_n	Equivalent Input Noise Voltage	$T_A = 25°C$, $R_S = 100\Omega$, $f = 1000 Hz$		16		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	$T_j = 25°C$, $f = 1000 Hz$		0.01		$pA/\sqrt{Hz}$

Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 150°C/W junction to ambient or 45°C/W junction to case.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

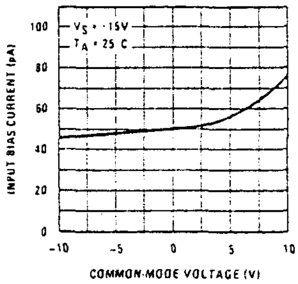
Note 3: These specifications apply for $V_S = \pm15V$ and $0°C \leq T_A \leq +70°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

Note 4: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to the limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \theta_{jA} P_D$ where θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

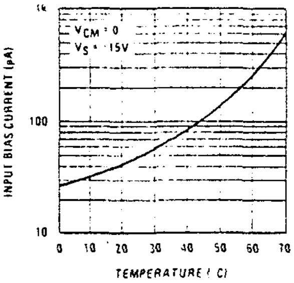
Note 5.: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

Typical Performance Characteristics

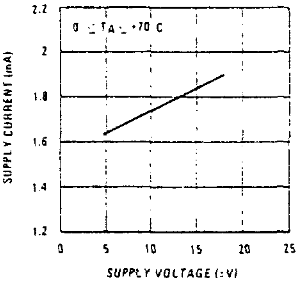
Input Bias Current



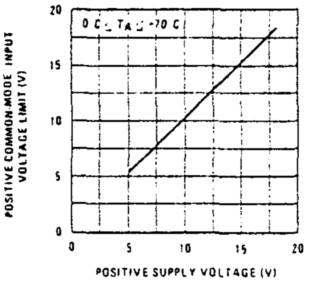
Input Bias Current



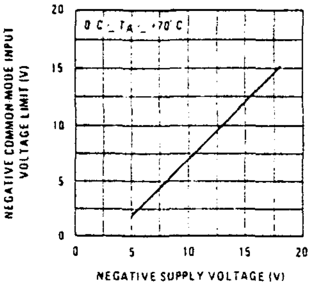
Supply Current



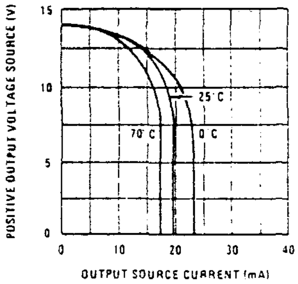
Positive Common-Mode Input Voltage Limit



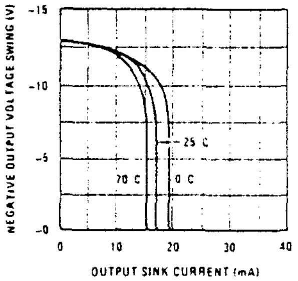
Negative Common-Mode Input Voltage Limit



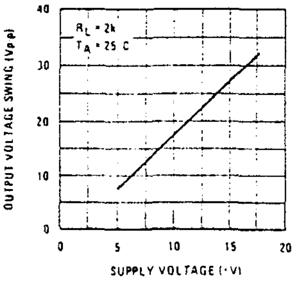
Positive Current Limit



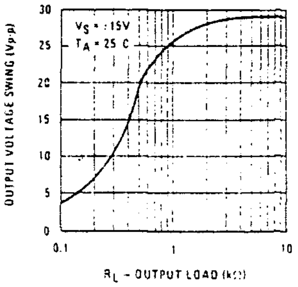
Negative Current Limit



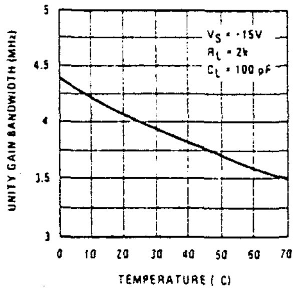
Voltage Swing



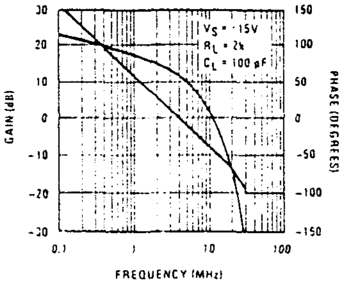
Output Voltage Swing



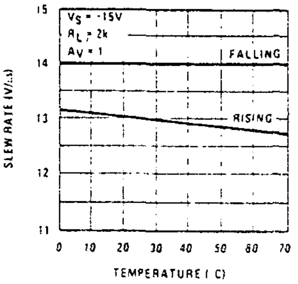
Gain Bandwidth



Bode Plot

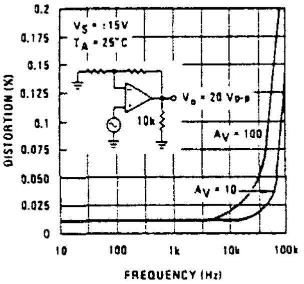


Slew Rate

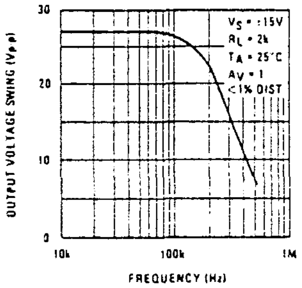


Typical Performance Characteristics (Continued)

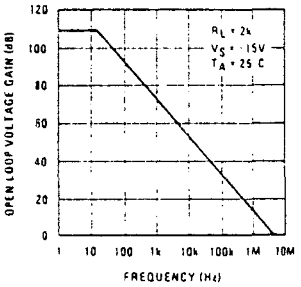
Distortion vs Frequency



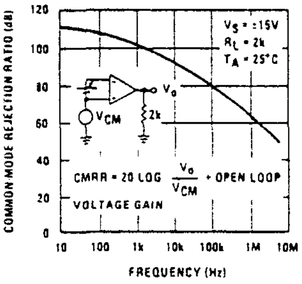
Undistorted Output Voltage Swing



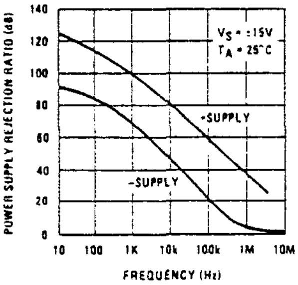
Open Loop Frequency Response



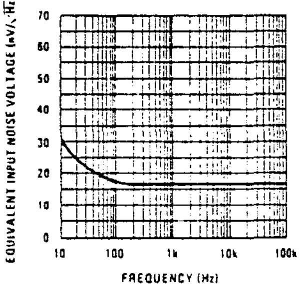
Common-Mode Rejection Ratio



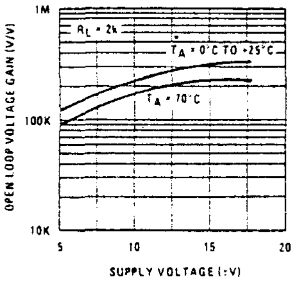
Power Supply Rejection Ratio



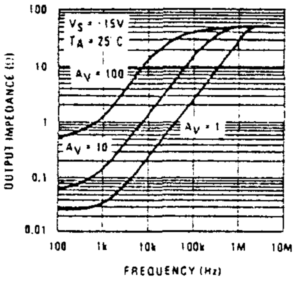
Equivalent Input Noise Voltage



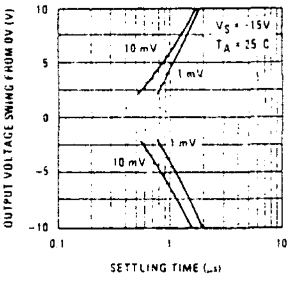
Open Loop Voltage Gain (V/V)



Output Impedance

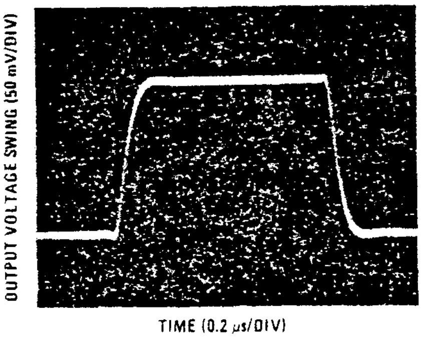


Inverter Settling Time

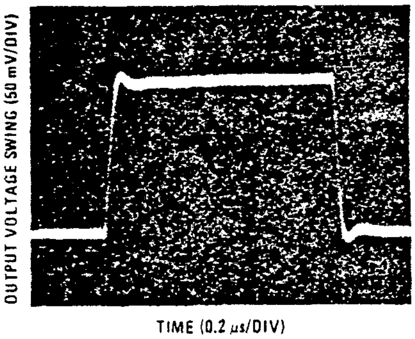


Pulse Response

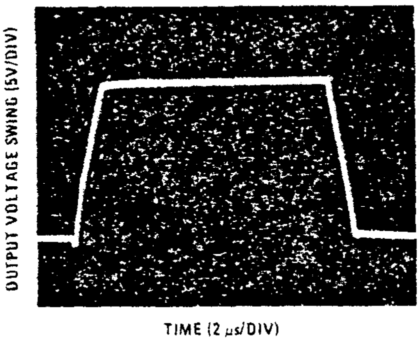
Small Signal Inverting



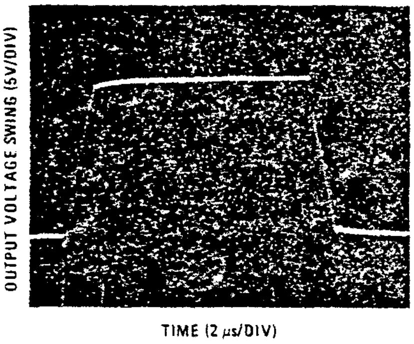
Small Signal Non-Inverting



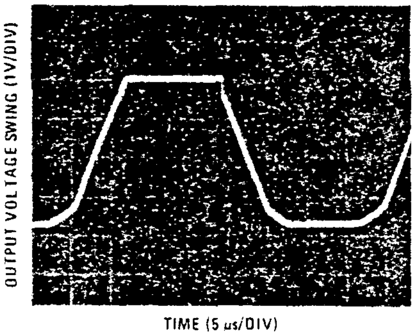
Large Signal Inverting



Large Signal Non-Inverting



Current Limit (R_L = 100Ω)



Application Hints

The LF351 is an op amp with an internally trimmed input offset voltage and JFET input devices (BI-FET II™). These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore, large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will cause a reversal of the phase to the output and force the amplifier output to the corresponding high or low state. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a

Application Hints (Continued)

high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

The amplifier will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

The LF351 is biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The LF351 will drive a 2 kΩ load resistance to ±10V over the full temperature range of 0°C to +70°C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

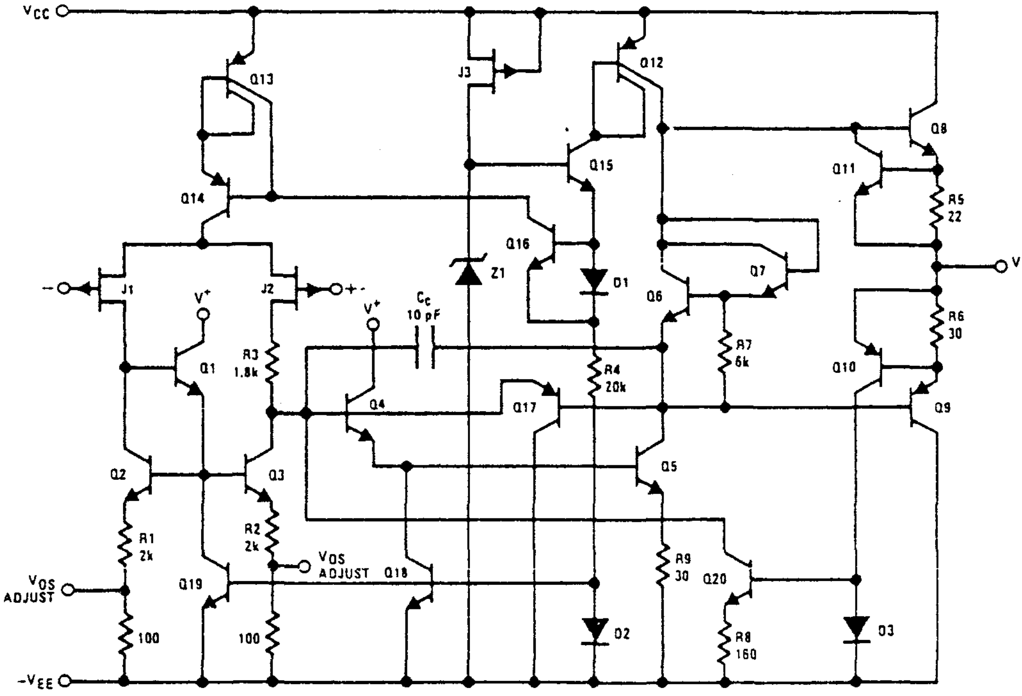
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of *this capacitor and the resistance it parallels* is greater than or equal to the original feedback pole time constant.

Detailed Schematic



* 4. MODULACIONES DIGITALES :

Hasta ahora, hemos visto las modulaciones con senales continuas, que poseen un numero infinito de formas de onda. En cambio en este caso queremos modular una senal con un numero finito de formas de onda o mensajes. Esta es la diferencia fundamental entre los sistemas de comunicacion de datos digitales y los de datos continuos (o datos analogicos).

El sistema PCM (modulacion por impulsos codificados), es un sistema de datos digitales que se emplea para transmitir datos continuos. Esta transmision es posible gracias a un proceso de cuantificacion que consiste en hacer una aproximacion de las senales continuas para que puedan tomar tan solo ciertas amplitudes discretas. Esencialmente esto es la digitalizacion de la senal continua. Los mensajes se pueden transmitir mediante un numero finito de simbolos (o niveles).

En este estudio no vamos a entrar con detalle, en la modulacion PCM, y solo nos vamos a limitar a tomar una senal digital (binaria), donde tenemos dos niveles (alto y bajo), y la modularemos en los tres siguientes sistemas:

- ASK (amplitude shift keying) Modulacion Binaria en Amplitud.

- PSK (phase shift keying) Modulacion Binaria en Fase.
- FSK (frequency shift keying) Modulacion Binaria en Frecuencia.

4.1 MODULACION BINARIA EN AMPLITUD [ASK]:

Consiste basicamente en modular en amplitud un sistema PCM binario.

La modulacion en amplitud traslada el espectro de baja frecuencia del PCM binario a una fracuencia superior (a la frecuencia de portadora).

Uno de los simbolos binarios se transmite mediante un pulso sinusoidal S(t) dado por:

$S(t) = A\ \mathrm{sen}(Wc\ t)$ para $0 < t < T$

$S(t) = 0$. en cualquier otro punto.

El otro simbolo se transmite mediante un espacio, (ausencia de senal). Una forma de onda ASK tipica se muestra en la figura (4.1).

La modulacion ASK tiene la ventaja de que la senal moduladora es muy facil de detectar, (con un detector de envolvente). Pero tambien tiene la desventaja de que transmite corriente continua y de que la probabilidad de error por bit es grande.

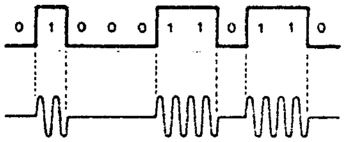
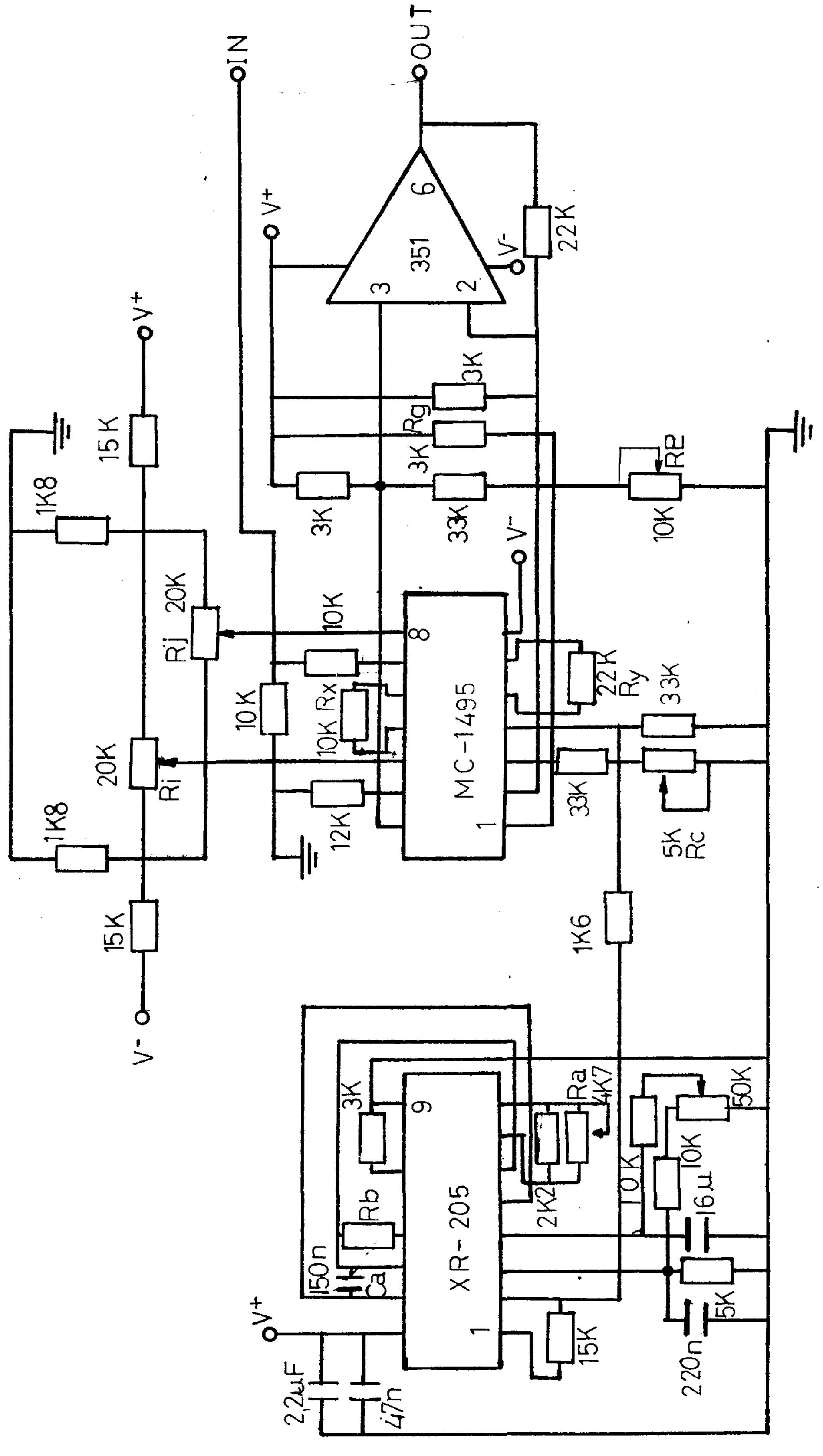


Figura (4.1)

4.1.1 CIRCUITO PROPUESTO : ASK



4.1.2 DESARROLLO PRACTICO :

La modulacion ASK la vamos a lograr mediante el conjunto formado por un generador de onda sinusoidal y un multiplicador analogico.

El XR-205 nos servira para conseguir el generador de onda sinusoidal, el cual queremos que oscile aproximadamente a 2200 Hz. La frecuencia de oscilacion es inversamente proporcional al valor del capacitor Ca, conectado entre las patillas 14 y 15. Con el circuito de barrido abierto, la frecuencia fo puede ser aproximada a:

$$fo = 400 / Ca$$

donde fo esta en Hz y Ca en uF.

Luego como queremos que oscile a 2200 Hz:

$$Ca = 400 / fo = 400 / 2200 \simeq 180 \text{ nF}.$$

Para ajustar la forma de onda de este generador hemos puesto entre las patillas 7 y 8 el potenciometro Ra, que minimiza el contenido de armonicos de la senal de salida. El ciclo de trabajo tambien puede ser ajustado mediante la resistencia Rb, entre las patillas 13 y 14. La maxima amplitud de salida es de 3 Vpp.

Con el circuito integrado MC-1495 y con un amplificador operacional (el LF-351), formamos el conjunto multiplicador analogico.

El MC-1495 es un multiplicador de cuatro cuadrantes, el cual se hace funcionar por el principio de las transconductancias.

El ancho de banda se determina principalmente por las resistencias de carga, las capacidades de salida del multiplicador y el amplificador operacional utilizado para cambiar el nivel de offset a la salida.

Si se desea un gran ancho de banda debemos poner una resistencia de carga de bajo valor y un amplificador operacional de gran ancho de banda.

Los maximos voltajes de entrada deben ser tal, que:

$V_x\ (max) < I_{13}\ R_y = 1\ mA \times 22\ K\Omega = 22\ V_{pp}$

$V_y\ (max) < I_3\ R_y = 1\ mA \times 22\ K\Omega = 22\ V_{pp}$

$I_{13} = I_3 = 1\ mA$

Si se excede de ese valor un lado del amplificador de entrada se cortara y provocara una respuesta no lineal.

El rango maximo de voltaje de salida depende de los componentes elegidos y de las tensiones de entrada, pero varia segun la relacion:

$$V_o = - K\ V_x'\ V_y'$$

Siendo V_x' e V_y' las tensiones a las entradas de los divisores de tension de las patillas 4 y 9.

$$V_x' = 2\ V_x$$

$$V_y' = V_y$$

Luego:

$$V_o = - 2K\ V_x\ V_y$$

El potenciometro Rc, es para ajustar el valor del factor de escala K.

Hemos seleccionado Rx Ry, de forma que seguremos que los transistores de entrada siempre esten en activo.

El voltaje de alimentacion, al igual que el resto de los circuitos, es de ±12V.

El voltaje en la base de los transistores Q5, Q6, Q7 y Q8 (ver hojas de datos), debe ser aproximadamente 0,7 V menor que el voltaje de la patilla 1 (que hemos fijado en 9 V con la resistencia Rg = 3KΩ). Luego para que esos transistores se mantengan en activo el voltaje en la patilla 2 y 14, debe estar aparoximadamente a la mitad, entre el voltaje de la patilla 1 y de +V, o sea aproximadamente unos 10,5 V.

El amplificador operacional puesto a la salida (el 351), debe tener bajas corrientes de compensacion (de offset), y un alto rango de voltaje de entrada en modo comun.

Para conseguir un ajuste perfecto del modulador, anulando los offset y estableciendo el factor de escala al valor deseado, debemos hacer lo siguiente:

1. Offset de la entrada X:

a) Conectar el generador (en 1 Kz y 5 Vpp de onda sinusoidal) a la entrada Y en la patilla 4.

b) Conectar la entrada X (patilla 9) a masa.

c) Ajustar el potenciometro Ri para obtener una AC nula a la salida.

2. Offset a la entrada Y:

a) Conectar el generador (en 1Kz y 5Vpp de onda sinusoidal) a la entrada X, en la patilla 9.

b) Conectar la entrada Y (patilla 4z) a masa.

c) Ajustar Rj para obtener una Ac nula a la salida.

3. Offset de salida.

a) Conectar ambas entradas X e Y a masa.

b) Ajustar Re, hasta que el voltaje Vo de salida, sea cero voltios DC.

4. Factor de escala.

a) Aplicar 10V. DC a ambas entradas X e Y.

b) Ajustar Rc hasta encontrar el valor deseado.

NOTA:

Para conseguir la modulacion ASK, la senal binaria moduladora debe ser toda positiva. O sea debe estar situada sobre el nivel de 0V de tension de offset.

4.2 MODULACION BINARIA EN FASE [PSK] :

Para que la modulacion PCM binaria sea eficiente, se deben emplear pulsos bipolares (dos pulsos de altura A/2 y -A/2) en lugar de los pulsos de altura 0 y A. Asi, en PCM bipolar, los dos simbolos se representan por S(t) y -S(t).

La modulacion binaria en fase se puede considerar como un PCM binario modulado en fase. Una forma de onda PSK tipica se ilustra en la figura (4.2).

La modulacion PSK tiene las ventajas de que la probabilidad de error por bit es pequena, y ademas se puede detectar por envolvente. Tambien tiene un ancho de banda menor que para el FSK.

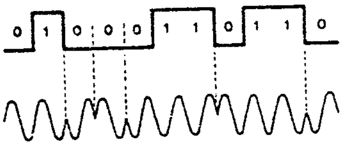
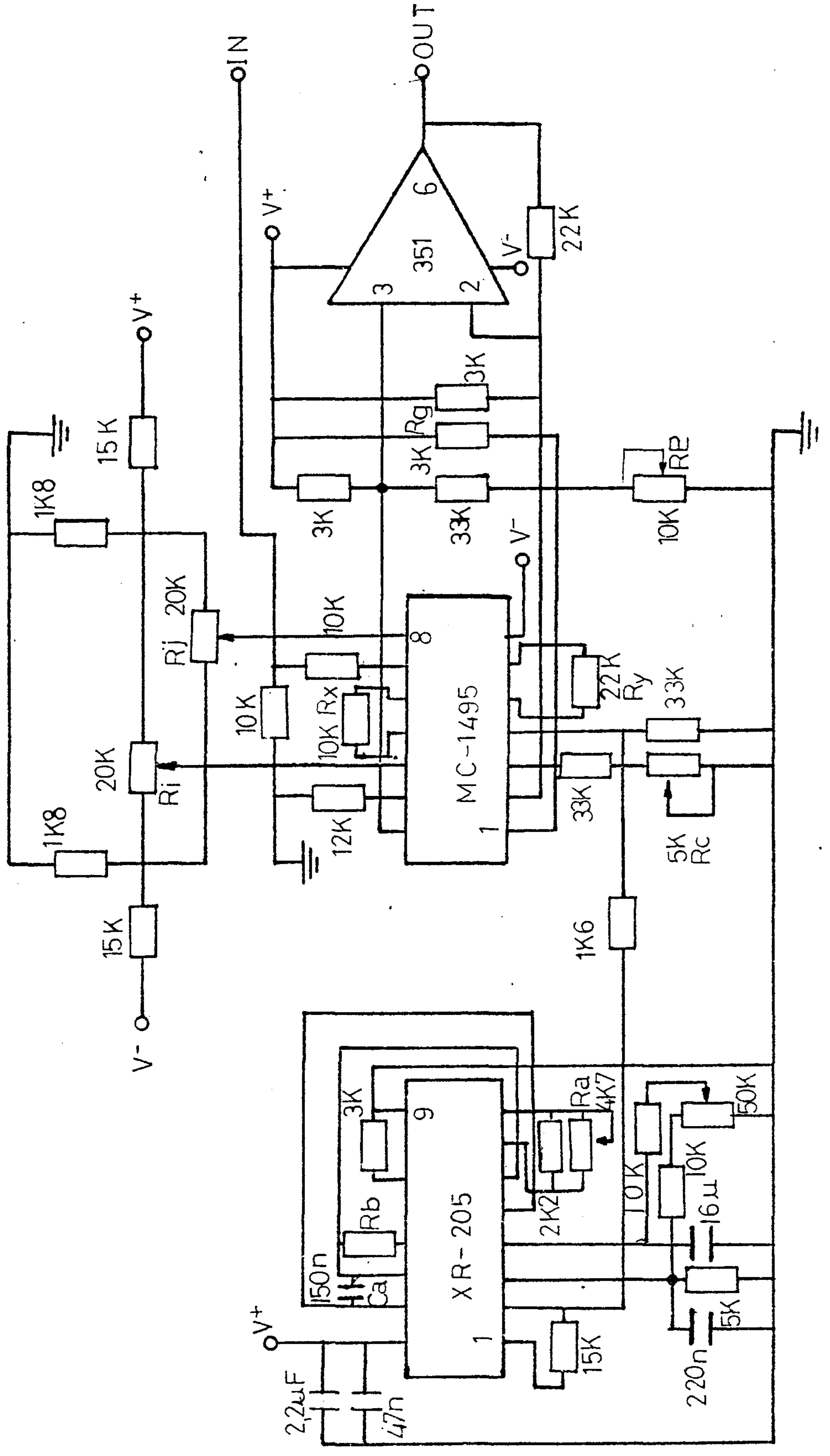


Figura (4.2)

4.2.1 CIRCUITO PROPUESTO : PSK



4.2.2 DESARROLLO PRACTICO:

Como vemos el circuito propuesto para la modulacion PSK es el mismo que para la ASK, solamente varia la senal moduladora, que en lugar de estar sobre el nivel de 0V de tension offset (toda positiva), debe situarse centrada sobre el, con lo cual su valor estara cambiando de positiva a negativa.

Al ser este circuito un multiplicador analogico, cuando la senal moduladora sea positiva, a la salida tendremos una onda sinusoidal con una fase, y cuando la senal moduladora sea negativa, a la salida tendremos la misma onda sinusoidal, pero desfasada en 180°.

Luego, obtenemos la modulacion binaria en fase ASK.

4.3 MODULACION BINARIA EN FRECUENCIA [FSK] :

La modulacion binaria en frecuencia puede considerarse como un PCM binario modulado en frecuencia. Los dos simbolos se representan por dos formas de onda, $S1(t)$ y $S2(t)$.

$S1(t) = A \, sen(m \, Wo \, t)$ para $0 < t < T$

$S1(t) = 0$ para cualquier otro punto.

Y

$S2(t) = A \, sen(n \, Wo \, t)$ para $0 < t < T$

$S2(t) = 0$ para cualquier otro punto.

en donde : $Wo = 2\pi / T$

Las dos formas de onda se ilustran en la figura (4.3).

La modulacion FSK tiene la ventaja de que la probabilidad de error por bit es pequena. Pero sin embargo tiene la desventaja de que su deteccion no puede hacerse por envolvente sino por metodos mas complicados.

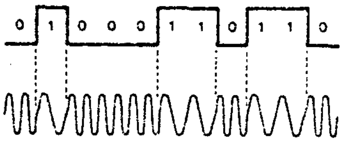
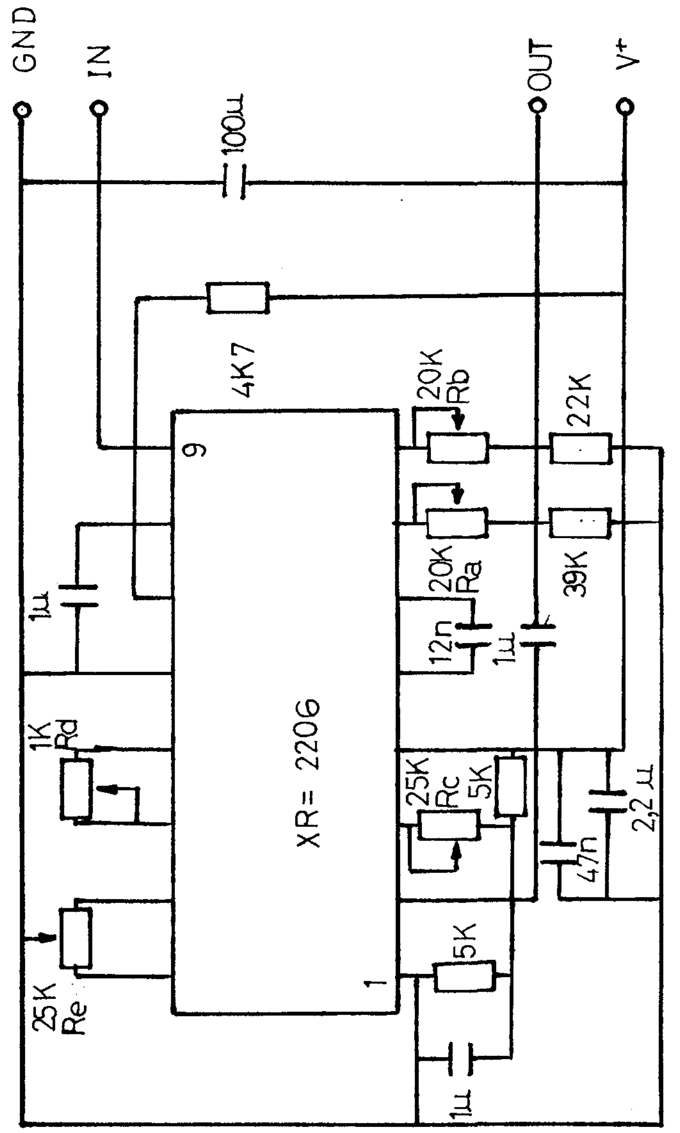


Figura (4.3)

4.3.1 CIRCUITO PROPUESTO : FSK



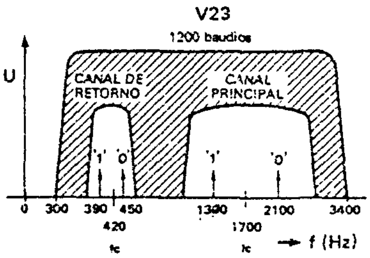
4.3.2 DESARROLLO PRACTICO:

Las lineas normales de la telefonica son de la red conmutada, asi llamada porque manejan un gran numero de puntos de conmutacion.

La banda pasante de una de esas lineas se extiende entre los 300 Hz y los 3400 Hz aproximadamente, limites que no alcanza nunca una persona por muy de prisa que hable.

Sin embargo, para un ordenador la estrechez de la banda pasante, implica una limitacion de la frecuencia de transmision (menos de 2400 Baudios). Para superar estas restricciones las companias telefonicas disponen de lineas de calidad superior que no aparecen en la red conmutada, y que permiten atender transmisiones hasta 4800 Baudios, llegando a 9600 en las especiales.

La norma V23 del C.C.I.T.T. (Consultative Committee for International Telegraph and Telephone) aconseja dos frecuencias (1200 / 75 Baudios). El canal de 75 Baudios sirve a efectos de control.



El CCITT tambien tiene la norma V21, pero dado que la V23 es la mas utilizada, vamos a tomar esta; donde los niveles altos tiene una frecuencia de 1300 Hz y los niveles bajos 2100 Hz.

El I.C. XR-2206 utilizado para producir esta modulacion FSK, ya fue tambien utilizado para generar la modulacion AM, y como alli vimos, esta compuesto por cuatro bloques funcionales: un VCO, un multiplicador analogico con generador de onda sinusoidal, un amplificador Buffer y unos conmutadores de corriente.

Su frecuencia de oscilacion es proporcional a la corriente total oscilante, sacada de las patillas 7 u 8.

$$f = 320\ It(mA) / C(uF)\ Hz.$$

Las patillas 7 y 8 son puntos de baja impedancia puestos internamente a 3 voltios con respecto a la patilla 12. La frecuencia varia linealmente con It sobre un rango de corrientes de 1 uA a 3 mA.

Hemos puesto dos potenciometro separados Raa y Rba, conectados a las patillas 7 y 8 respectivamente. Dependiendo de la polaridad de la senal logica de la patilla 9, es activa una u otra de las resistencias Ra o Rb. Si la patilla 9 esta a circuito abierto o conectada a un voltaje mayor o igual a 2V, solo se activara la Ra. Similarmente, si el nivel de voltaje de la patilla 9 es menor o igual a 1V, solo se activara Rb. De esta forma la frecuencia de salida puede ser controlada entre dos niveles, fa y fb :

$$fa = 1 / (Ra\ C) \qquad fb = 1 / (Rb\ C)$$

Como queremos que las frecuencias de oscilacion sean de 1300 Hz para los niveles altos y 2100 Hz para los bajos:

$$fa = 1 / (63K\Omega\ 12{,}2\ nF) \simeq 1300\ Hz.$$

$$fb = 1 / (39K\Omega\ 12{,}2\ nF) \simeq 2100\ Hz.$$

Luego los valores tomados son:

$$Ra = Raa + Rab = 20K\Omega + 47K\Omega$$

$$Rb = Rba + Rbb = 20K\Omega + 22K\Omega$$

$$C = 12{,}2\ nF.$$

El nivel de DC en la salida (patilla 2) es aproximadamente el mismo que el de la patilla 3. En este caso particular la patilla 3 la hemos puesto a la mitad de V+ (6V.), luego a la salida tendremos 6V de DC.

La amplitud de la salida puede variarse, porque es inversamente proporcional a la resistencia externa Rc conectada a la patilla 3. Para salidas de onda sinusoidal la amplitud es aproximadamente de 60 mV de pico por KΩ de Rc.

Para mejorar la calidad de la senal de salida hemos puesto los potenciometros Rd y Re. El Re, ajusta la forma de onda, y Rd pruduce el ajuste fino de la simetria. Los ajustes los debemos hacer de la siguiente forma:

a) Ponemos Rd a la mitad y ajustamos Re para la minima distorsion.

b) Con Re ajustada, ajustamos Rd hasta reducir aun mas la distorsion.

NOTA:

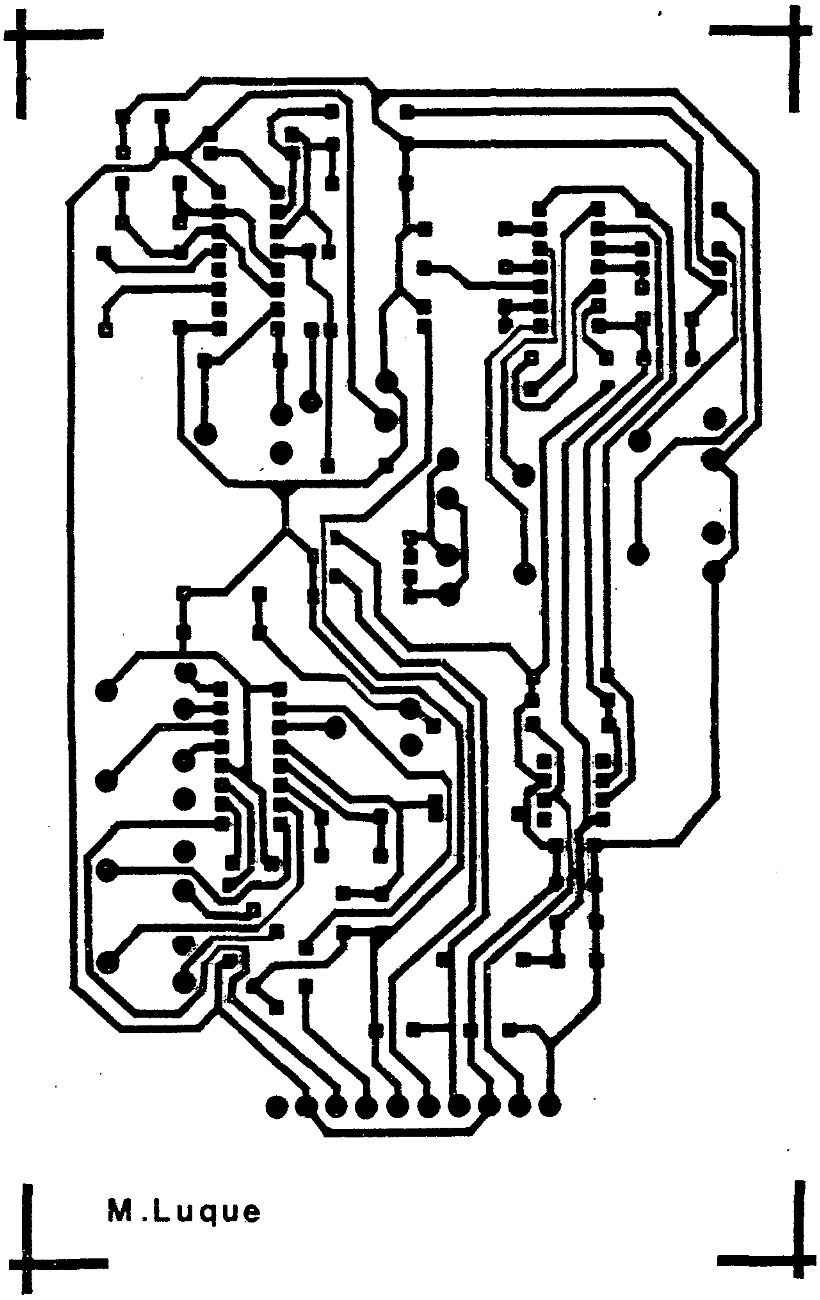
La senal moduladora no debe tener menos de 2Vpp ni mas de 5Vpp.

El nivel de tesion de offset debe estar entre 0V y 1V.

Variando Rc podemos hacer que la amplitud de la salida varie entre 0Vpp y 3Vpp.

La impedancia de salida es de 600Ω.

4.4 MECANORMA ASK, PSK, FSK :



XR-205

1

Monolithic Waveform Generator

GENERAL DESCRIPTION

The XR-205 is a highly versatile, monolithic waveform generator designed for diverse applications in communication and telemetry equipment, as well as in systems design and testing. It is a self-contained, totally monolithic signal generator that provides sine, square, triangle, ramp and sawtooth output waveforms, which can be both amplitude and frequency modulated.

The functional block diagram of the monolithic waveform generator is shown below. The circuit has three separate sections: a voltage-controlled oscillator (VCO) which generates the basic periodic waveforms; a balance modulator which provides amplitude or phase modulation; a buffer amplifier section which provides a low impedance output with high current drive capability.

APPLICATIONS

Waveform Generation

Sinewave	Sawtooth
Triangle	Ramp
Square	Pulse

AM Generation Double Sideband Suppressed Carrier

Crystal-Controlled

FM Generation

Sweep Generation

Tone Burst Generation

Simultaneous AM/FM

Frequency-Shift Keyed (FSK) Signal Generation

Phase-Shift Keyed (PSK) Signal Generation

On-Off Keyed Oscillation

Clock Generation

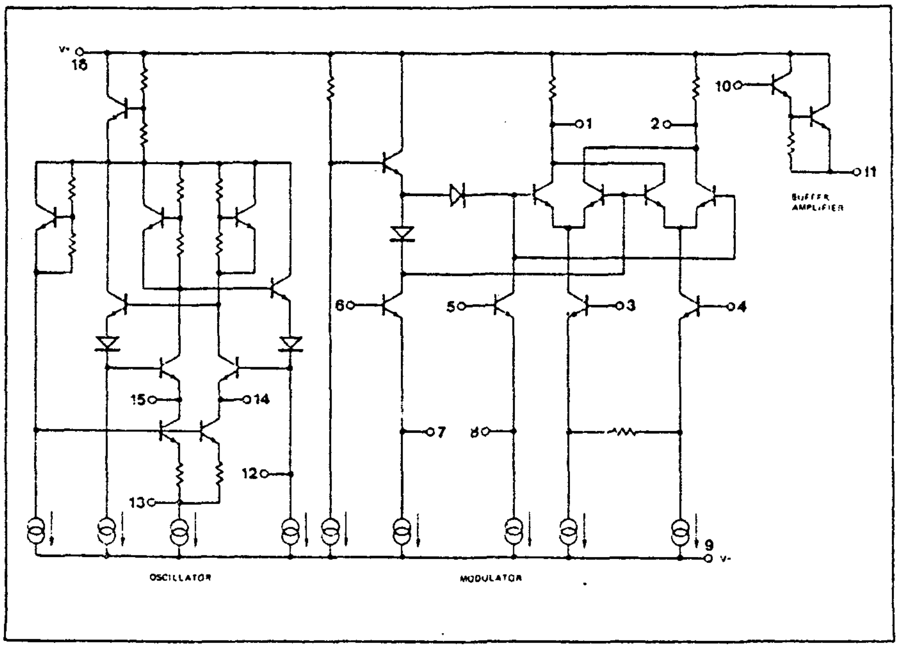
ABSOLUTE MAXIMUM RATINGS

Power Supply	26 volts
Power Dissipation	750 mW
Derate above +25°C	6 mW/°C
Temperature	
Storage	-65°C to +150°C

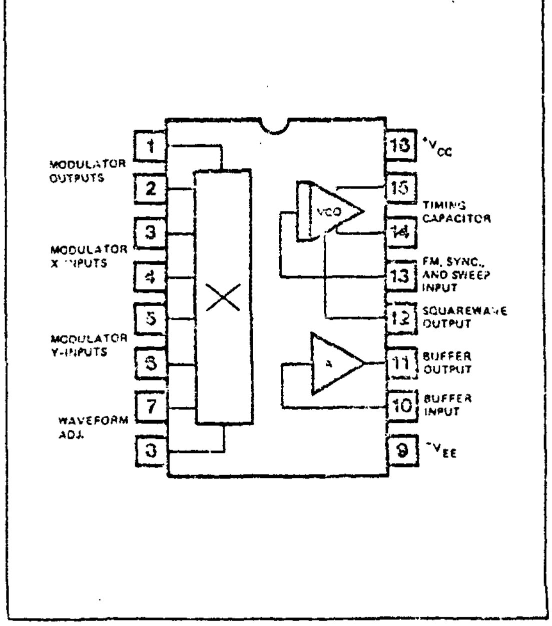
AVAILABLE TYPES

Part Number	Package Type	Operating Temperature Range
XR-205	Ceramic	0°C to +75°C

EQUIVALENT SCHEMATIC DIAGRAM



FUNCTIONAL BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

Test Conditions: Supply Voltage = 12V (single supply) $T_A = 25°C$, f = 10 kHz, $R_L = 3\ k\Omega$, unless otherwise specified.

CHARACTERISTICS	LIMITS			UNITS	CONDITIONS
	MIN.	TYP.	MAX.		
I — General Characteristics					
Supply Voltage:					
Single Supply	8		26	Vdc	See Figure 1
Split Supply	±5		±13	Vdc	See Figures 2 and 3
Supply Current	8	10	12	mA	w/o buffer amp
Frequency Stability:					
Power Supply		0.2	0.5	%/V	$\lvert V_{CC} - V_{EE} \rvert > 10V$
Temperature		300	600	ppm/°C	Sweep input open circuit
Frequency Sweep Range	7:1	10:1			See Figure 7
Output Swing:					
Single Ended	2	3		Vpp	Measured at pin 1 or 2
Differential	4	6		Vpp	Measured across 1 and 2
Output Diff. Offset Voltage		0.1	0.4	Vdc	Measured across 1 and 2
Amplitude Control Range		60		dB	Controlled by R_q (see Figure 1)
Buffer Amplifier Output Resistance		50		ohms	$R_L = 750\Omega$
Output Current Swing	±6	±10		mA	
II — Output Waveforms					
Sinusoidal:					
Upper Frequency Limit	2	4		MHz	Measured at Pin 11
Peak Output Swing	2	3		Vpp	S_1, S_3 closed, S_2 open
Distortion (THD)		2.5	4	%	closed S_2 open
Triangle:					
Peak Swing	2	4		Vpp	Measured at Pin 11
Non-Linearity		±1		%	S_1, S_2 open, S_3 closed
Asymmetry		±1		%	f = 10 kHz
Sawtooth:					
Peak Swing	2	3		Vpp	See Figure 1, S_2 closed;
Non-Linearity		1.5		%	S_2 and S_3 closed
Ramp:					
Peak-Swing	1	1.4		Vpp	See Figure 1, S_2 and S_3 open
Non-Linearity		1		%	pin 10 shorted to pin 15
Squarewave (Low Level):					
Output Swing	0.5	0.7		Vpp	See Figure 1, S_2 and S_3 open,
Duty Cycle Asymmetry		±1	±4	%	pin 10 shorted to pin 12
Rise Time		20		ns	10 pF connected from pin 11
Fall Time		20		ns	to ground
Squarewave (High Level):					
Peak Swing	2	3		Vpp	See Figure 3, S_2 open
Duty Cycle Asymmetry		±1	±4	%	
Rise Time		80		ns	10 pF connected from pin 11
Fall Time		60		ns	to ground
Pulse Output:	2	3		Vpp	See Figure 3, S_2 closed
Peak Swing	2	3		Vpp	See Figure 3, S_2 closed
Rise Time		80		ns	
Fall Time		60		ns	
Duty Cycle Range		20-80		%	Adjustable (see Figure 6)
III — Modulation Characteristics (sine, triangle and squarewave):					
Amplitude Modulation:					
Double Sideband					
Modulation Range		0-100		%	See Figure 2
Linearity		0.5		%	for 30% modulation
Sideband Symmetry		1.0		%	
Suppressed Carrier					
Carrier Suppression		52		dB	f < 1 MHz
Frequency Modulation:					
Distortion		0.3		%	See Figure 2 (±10 frequency deviation)

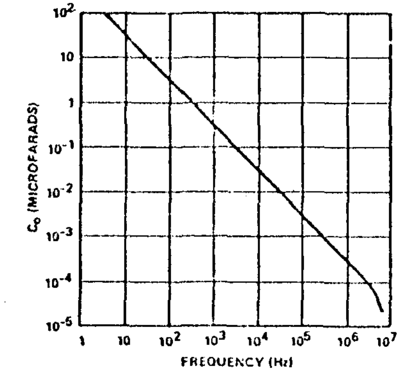


Figure 4. Frequency as a Function of C_O Across Pins 14 and 15

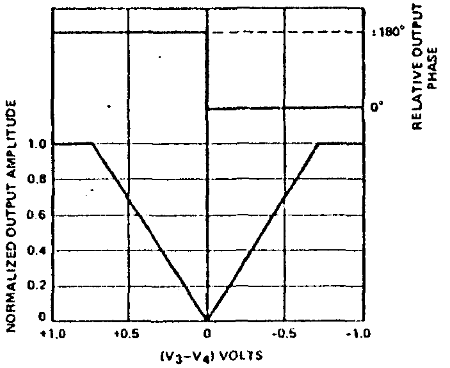


Figure 5. Modulator Section Phase and Amplitude Transfer Characteristics

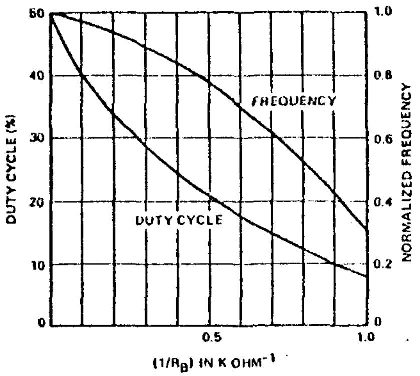


Figure 6. Duty-Cycle and Frequency Variation as a Function of Resistor R_B Connected Across Pins 13 and 14

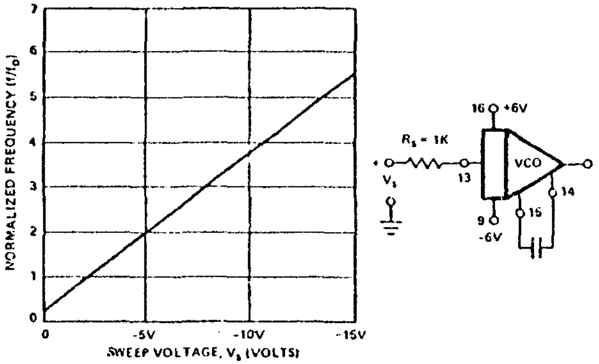


Figure 7. Normalized Frequency vs. Sweep Voltage

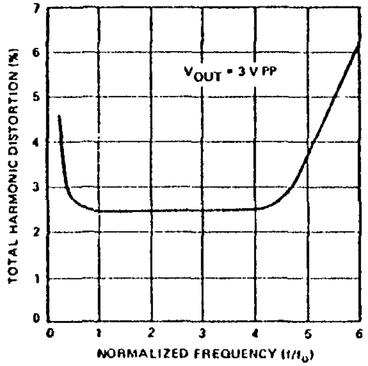


Figure 8. Sinusoidal Output Distorition as a Function of Frequency Sweep

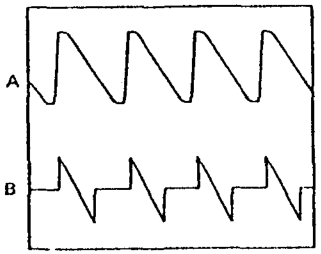


Figure 9. Sinusoidal Sawtooth and Linear Ramp Outputs

ORDERING INFORMATION

Device	Temperature Range	Package
MC1495L	0°C to +70°C	Ceramic DIP
MC1595L	−55°C to +125°C	Ceramic DIP

MC1495L
MC1595L

Specifications and Applications Information

WIDEBAND MONOLITHIC FOUR-QUADRANT MULTIPLIER

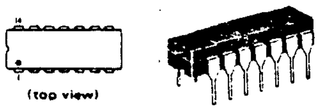
. . . designed for uses where the output is a linear product of two input voltages. Maximum versatility is assured by allowing the user to select the level shift method. Typical applications include: multiply, divide*, square root*, mean square*, phase detector, frequency doubler, balanced modulator/demodulator, electronic gain control.

*When used with an operational amplifier.

- Wide Bandwidth
- Excellent Linearity – 1% max Error on X-Input, 2% max Error on Y-Input – MC1595L
- Excellent Linearity – 2% max Error on X-Input, 4% max Error on Y-Input – MC1495L
- Adjustable Scale Factor, K
- Excellent Temperature Stability
- Wide Input Voltage Range – ± 10 Volts
- ± 15 Volt Operation

LINEAR FOUR-QUADRANT MULTIPLIER INTEGRATED CIRCUIT

MONOLITHIC SILICON
EPITAXIAL PASSIVATED



CERAMIC PACKAGE
CASE 632
TO-116

FIGURE 1 – FOUR-QUADRANT MULTIPLIER TRANSFER CHARACTERISTIC

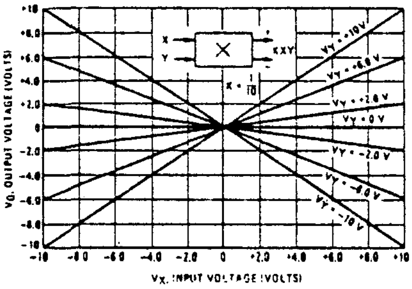


FIGURE 2 – TRANSCONDUCTANCE BANDWIDTH

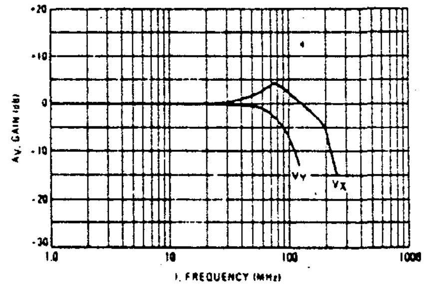
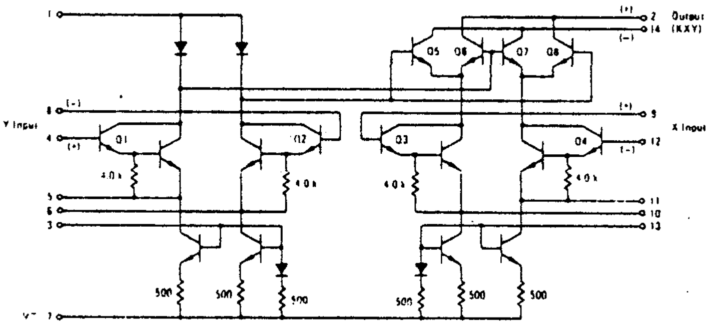


FIGURE 3 – CIRCUIT SCHEMATIC



ELECTRICAL CHARACTERISTICS ($V^+ = +32V$, $V^- = -15$ V, $T_A = +25°C$, $I_3 = I_{13} = 1$ mA, $R_X = R_Y = 15$ kΩ, $R_L = 11$ kΩ unless otherwise noted)

Characteristic		Figure	Symbol	Min	Typ	Max	Unit
Linearity:							
Output Error in Percent of Full Scale:		5					%
$T_A = +25°C$							
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)	MC1495		E_{RX}	–	± 1.0	± 2.0	
	MC1595			–	± 0.5	± 1.0	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)	MC1495		E_{RY}	–	± 2.0	± 4.0	
	MC1595			–	± 1.0	± 2.0	
$T_A = 0$ to $+70°C$	MC1495						
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)			E_{RX}	–	± 1.5	–	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)			E_{RY}	–	± 3.0	–	
$T_A = -55°C$ to $+125°C$	MC1595						
$-10 < V_X < +10$ ($V_Y = \pm 10$ V)			E_{RX}	–	± 0.75	–	
$-10 < V_Y < +10$ ($V_X = \pm 10$ V)			E_{RY}	–	± 1.50	–	
Squaring Mode Error: Accuracy in Percent of Full Scale After Offset and Scale Factor Adjustment		5	E_{SQ}				%
$T_A = +25°C$	MC1495			–	± 0.75	–	
	MC1595			–	± 0.5	–	
$T_A = 0$ to $+70°C$	MC1495			–	± 1.0	–	
$T_A = -55°C$ to $+125°C$	MC1595				± 0.75		
Scale Factor (Adjustable) $\left(K = \frac{2R_L}{I_3 R_X R_Y}\right)$		–	K		0.1	–	–
Input Resistance (f = 20 Hz)	MC1495	7	R_{INX}	–	20	–	MegOhms
	MC1595			–	35	–	
	MC1495		R_{INY}	-	20	–	
	MC1595			-	35	–	
Differential Output Resistance (f = 20 Hz)		8	R_O	-	300	–	k Ohms
Input Bias Current $I_{bx} = \frac{(I_9 + I_{12})}{2}$, $I_{by} = \frac{(I_4 + I_8)}{2}$	MC1495	6	I_{bx}	-	2.0	12	µA
	MC1595			–	2.0	8.0	
	MC1495		I_{by}	–	2.0	12	
	MC1595			–	2.0	8.0	
Input Offset Current $\|I_9 - I_{12}\|$	MC1495	6	$\|I_{iox}\|$	–	0.4	2.0	µA
	MC1595			–	0.2	1.0	
$\|I_4 - I_8\|$	MC1495		$\|I_{ioy}\|$	-	0.4	2.0	
	MC1595			-	0.2	1.0	
Average Temperature Coefficient of Input Offset Current		6	$\|TC_{Iio}\|$				nA/°C
($T_A = 0$ to $+70°C$)	MC1495			–	2.0	–	
($T_A = -55°C$ to $+125°C$)	MC1595			–	2.0	–	
Output Offset Current $\|I_{14} - I_2\|$		6	$\|I_{oo}\|$				µA
	MC1495			–	20	100	
	MC1595			-	10	50	
Average Temperature Coefficient of Output Offset Current		6	$\|TC_{Ioo}\|$				nA/°C
($T_A = 0$ to $+70°C$)	MC1495			–	1.0	-	
($T_A = -55°C$ to $+125°C$)	MC1595			-	1.0	–	
Frequency Response							
3.0 dB Bandwidth, $R_L = 11$ kΩ		9,10	BW_{3dB}	–	3.0	–	MHz
3.0 dB Bandwidth, $R_L = 50$ Ω (Transconductance Bandwidth)			$T_{BW3\,dB}$	–	80	–	MHz
3° Relative Phase Shift Between V_X and V_Y			f_ϕ	–	750	-	kHz
1% Absolute Error Due to Input-Output Phase Shift			f_θ	–	30	–	kHz
Common Mode Input Swing (Either Input)		11	CMV				Vdc
	MC1495			±10.5	±12	–	
	MC1595			±11.5	±13	–	
Common Mode Gain (Either Input)		11	A_{CM}				dB
	MC1495			-40	-50	–	
	MC1595			-50	-60	–	
Common Mode Quiescent Output Voltage		12	V_{o1}	–	21	–	Vdc
			V_{o2}	–	21	–	
Differential Output Voltage Swing Capability		9	V_O	–	±14	–	V_{peak}
Power Supply Sensitivity		12	S^+	–	5.0	–	mV/V
			S^-	–	10	–	
Power Supply Current		12	I_7	–	6.0	7.0	mA
DC Power Dissipation		12	P_D	–	135	170	mW

TYPICAL CHARACTERISTICS

FIGURE 15 – LINEARITY versus TEMPERATURE

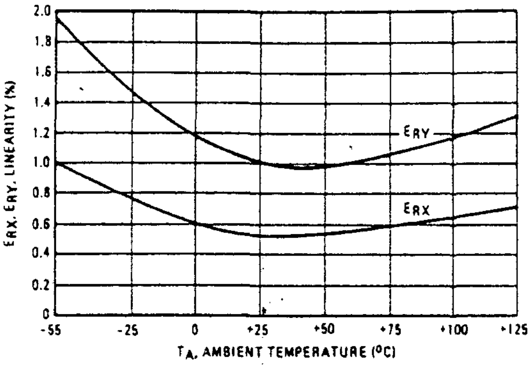


FIGURE 16 – SCALE FACTOR versus TEMPERATURE

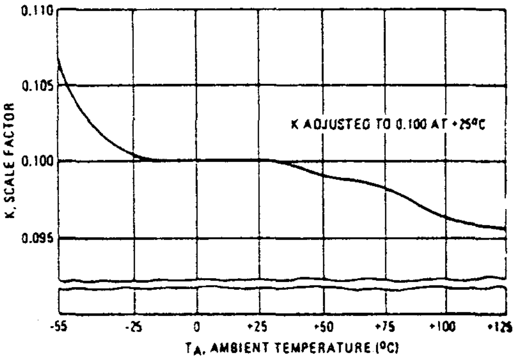


FIGURE 17 – ERROR CONTRIBUTED BY INPUT DIFFERENTIAL AMPLIFIER

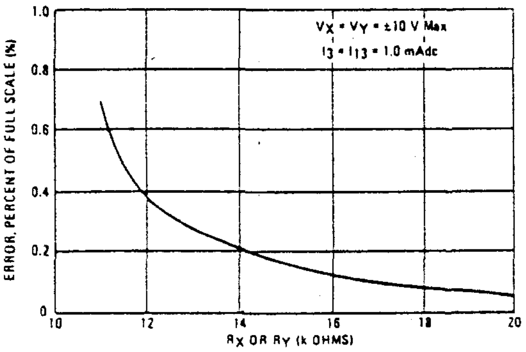


FIGURE 18 – ERROR CONTRIBUTED BY INPUT DIFFERENTIAL AMPLIFIER

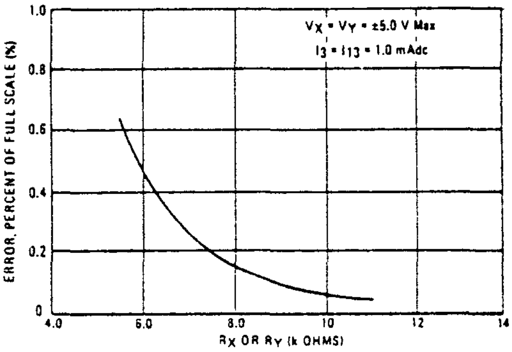
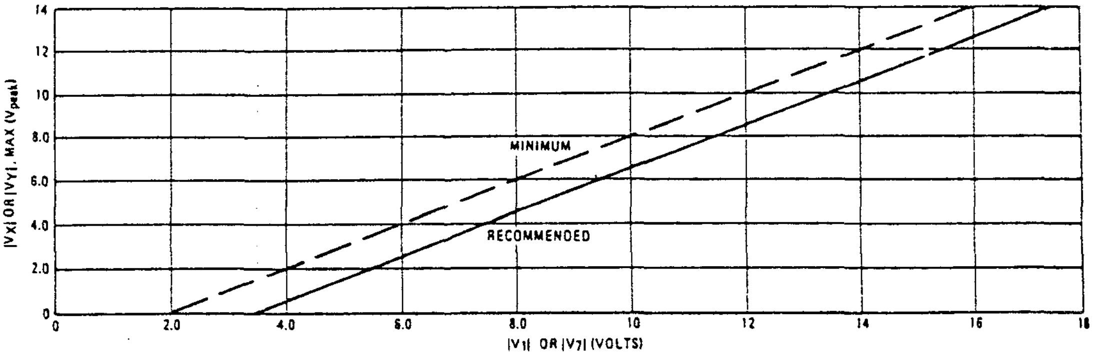


FIGURE 19 – MAXIMUM ALLOWABLE INPUT VOLTAGE versus VOLTAGE AT PIN 1 OR PIN 7

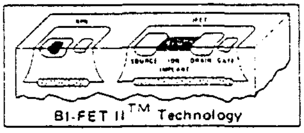


MAXIMUM RATINGS (T_A = +25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Applied Voltage (V_2-V_1, $V_{14}-V_1$, V_1-V_9, V_1-V_{12}, V_1-V_4, V_1-V_8, $V_{12}-V_7$, V_9-V_7, V_8-V_7, V_4-V_7)	ΔV	30	Vdc
Differential Input Signal	$V_{12}-V_9$ V_4-V_8	$\pm(6+I_{13}R_X)$ $\pm(6+I_3R_Y)$	Vdc Vdc
Maximum Bias Current	I_3 I_{13}	10 10	mA
Power Dissipation (Package Limitation) Ceramic Package Derate above T_A = +25°C	P_D	750 5.0	mW mW/°C
Operating Temperature Range	T_A		°C
MC1495		0 to +70	°C
MC1585		-55 to +125	
Storage Temperature Range	T_{stg}	-65 to +150	°C

National Semiconductor

Operational Amplifiers/Buffers



LF351 Wide Bandwidth JFET Input Operational Amplifier

General Description

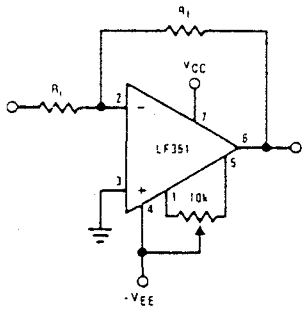
The LF351 is a low cost high speed JFET input operational amplifier with an internally trimmed input offset voltage (BI-FET II™ technology). The device requires a low supply current and yet maintains a large gain bandwidth product and a fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF351 is pin compatible with the standard LM741 and uses the same offset voltage adjustment circuitry. This feature allows designers to immediately upgrade the overall performance of existing LM741 designs.

The LF351 may be used in applications such as high speed integrators, fast D/A converters, sample-and-hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The device has low noise and offset voltage drift, but for applications where these requirements are critical, the LF356 is recommended. If maximum supply current is important, however, the LF351 is the better choice.

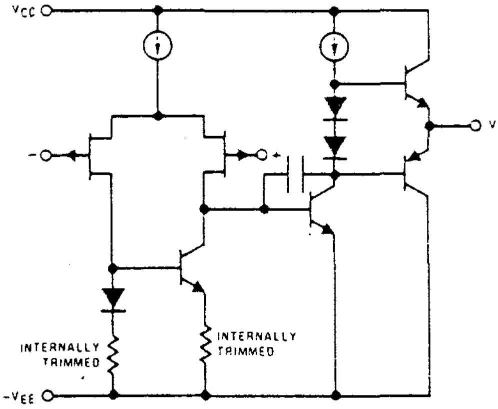
Features

■ Internally trimmed offset voltage	10 mV
■ Low input bias current	50 pA
■ Low input noise voltage	16 nV/√Hz
■ Low input noise current	0.01 pA/√Hz
■ Wide gain bandwidth	4 MHz
■ High slew rate	13 V/µs
■ Low supply current	1.8 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20\,Vp\text{-}p$, BW = 20 Hz-20 kHz	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01%	2 µs

Typical Connection

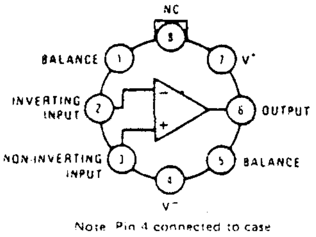


Simplified Schematic



Connection Diagrams (Top Views)

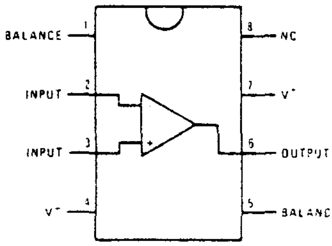
Metal Can Package



Note: Pin 4 connected to case

Order Number LF351H
See NS Package H08C

Dual-In-Line Package



Order Number LF351N
See NS Package N08A

Absolute Maximum Ratings

Supply Voltage	±18V
Power Dissipation (Note 1)	500 mW
Operating Temperature Range	0 °C to +70 °C
$T_{j(MAX)}$	115 °C
Differential Input Voltage	±30V
Input Voltage Range (Note 2)	±15V
Output Short Circuit Duration	Continuous
Storage Temperature Range	−65 °C to +150 °C
Lead Temperature (Soldering, 10 seconds)	300 °C

DC Electrical Characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF351			UNITS
			MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 10\,k\Omega$; $T_A = 25\,°C$		5	10	mV
		Over Temperature			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10\,k\Omega$		10		µV/°C
I_{OS}	Input Offset Current	$T_j = 25\,°C$, (Notes 3, 4)		25	100	pA
		$T_j \leq 70\,°C$			4	nA
I_B	Input Bias Current	$T_j = 25\,°C$, (Notes 3, 4)		50	200	pA
		$T_j \leq 70\,°C$			8	nA
R_{IN}	Input Resistance	$T_j = 25\,°C$		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 15V$, $T_A = 25\,°C$ $V_O = \pm 10V$, $R_L = 2\,k\Omega$	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\,k\Omega$	±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm 15V$	±11	+15 −12		V V
CMRR	Common-Mode Rejection Ratio	$R_S \leq 10\,k\Omega$	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 5)	70	100		dB
I_S	Supply Current			1.8	3.4	mA

AC Electrical Characteristics (Note 3)

SYMBOL	PARAMETER	CONDITIONS	LF351			UNITS
			MIN	TYP	MAX	
SR	Slew Rate	$V_S = \pm 15V$, $T_A = 25\,°C$		13		V/µs
GBW	Gain Bandwidth Product	$V_S = \pm 15V$, $T_A = 25\,°C$		4		MHz
e_n	Equivalent Input Noise Voltage	$T_A = 25\,°C$, $R_S = 100\Omega$, $f = 1000\,Hz$		16		$nV/\sqrt{Hz}$
i_n	Equivalent Input Noise Current	$T_j = 25\,°C$, $f = 1000\,Hz$		0.01		$pA/\sqrt{Hz}$

Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 150 °C/W junction to ambient or 45 °C/W junction to case.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

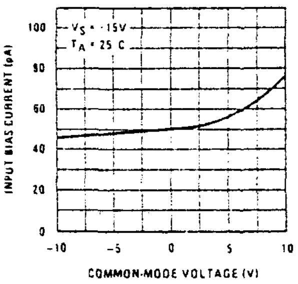
Note 3: These specifications apply for $V_S = \pm 15V$ and $0\,°C \leq T_A \leq +70\,°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

Note 4: The input bias currents are junction leakage currents which approximately double for every 10 °C increase in the junction temperature, T_j. Due to the limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \theta_{jA} P_D$ where θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

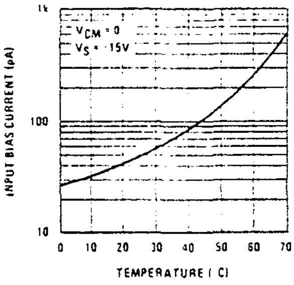
Note 5.: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

Typical Performance Characteristics

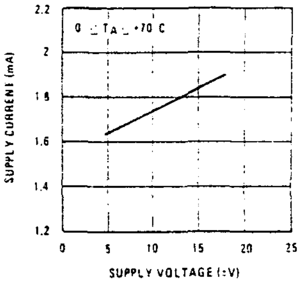
Input Bias Current



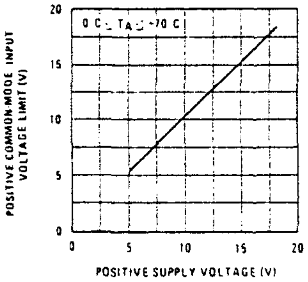
Input Bias Current



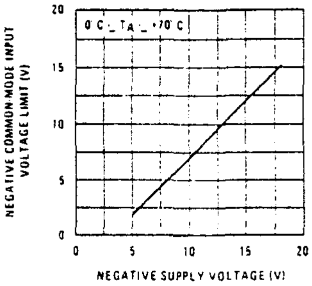
Supply Current



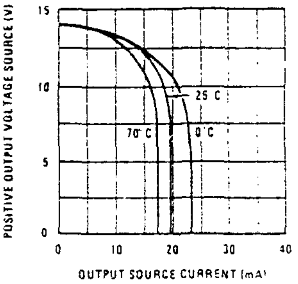
Positive Common-Mode Input Voltage Limit



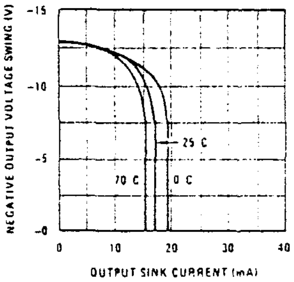
Negative Common-Mode Input Voltage Limit



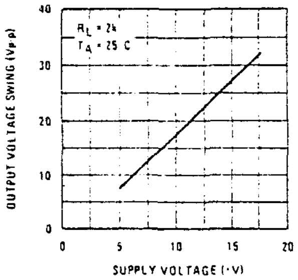
Positive Current Limit



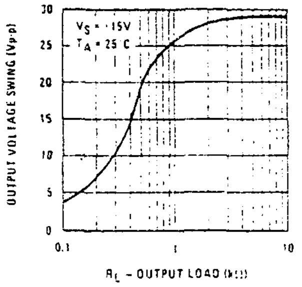
Negative Current Limit



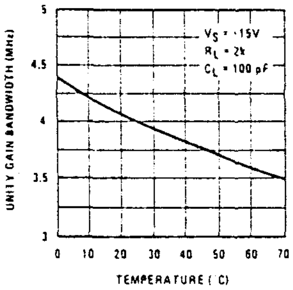
Voltage Swing



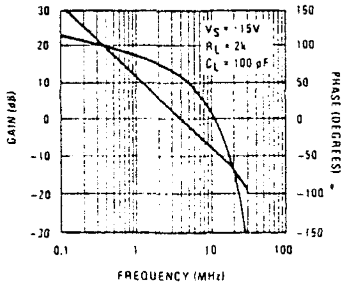
Output Voltage Swing



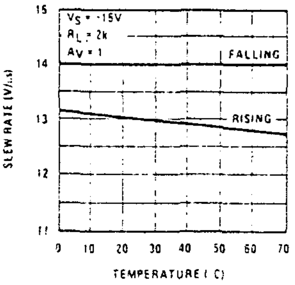
Gain Bandwidth



Bode Plot

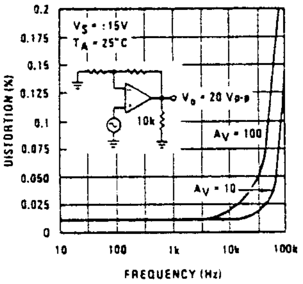


Slew Rate

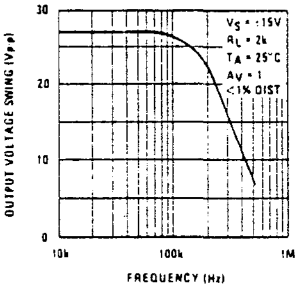


Typical Performance Characteristics (Continued)

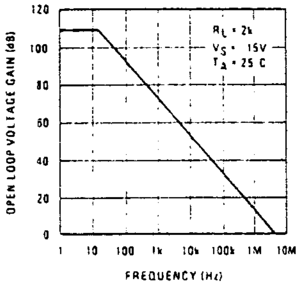
Distortion vs Frequency



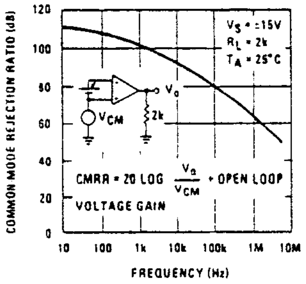
Undistorted Output Voltage Swing



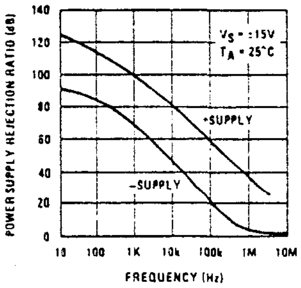
Open Loop Frequency Response



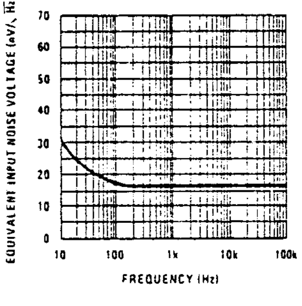
Common-Mode Rejection Ratio



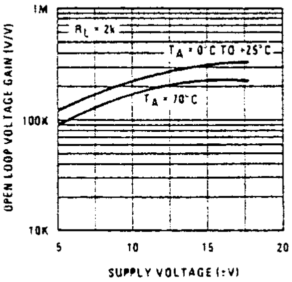
Power Supply Rejection Ratio



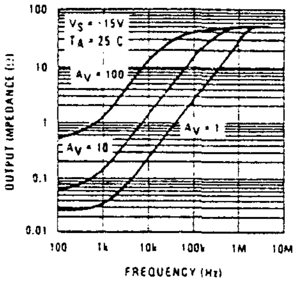
Equivalent Input Noise Voltage



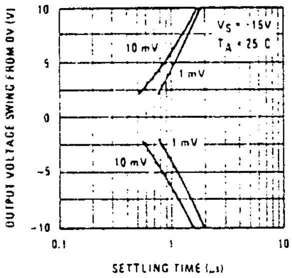
Open Loop Voltage Gain (V/V)



Output Impedance

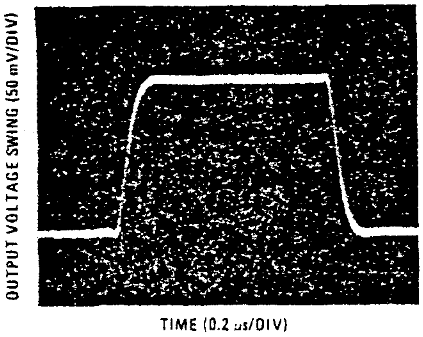


Inverter Settling Time

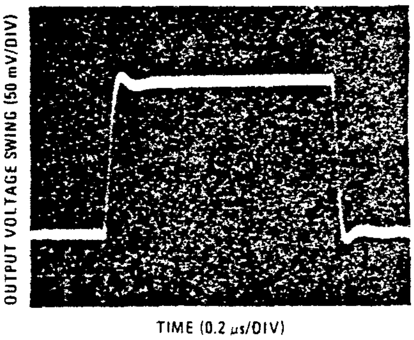


Pulse Response

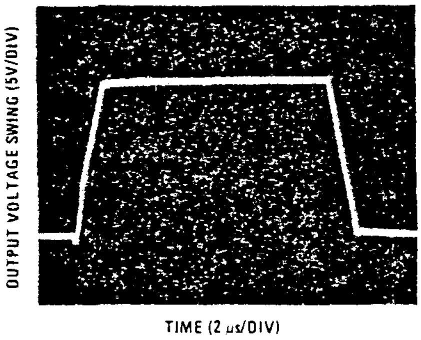
Small Signal Inverting



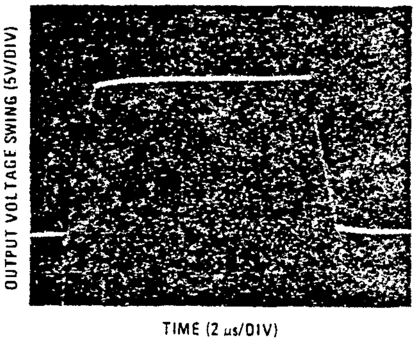
Small Signal Non-Inverting



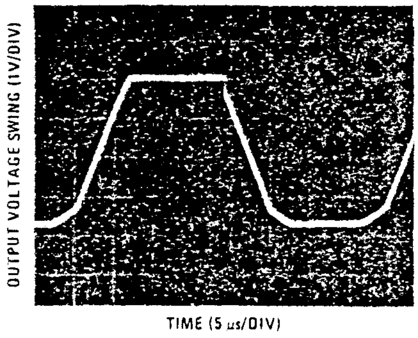
Large Signal Inverting



Large Signal Non-Inverting



Current Limit (R_L = 100Ω)



Application Hints

The LF351 is an op amp with an internally trimmed input offset voltage and JFET input devices (BI-FET II™). These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore, large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will cause a reversal of the phase to the output and force the amplifier output to the corresponding high or low state. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a

Application Hints (Continued)

high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

The amplifier will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

The LF351 is biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The LF351 will drive a 2 kΩ load resistance to ±10V over the full temperature range of 0°C to +70°C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

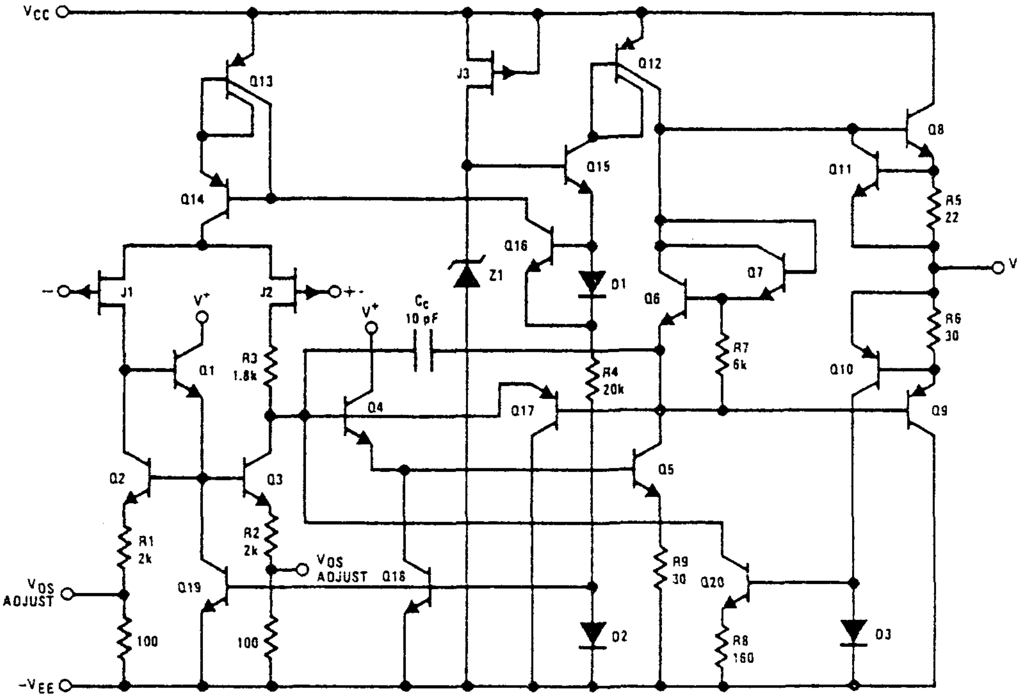
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

Detailed Schematic



XR-2206

Monolithic Function Generator

The XR-2206 is a monolithic function generator integrated circuit capable of producing high quality sine, square, triangle, ramp and pulse waveforms of high stability and accuracy. The output waveforms can be both amplitude and frequency modulated by an external voltage. Frequency of operation can be selected externally over a range of 0.01 Hz to more than 1 MHz.

The XR-2206 is ideally suited for communications, instrumentation, and function generator applications requiring sinusoidal tone, AM, FM or FSK generation. It has a typical drift specification of 20 ppm/°C. The oscillator frequency can be linearly swept over a 2000: 1 frequency range with an external control voltage with very little affect on distortion.

As shown in Figure 1, the monolithic circuit is comprised of four functional blocks: a voltage-controlled oscillator (VCO); an analog multiplier and sine-shaper; a unity gain buffer amplifier; and a set of current switches. The internal current switches transfer the oscillator current to any one of the two external timing resistors to produce two discrete frequencies selected by the logic level at the FSK input terminal (pin 9).

FEATURES

Low Sinewave Distortion (THD .5%) –
insensitive to signal sweep
Excellent Stability (20 ppm/°C, typ)
Wide Sweep Range (2000:1, typ)
Low Supply Sensitivity (0.01%/V, typ)
Linear Amplitude Modulation
Adjustable Duty-Cycle (1% to 99%)
TTL Compatible FSK Controls
Wide Supply Range (10V to 26V)

APPLICATIONS

Waveform Generation
Sine, Square, Triangle, Ramp
Sweep Generation
AM/FM Generation
FSK and PSK Generation
Voltage-to-Frequency Conversion
Tone Generation
Phase-Locked Loops

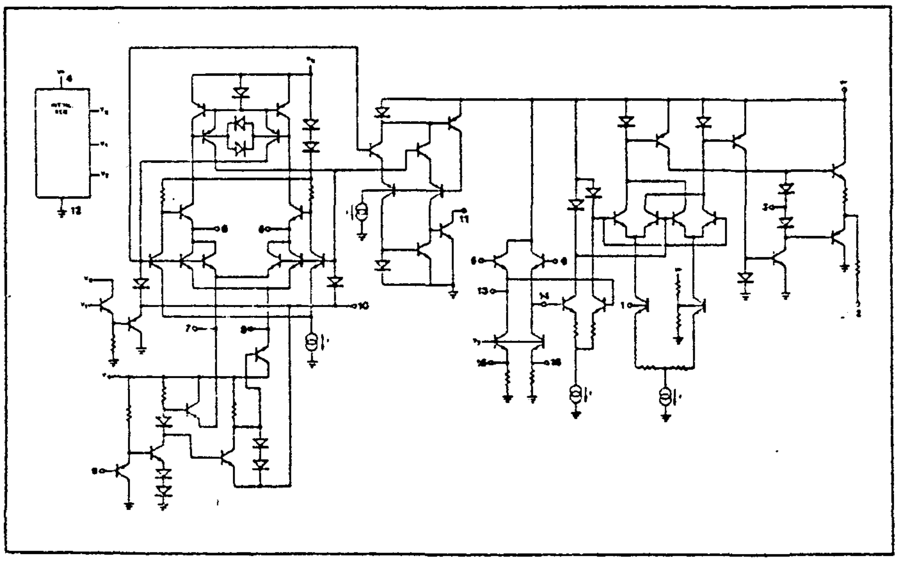
ABSOLUTE MAXIMUM RATINGS

Power Supply	26V
Power Dissipation (package limitation)	
Ceramic package	750 mW
Derate above +25°C	6.0 mW/°C
Plastic package	625 mW
Derate above +25°C	5 mW/°C
Storage Temperature Range	-65°C to +150°C

AVAILABLE TYPES

Part Number	Package Types	Operating Temperature Range
XR-2206M	Ceramic	–55°C to +125°C
XR-2206N	Ceramic	0°C to +75°C
XR-2206P	Plastic	0°C to +75°C
XR-2206CN	Ceramic	0°C to +75°C
XR-2206CP	Plastic	0°C to +75°C

EQUIVALENT SCHEMATIC DIAGRAM



FUNCTIONAL BLOCK DIAGRAM

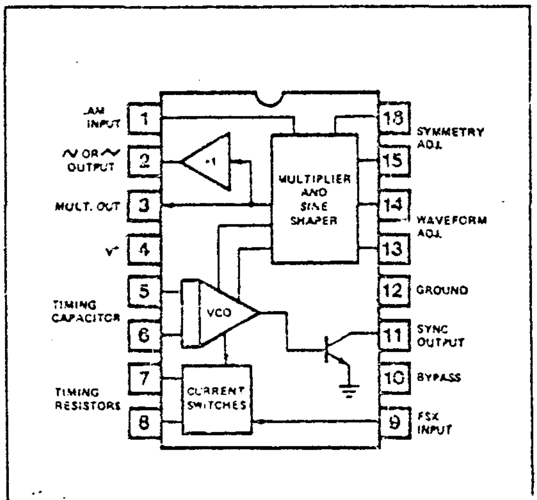


Figure 1.

ELECTRICAL CHARACTERISTICS

Test Conditions: Test Circuit of Fig. 2, $V^+ = 12V$, $T_A = 25°C$, $C = 0.01\ \mu F$, $R_1 = 100\ K\Omega$, $R_2 = 10\ K\Omega$ $R_3 = 25\ K\Omega$ unless otherwise specified. S_1 open for triangle, closed for sinewave.

CHARACTERISTICS	XR-2206/XR-2206M			XR-2206C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
Supply Voltage								
Single Supply	10		26	10		26	V	
Split Supply	±5		±13	±5		±13	V	
Supply Current		12	17		14	20	mA	$R_1 \geq 10\ K\Omega$
Oscillator Section								
Max. Operating Frequency	0.5	1		0.5	1		MHz	C=1000 pF, R_1=1 KΩ
Lowest Practical Frequency		0.01			0.01		Hz	C=50 μF, R_1=2 MΩ
Frequency Accuracy		±1	±4		±2		% of f_o	$f_o = 1/R_1C$
Temperature Stability		±10	±50		±20		ppm/°C	$0°C \leq T_A \leq 75°C$, $R_1 = R_2 = 20\ K\Omega$
Supply Sensitivity		0.01	0.1		0.01		%/V	V_{LOW} = 10V, V_{HIGH} = 20V, $R_1 = R_2 = 20\ K\Omega$
Sweep Range	1000:1	2000:1			2000:1		$f_H = f_L$	f_H @ R_1 = 1 KΩ f_L @ R_1 = 2 MΩ
Sweep Linearity								
10:1 Sweep		2			2		%	f_L = 1 kHz, f_H = 10 kHz
1000:1 Sweep		8			8		%	f_L = 100 Hz, f_H = 100 kHz
FM Distortion		0.1			0.1		%	±10% Deviation
Recommended Timing Components								
Timing Capacitor: C	0.001		100	0.001		100	μF	See Figure 5
Timing Resistors: R_1 & R_2	1		2000	1		2000	KΩ	
Triangle/Sinewave Output								See Note 1, Fig. 3
Triangle Amplitude		160			160		mV/KΩ	Fig. 2 S_1 Open
Sinewave Amplitude	40	60	80		60		mV/KΩ	Fig. 2 S_1 Closed
Max. Output Swing		6			6		Vpp	
Output Impedance		600			600		Ω	
Triangle Linearity		1			1		%	
Amplitude Stability		0.5			0.5		dB	For 1000:1 Sweep
Sinewave Amplitude Stability		-4800			-4800		ppm/°C	See Note 2
Sinewave Distortion								R_1 = 30 KΩ
Without Adjustment		2.5			2.5		%	See Figure 11
With Adjustment		0.4	1.0		0.5	1.5	%	See Figure 12
Amplitude Modulation								
Input Impedance	50	100		50	100		KΩ	
Modulation Range		100			100		%	
Carrier Suppression		55			55		dB	
Linearity		2			2		%	For 95% modulation
Square Wave Output								Measured at Pin 11
Amplitude		12			12		Vpp	
Rise Time		250			250		nsec	C_L = 10 pF
Fall Time		50			50		nsec	C_L = 10 pF
Saturation Voltage		0.2	0.4		0.2	0.6	V	I_L = 2 mA
Leakage Current		0.1	20		0.1	100	μA	V_{11} = 26V
FSK Keying Level (Pin 9)	0.8	1.4	2.4	0.8	1.4	2.4	V	See Section on Circuit Controls
Reference Bypass Voltage	2.9	3.1	3.3	2.5	3	3.5	V	Measured at Pin 10.

Note 1: Output Amplitude is directly proportional to the resistance R_3 on Pin 3. See Figure 3.
Note 2: For maximum amplitude stability R_3 should be a positive temperature coefficient resistor.

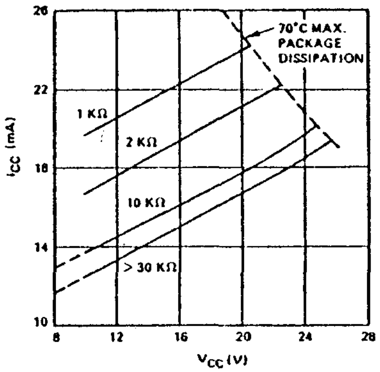


Figure 4. Supply Current vs Supply Voltage, Timing R

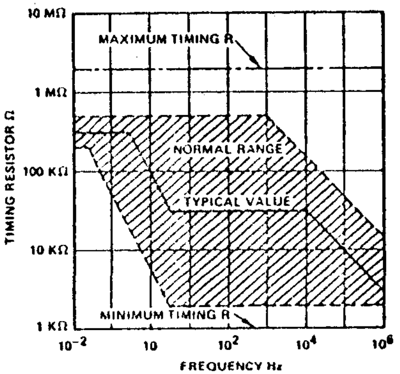


Figure 5. R vs Oscillation Frequency

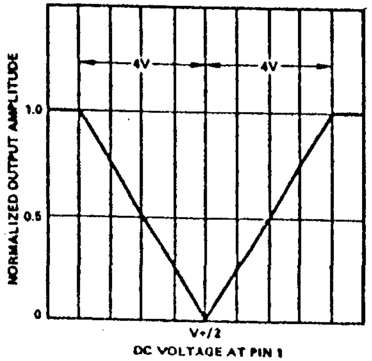


Figure 6. Normalized Output Amplitude vs DC Bias at AM Input (Pin 1).

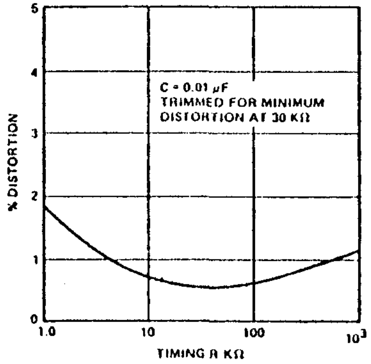


Figure 7. Trimmed Distortion vs Timing Resistor

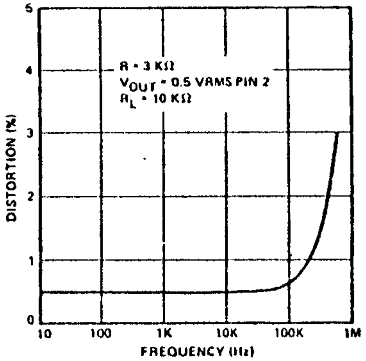


Figure 8. Signwave Distortion vs Operating Frequency With Timing Capacitors Varied

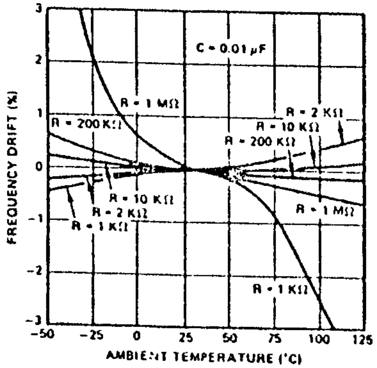
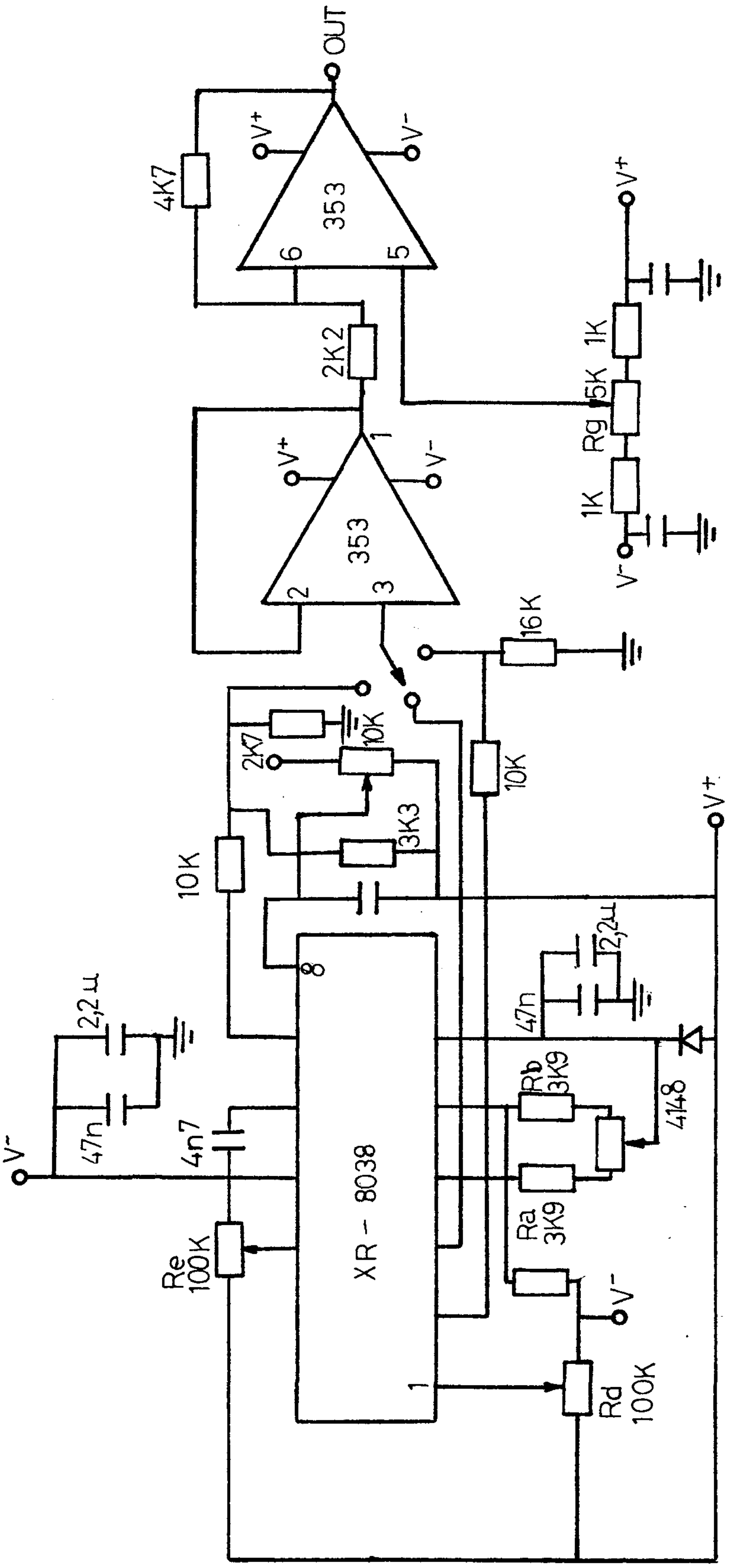


Figure 9. Frequency Drift vs Temperature

* 5. GENERADOR DE FUNCIONES.



5.1 CIRCUITO PROPUESTO : GENERADOR DE FUNCIONES.

5.2 DESARROLLO PRACTICO :

Para hacer nuestro generador de funciones, que nos dara las senales moduladoras del sistema, hemos elegido el I.C. 8038. Este circuito puede funcionar sobre una gama de frecuencias de 0,001 Hz a 1 MHz con una gran estabilidad a las variaciones de tension y temperatura.

Nosotros nos vamos a limitar al rango de frecuencias de audio, 20 Hz a 20 KHz, con salidas sinusoidal triangular y cuadrada. Y ademas darle la posibilidad de correccion del nivel de tension de offset.

El valor de la frecuencia de oscilacion depende del valor de Ca, de las resistencias Ra y Rb, y de la tension de referencia (patilla 8) de las fuentes de corriente.

Las corrientes que atraviesan las resistencias Ra y Rb sirven para cargar y descargar el condensador conectado a la patilla 10. Como el sistema es lineal, si en los bornes de estas resistencias aplicamos una tension variable entre 10V y 10 mV, la variacion de frecuencia sera de 1000 / 1.

La tension en los bornes de las resistencias Ra y Rb, con la patilla 8 conectada directamente a +V, sera superior a 100 mV. Para obtener tensiones mas pequenas, necesarias para alcanzar el factor de variacion buscado, la tension sobre la patilla 8 debe ser superior a la de alimentacion. Esta elevacion sera del orden de algunas centenas de mV, y la obtenemos disponiendo el diodo D en serie entre +V y la patilla 6. En realidad, no hemos elevado la tension en la patilla 8, sino que hemos llevado la patilla 6 a un potencial ligeramente inferior.

La corriente de carga de los transistores internos esta determinada por la impedancia presente entre las patillas 4 y 5 del circuito integrado, y por las corrientes de polarizacion de estos transistores. Cada tension diferencial provoca un desequilibrio de las corrientes de carga y descarga, arrastrando una importante variacion del "dutycicle". El error remanente de este "dutycicle" es compensado conectando una resistencia de valor elevado sobre la patilla 5 y la masa.

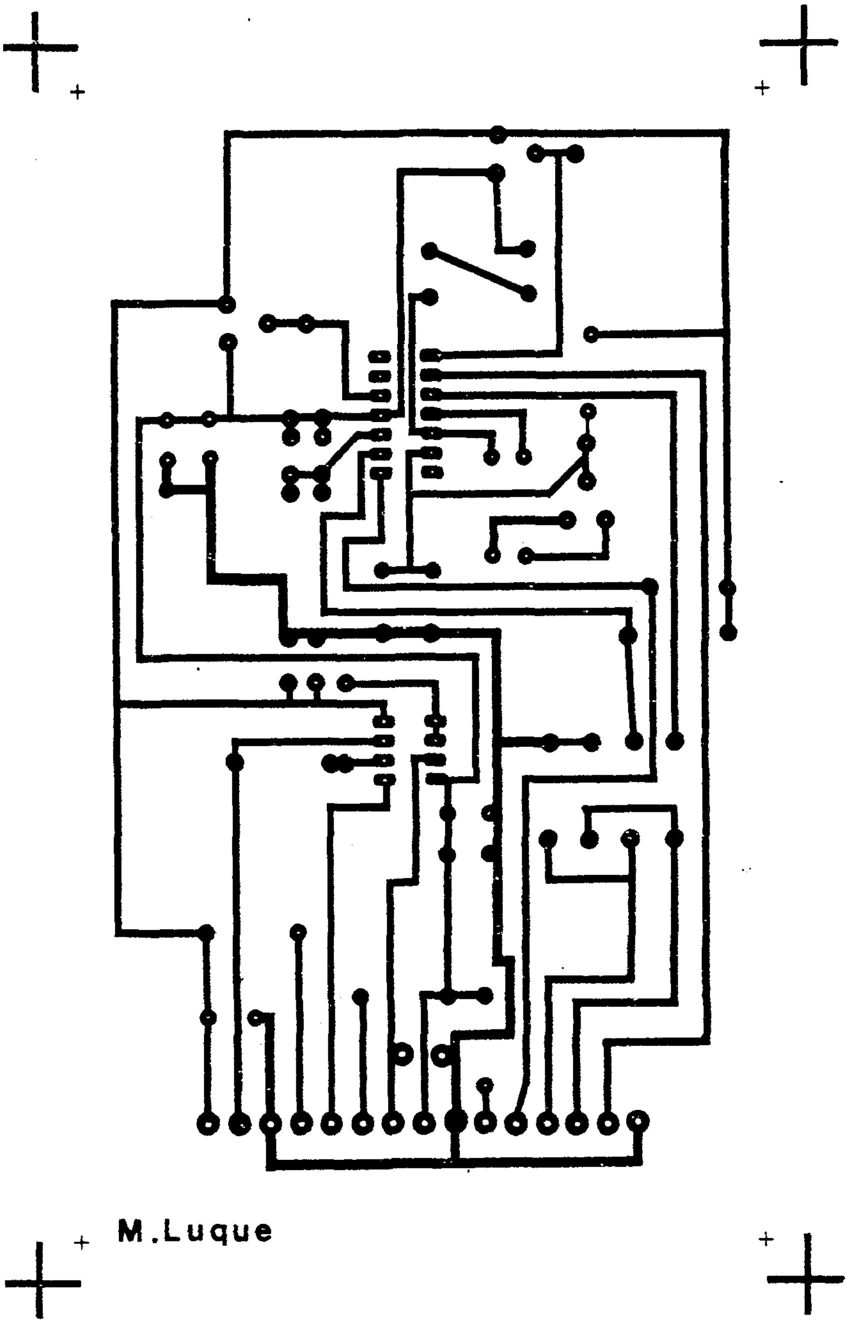
Para disminuir la distorsion a la salida, las tensiones aplicadas a las patillas 1 y 12 son reguladas a traves de dos resistencias variables Rd y Re.

Para conseguir que el generador de funciones tenga correccion de tension de offset, hemos puesto un amplificador operacional, acoplado al circuito mediante un seguidor. Esta tension la podemos variar con el potenciometro Rg.

NOTA:

El voltaje maximo que podemos obtener a la salida es de 10 Vpp, pudiendo variar la tension de offset.

5.3 MECANORMA GENERADOR DE FUNCIONES :



M.Luque

XR-8038

Precision Waveform Generator

GENERAL DESCRIPTION

The XR-8038 is a precision waveform generator IC capable of producing sine, square, triangular, sawtooth and pulse waveforms with a minimum number of external components and adjustments. Its operating frequency can be selected over nine decades of frequency, from 0.001 Hz to 1 MHz, by the choice of external R-C components. The frequency of oscillation is highly stable over a wide range of temperature and supply voltage changes. The frequency control, sweep and modulation can be accomplished with an external control voltage, without effecting the quality of the output waveforms. Each of the three basic waveforms, i.e. sinewave, triangle and square wave outputs are available simultaneously, trom independent output terminals.

The XR-8038 monolithic waveform generator uses advanced processing technology and Schottky-barrier diodes to enhance its frequency performance. It can be readily interfaced with a monolithic phase-detector circuit, such as the XR-2208, to form stable phase-locked loop circuits.

FEATURES

Direct Replacement for Intersil 8038
Low Frequency Drift--50 ppm/°C Max.
Simultaneous Sine, Triangle and Square-Wave Outputs
Low Distortion –THD ≃ 1%
High FM and Triangle Linearity
Wide Frequency Range – 0.001 Hz to 1 MHz
Variable Duty-Cycle – 2% to 98%

APPLICATIONS

Precision Waveform Generation Sine, Triangle, Square, Pulse
Sweep and FM Generation
Tone Generation
Instrumentation and Test Equipment Design
Precision PLL Design

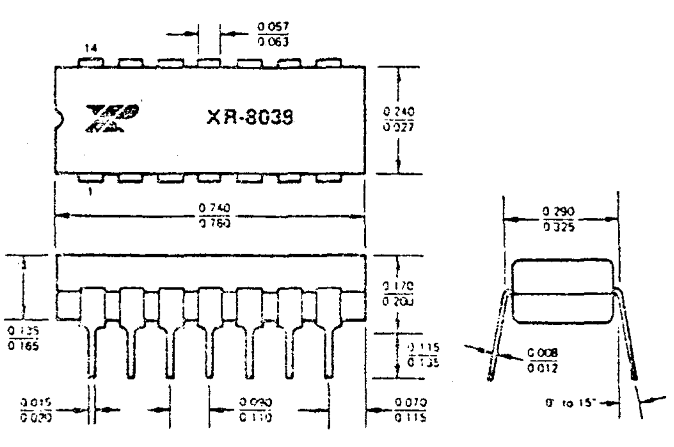
ABSOLUTE MAXIMUM RATINGS

Power Supply	36V
Power Dissipation (package limitation)	
Ceramic package	750 mW
Derate above +25°C	6.0 mW/°C
Plastic package	625 mW
Derate above +25°C	5 mW/°C
Storage Temperature Range	–65°C to +150°C

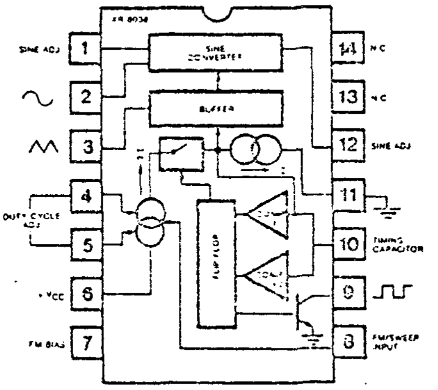
AVAILABLE TYPES

Part Number	Package	Operating Temperature
XR-8038M	Ceramic	–55°C to +125°C
XR-8038N	Ceramic	0°C to +75°C
XR-8038P	Plastic	0°C to +75°C
XR-8038CN	Ceramic	0°C to +75°C
XR-8038CP	Plastic	0°C to +75°C

PACKAGE INFORMATION



FUNCTIONAL BLOCK DIAGRAM

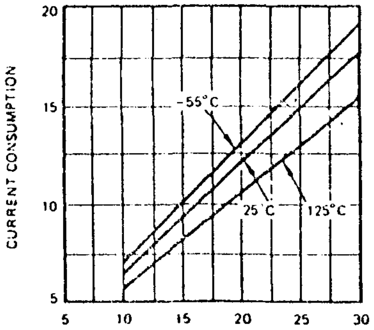


ELECTRICAL CHARACTERISTICS

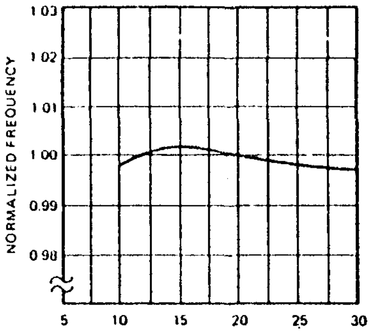
Test Conditions: $V_s = \pm 5V$ to $\pm 15V$, $T_A = 25^\circ C$, $R_L = 1\ M\Omega$, $R_A = R_B = 10k\Omega$, $C_1 = 3300\ pF$, S_1 closed, unless otherwise specified. See Test Circuit of Figure 1.

CHARACTERISTICS	XR-8038M/XR-8038			XR-8038C			UNITS	CONDITIONS
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.		
GENERAL CHARACTERISTICS								
Supply Voltage, V_s								
Single Supply	10		30	10		30	V	
Dual Supplies	±5		±15	±5		±15	V	
Supply Current		12	15		12	20	mA	$V_s = \pm 10V$. See Note 1.
FREQUENCY CHARACTERISTICS (Measured at Pin 9)								
Range of Adjustment								
Max. Operating Frequency		1			1		MHz	$R_A = R_B = 500\Omega$, $C_1 = 0$, $R_L = 15\ k\Omega$
Lowest Practical Frequency		0.001			0.001		Hz	$R_A = R_B = 1\ M\Omega$, $C_1 = 500\ \mu F$
Max. FM Sweep Frequency		100			100		kHz	
FM Sweep Range		1000:1			1000:1			S_1 Open. See Notes 2 and 3.
FM Linearity		0.1			0.2		%	S_1 Open. See Note 3.
Range of Timing Resistors	0.5		1000	0.5		1000	kΩ	Values of R_A and R_B.
Temperature Stability								
XR-8038M		20	50	–	–	–	ppm/°C	
XR-8038		50	100	–	–	–	ppm/°C	
XR-8038C	–	–	–		50		ppm/°C	
Power Supply Stability		0.05			0.05		%/V	See Note 4.
OUTPUT CHARACTERISTICS								
Square-Wave								Measured at Pin 9.
Amplitude	0.9	0.98		0.9	0.98		x V_s	$R_L = 100\ k\Omega$
Saturation Voltage		0.2	0.4		0.2	0.5	V	$I_{sink} = 2\ mA$
Rise Time		100			100		nsec	$R_L = 4.7\ k\Omega$
Fall Time		40			40		nsec	$R_L = 4.7\ k\Omega$
Duty Cycle Adj.	2		98	2		98	%	
Triangle/Sawtooth/Ramp								Measured at Pin 3.
Amplitude	0.3	0.33		0.3	0.33		x V_s	$R_L = 100\ k\Omega$
Linearity		0.05			0.1		%	
Output Impedance		200			200			$I_{out} = 5\ mA$
Sine-Wave Amplitude	0.2	0.22		0.2	0.22		x V_s	$R_L = 100\ k\Omega$
Distortion								
Unadjusted		0.7	1.5		0.8	3	%	$R_L = 1\ M\Omega$. See Note 5.
Adjusted		0.5			0.5		%	$R_L = 1\ M\Omega$

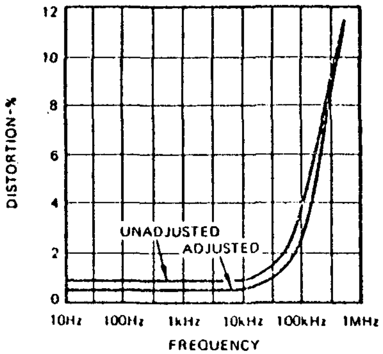
CHARACTERISTIC CURVES



Supply Voltage
Power Dissipation vs. Supply Voltage



Supply Voltage
Frequency Drift vs. Power Supply

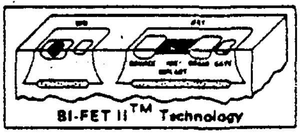


Sinewave THD vs. Frequency

National Semiconductor

Operational Amplifiers/Buffers

LF353 Wide Bandwidth Dual JFET Input Operational Amplifier



General Description

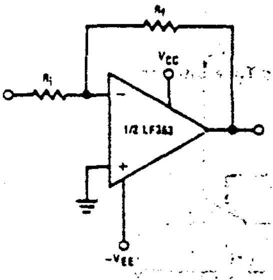
These devices are low cost, high speed, dual JFET input operational amplifiers with an internally trimmed input offset voltage (BI-FET II™ technology). They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF353 is pin compatible with the standard LM1558 allowing designers to immediately upgrade the overall performance of existing LM1558 and LM358 designs.

These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset voltage, low input bias current, high input impedance, high slew rate and wide bandwidth. The devices also exhibit low noise and offset voltage drift.

Features

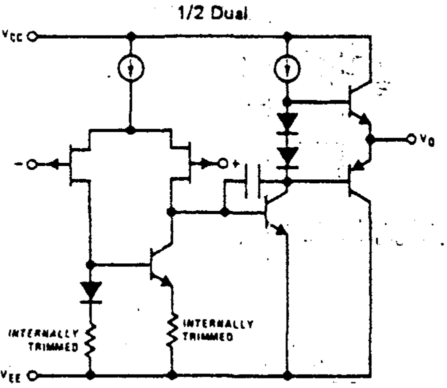
■ Internally trimmed offset voltage	10 mV
■ Low input bias current	50 pA
■ Low input noise voltage	16 nV/√Hz
■ Low input noise current	0.01 pA/√Hz
■ Wide gain bandwidth	4 MHz
■ High slew rate	13 V/μs
■ Low supply current	3.6 mA
■ High input impedance	$10^{12}\Omega$
■ Low total harmonic distortion $A_V = 10$, $R_L = 10k$, $V_O = 20\,V_{p-p}$, BW = 20 Hz-20 kHz	<0.02%
■ Low 1/f noise corner	50 Hz
■ Fast settling time to 0.01%	2 μs

Typical Connection



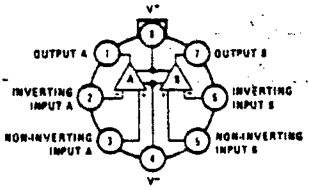
Simplified Schematic

1/2 Dual



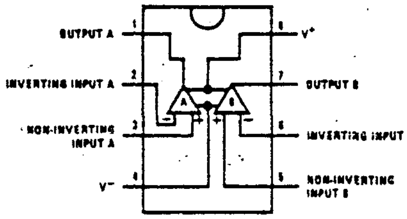
Connection Diagrams

LF353H Metal Can Package (Top View)



Order Number LF353H
See NS Package H08C

LF353N Dual-In-Line Package (Top View)



Order Number LF353N
See NS Package N08A

Absolute Maximum Ratings

Supply Voltage	±18V	Input Voltage Range (Note 2)	±15V
Power Dissipation (Note 1)	500 mW	Output Short Circuit Duration	Continuous
Operating Temperature Range	0°C to +70°C	Storage Temperature Range	−65°C to +150°C
T_j(MAX)	115°C	Lead Temperature (Soldering, 10 seconds)	300°C
Differential Input Voltage	±30V		

DC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353			UNITS
			MIN	TYP	MAX	
V_{OS}	Input Offset Voltage	$R_S = 10\,k\Omega$, $T_A = 25°C$		5	10	mV
		Over Temperature			13	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S = 10\,k\Omega$		10		μV/°C
I_{OS}	Input Offset Current	$T_j = 25°C$, (Notes 4, 5)		25	100	pA
		$T_j < 70°C$			4	nA
I_B	Input Bias Current	$T_j = 25°C$, (Notes 4, 5)		50	200	pA
		$T_j < 70°C$			8	nA
R_{IN}	Input Resistance	$T_j = 25°C$		10^{12}		Ω
A_{VOL}	Large Signal Voltage Gain	$V_S = \pm 15V$, $T_A = 25°C$ $V_O = \pm 10V$, $R_L = 2\,k\Omega$	25	100		V/mV
		Over Temperature	15			V/mV
V_O	Output Voltage Swing	$V_S = \pm 15V$, $R_L = 10\,k\Omega$	±12	±13.5		V
V_{CM}	Input Common-Mode Voltage Range	$V_S = \pm 15V$	±11	+15 −12		V V
CMRR	Common-Mode Rejection Ratio	$R_S < 10\,k\Omega$	70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 6)	70	100		dB
I_S	Supply Current			3.6	6.5	mA

AC Electrical Characteristics (Note 4)

SYMBOL	PARAMETER	CONDITIONS	LF353			UNITS
			MIN	TYP	MAX	
	Amplifier to Amplifier Coupling	$T_A = 25°C$, f = 1 Hz–20 kHz (Input Referred)		−120		dB
SR	Slew Rate	$V_S = \pm 15V$, $T_A = 25°C$		13		V/μs
GBW	Gain Bandwidth Product	$V_S = \pm 15V$, $T_A = 25°C$		4		MHz
e_n	Equivalent Input Noise Voltage	$T_A = 25°C$, $R_S = 100\Omega$, f = 1000 Hz		16		nV/√Hz
i_n	Equivalent Input Noise Current	$T_j = 25°C$, f = 1000 Hz		0.01		pA/√Hz

Note 1: For operating at elevated temperature, the device must be derated based on a thermal resistance of 160°C/W junction to ambient for the N package, and 150°C/W junction to ambient for the H package.

Note 2: Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

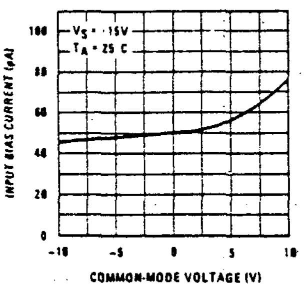
Note 3: The power dissipation limit, however, cannot be exceeded.

Note 4: These specifications apply for $V_S = \pm 15V$ and $0°C < T_A < +70°C$. V_{OS}, I_B and I_{OS} are measured at $V_{CM} = 0$.

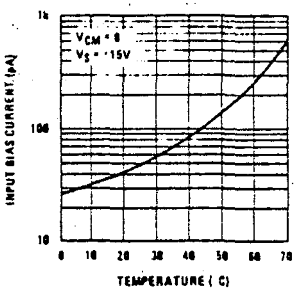
Note 5: The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_j. Due to the limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_j = T_A + \theta_{jA} P_D$ where θ_{jA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

Note 6.: Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice.

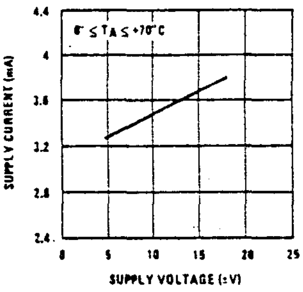
Typical Performance Characteristics



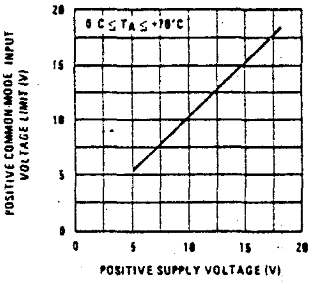
Input Bias Current



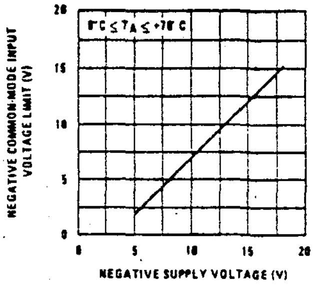
Input Bias Current



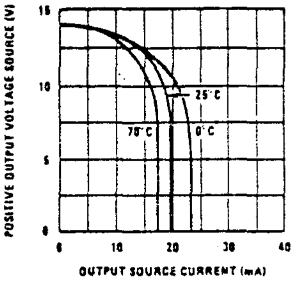
Supply Current



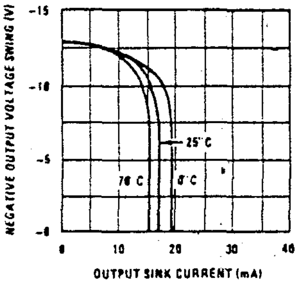
Positive Common-Mode Input Voltage Limit



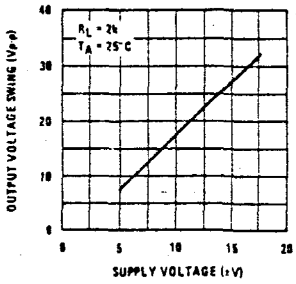
Negative Common-Mode Input Voltage Limit



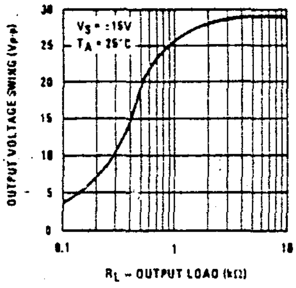
Positive Current Limit



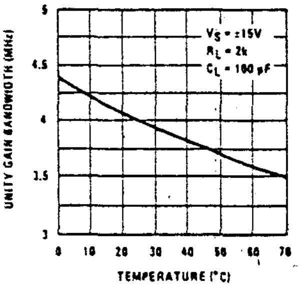
Negative Current Limit



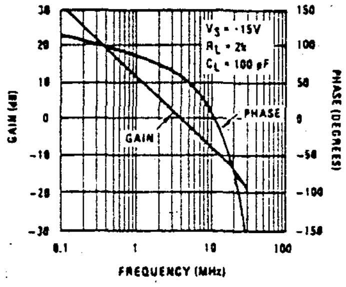
Voltage Swing



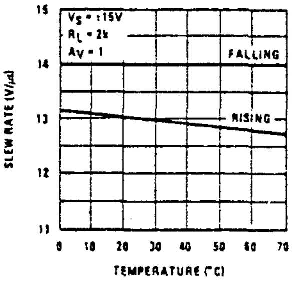
Output Voltage Swing



Gain Bandwidth



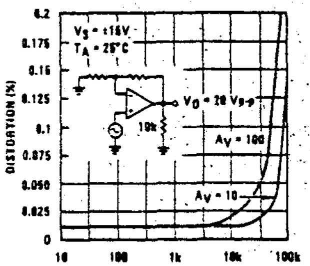
Bode Plot



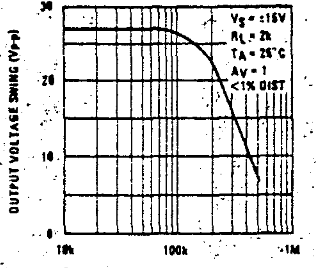
Slew Rate

Typical Performance Characteristics (Continued)

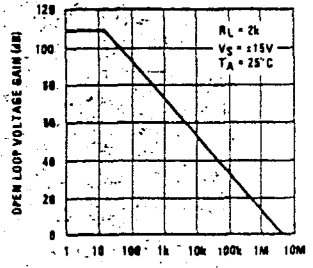
Distortion vs Frequency



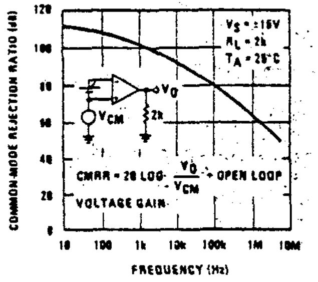
Undistorted Output Voltage Swing



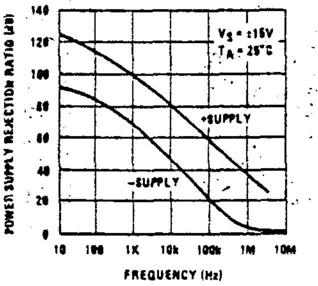
Open Loop Frequency Response



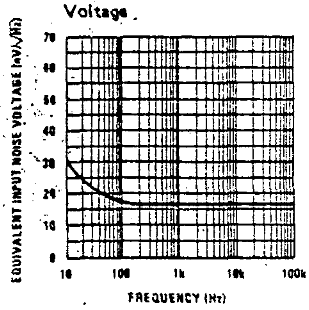
Common-Mode Rejection Ratio



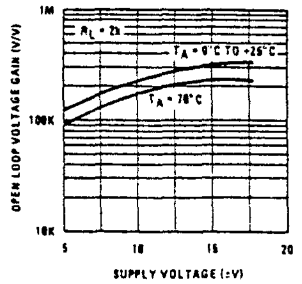
Power Supply Rejection Ratio



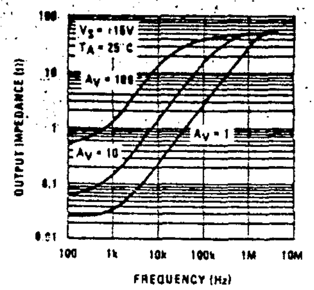
Equivalent Input Noise Voltage



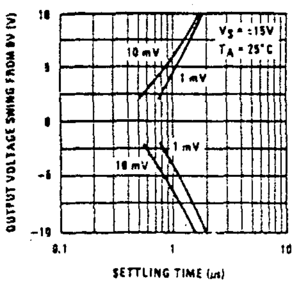
Open Loop Voltage Gain (V/V)



Output Impedance



Inverter Settling Time



Application Hints (Continued)

high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier will be forced to a high state.

The amplifiers will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

Each amplifier is individually biased by a zener reference which allows normal circuit operation on ±4V power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The amplifiers will drive a 2 kΩ load resistance to ±10V over the full temperature range of 0°C to +70°C. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

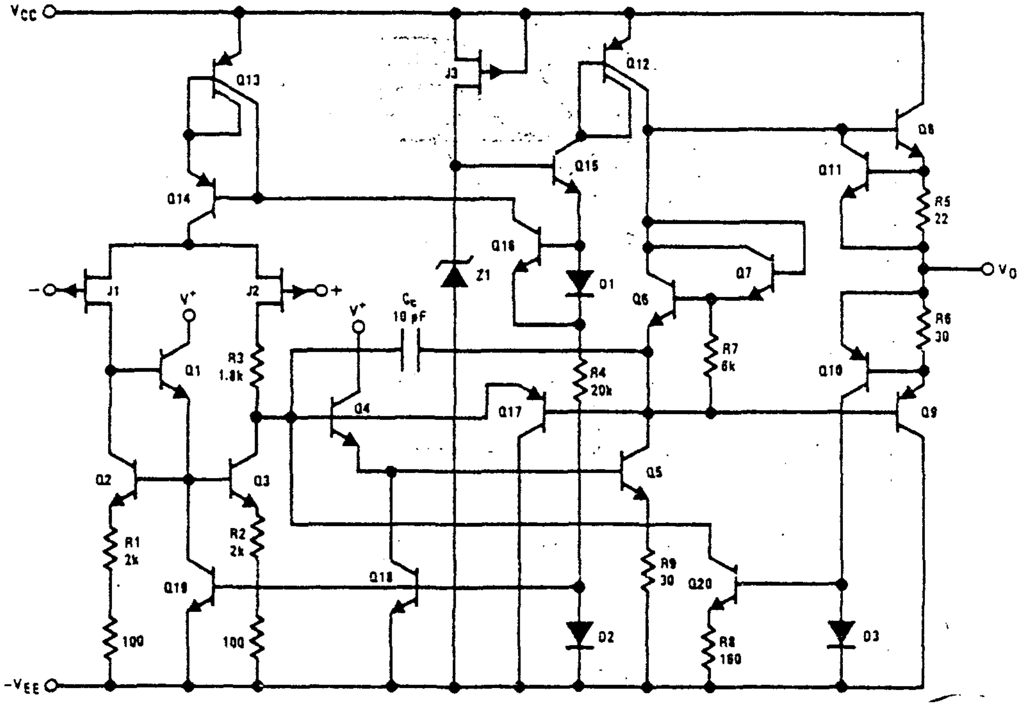
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

Because these amplifiers are JFET rather than MOSFET input op amps they do not require special handling.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

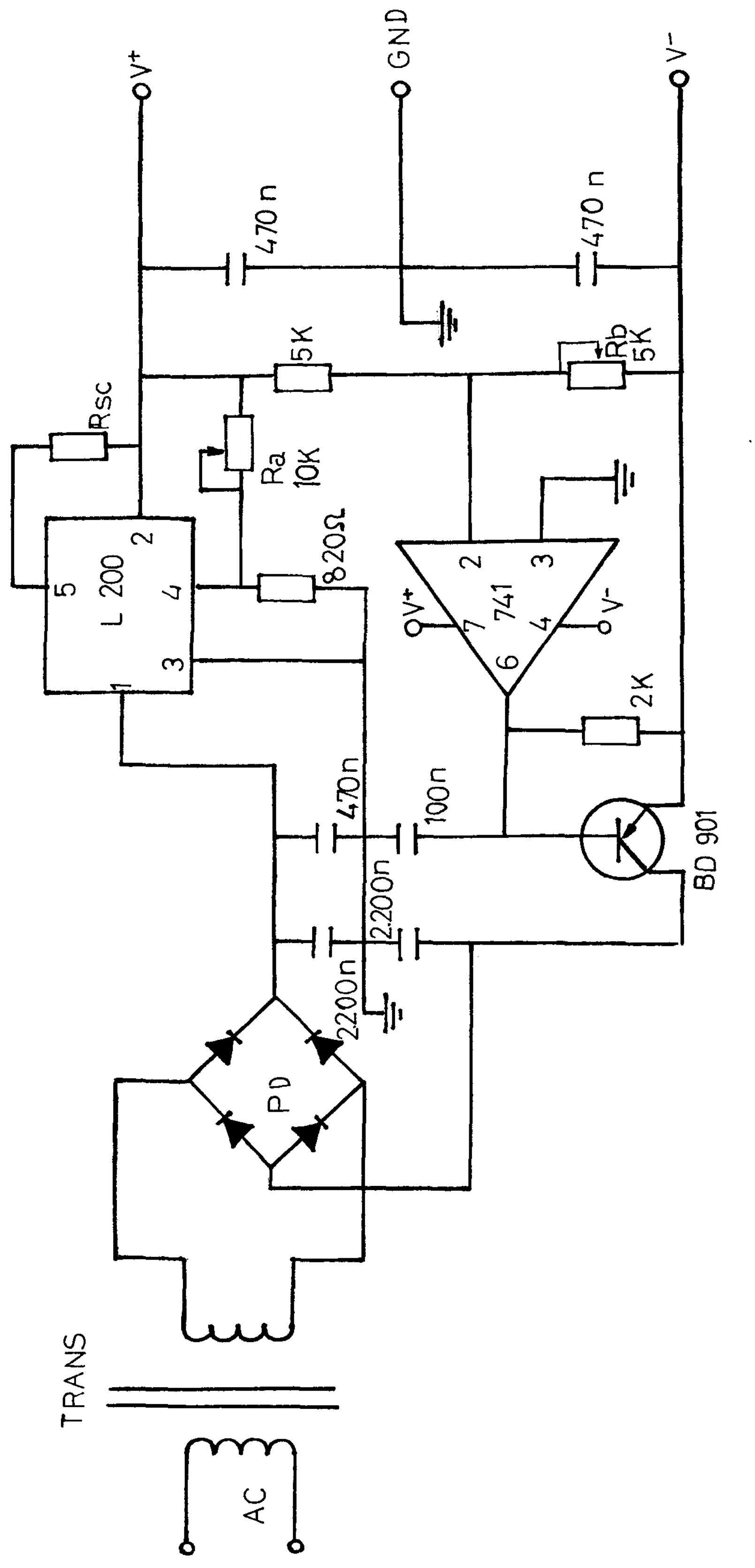
A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

Detailed Schematic



* 6. FUENTE DE ALIMENTACION.

6.1 CIRCUITO PROPUESTO : FUENTE DE ALIMENTACION.



6.2 DESARROLLO PRACTICO :

En el esquema anterior podemos apreciar la fuente de alimentacion elegida para nuestro sistema.

El circuito integrado L-200 nos ofrece grandes posibilidades, podemos variar el voltaje de 3V a 30V, tiene salida cortocircuitable, un amperaje maximo de 2 Amp, etc. Pero no todas sus caracteristicas son aprovechadas en este diseno, porque hemos fijado el voltaje de salida a 12V con el potenciometro Ra.

Siendo Rb para que las dos salidas simetricas tengan igual potencial en valor absoluto. Tampoco le exigimos su maximo amperaje, porque el transformador montado solo nos ofrece 1,5 Amp.

Luego es una fuente simetrica, regulada y estabilizada, que nos proporciona una corriente maxima de 1,5 Amp a una tension de 12V.

See last page of data sheet for ordering information.

MC1741, MC1741C
MC1741N, MC1741NC

OPERATIONAL AMPLIFIER
SILICON MONOLITHIC
INTEGRATED CIRCUIT

INTERNALLY COMPENSATED, HIGH PERFORMANCE OPERATIONAL AMPLIFIERS

. . . designed for use as a summing amplifier, integrator, or amplifier with operating characteristics as a function of the external feedback components.

- *No Frequency Compensation Required*
- Short-Circuit Protection
- Offset Voltage Null Capability
- Wide Common-Mode and Differential Voltage Ranges
- Low-Power Consumption
- No Latch Up
- Low Noise Selections Offered — N Suffix

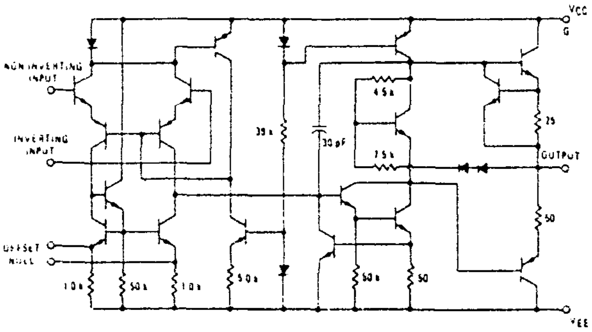
MAXIMUM RATINGS (T_A = +25°C unless otherwise noted)

Rating	Symbol	MC1741C	MC1741	Unit
Power Supply Voltage	V_{CC} V_{EE}	+18 -18	+22 -22	Vdc Vdc
Input Differential Voltage	V_{ID}	±30		Volts
Input Common Mode Voltage (Note 1)	V_{ICM}	±15		Volts
Output Short Circuit Duration (Note 2)	t_S	Continuous		
Operating Ambient Temperature Range	T_A	0 to +70	-55 to +125	°C
Storage Temperature Range Metal, Flat and Ceramic Packages Plastic Packages	T_{stg}	 -65 to +150 -55 to +125		°C
Junction Temperature Range Metal and Ceramic Packages Plastic Packages	T_J	 175 150		°C

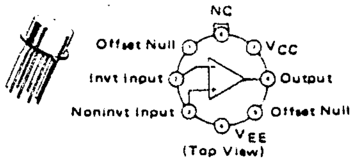
Note 1 For supply voltages less than ± 15 V, the absolute maximum input voltage is equal to the supply voltage.

Note 2. Supply voltage equal to or less than 15 V.

EQUIVALENT CIRCUIT SCHEMATIC

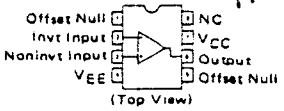


G SUFFIX
METAL PACKAGE
CASE 601



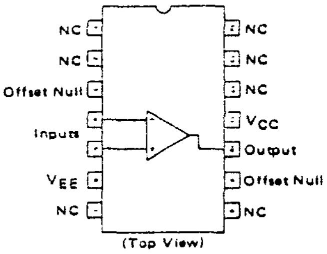
P1 SUFFIX
PLASTIC PACKAGE
CASE 626
(MC1741C,MC1741NC)

U SUFFIX
CERAMIC PACKAGE
CASE 693

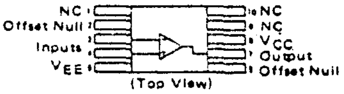


L SUFFIX
CERAMIC PACKAGE
CASE 632
TO-116

P2 SUFFIX
PLASTIC PACKAGE
CASE 646
(MC1741C,MC1741NC)



F SUFFIX
CERAMIC PACKAGE
CASE 606-04
TO-91



ELECTRICAL CHARACTERISTICS (V_{CC} = 15 V, V_{EE} = 15 V, T_A = 25°C unless otherwise noted).

Characteristic	Symbol	MC1741			MC1741C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \leqslant 10$ k)	V_{IO}	–	1.0	5.0	–	2.0	6.0	mV
Input Offset Current	I_{IO}	–	20	200	–	20	200	nA
Input Bias Current	I_{IB}	–	80	500	–	80	500	nA
Input Resistance	r_i	0.3	2.0	–	0.3	2.0	–	MΩ
Input Capacitance	C_i	–	1.4	–	–	1.4	–	pF
Offset Voltage Adjustment Range	V_{IOR}	–	±15	–	–	±15	–	mV
Common Mode Input Voltage Range	V_{ICR}	±12	±13	–	±12	±13	–	V
Large Signal Voltage Gain (V_O = ±10 V, $R_L \geqslant 2.0$ k)	A_v	50	200	–	20	200	–	V/mV
Output Resistance	r_o	–	75	–	–	75	–	Ω
Common Mode Rejection Ratio ($R_S \leqslant 10$ k)	CMRR	70	90	–	70	90	–	dB
Supply Voltage Rejection Ratio ($R_S \leqslant 10$ k)	PSRR	–	30	150	–	30	150	µV/V
Output Voltage Swing ($R_L \geqslant 10$ k) ($R_L \geqslant 2$ k)	V_O	 ±12 ±10	 ±14 ±13	 – –	 ±12 ±10	 ±14 ±13	 – –	V
Output Short-Circuit Current	I_{os}	–	20	–	–	20	–	mA
Supply Current	I_D	–	1.7	2.8	–	1.7	2.8	mA
Power Consumption	P_C	–	50	85	–	50	85	mW
Transient Response (Unity Gain – Non-Inverting) (V_I = 20 mV, R_L > 2 k, C_L < 100 pF) Rise Time (V_I = 20 mV, R_L > 2 k, C_L < 100 pF) Overshoot (V_I = 10 V, R_L > 2 k, C_L < 100 pF) Slew Rate	 t_{TLH} os SR	 – – –	 0.3 15 0.5	 – – –	 – – –	 0.3 15 0.5	 – – –	 µs % V/µs

ELECTRICAL CHARACTERISTICS (V_{CC} = 15 V, V_{EE} = 15 V, T_A = *T_{high} to T_{low} unless otherwise noted.)

Characteristic	Symbol	MC1741			MC1741C			Unit
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage ($R_S \leqslant 10$ kΩ	V_{IO}	–	1.0	6.0	–	–	7.5	mV
Input Offset Current (T_A = 125°C) (T_A = -55°C) (T_A = 0°C to +70°C)	I_{IO}	 – – –	 7.0 85 –	 200 500 –	 – – –	 – – –	 – – 300	nA
Input Bias Current (T_A = 125°C) (T_A = -55°C) (T_A = 0°C to +70°C)	I_{IB}	 – – –	 30 300 –	 500 1500 –	 – – –	 – – –	 – – 800	nA
Common Mode Input Voltage Range	V_{ICR}	±12	±13	–	–	–	–	V
Common Mode Rejection Ratio ($R_S \leqslant 10$ k)	CMRR	70	90	–	–	–	–	dB
Supply Voltage Rejection Ratio ($R_S \leqslant 10$ k)	PSRR	–	30	150	–	–	–	µV/V
Output Voltage Swing ($R_L \geqslant 10$ k) ($R_L \geqslant 2$ k)	V_O	 ±12 ±10	 ±14 ±13	 – –	 – ±10	 – ±13	 – –	V
Large Signal Voltage Gain ($R_L \geqslant 2$ k, V_{out} = ±10 V)	A_v	25	–	–	15	–	–	V/mV
Supply Currents (T_A = 125°C) (T_A = -55°C)	I_D	 – –	 1.5 2.0	 2.5 3.3	 – –	 – –	 – –	mA
Power Consumption (T_A = +125°C) (T_A = -55°C)	P_C	– –	45 60	75 100	– –	– –	– –	mW

*T_{high} = 125°C for MC1741 and 70°C for MC1741C
T_{low} = -55°C for MC1741 and 0°C for MC1741C

NOISE CHARACTERISTICS

(Applies for MC1741N and MC1741NC only, V_{CC} = 15 V, V_{EE} = −15 V, T_A = +25°C)

Characteristic	Symbol	MC1741N			MC1741NC			Unit
		Min	Typ	Max	Min	Typ	Max	
Burst Noise (Popcorn Noise) (BW = 1.0 Hz to 1.0 kHz, t = 10 s, R_S = 100 k) (Input Referenced)	E_n	–	–	20	–	–	20	µV/peak

FIGURE 1 – BURST NOISE versus SOURCE RESISTANCE

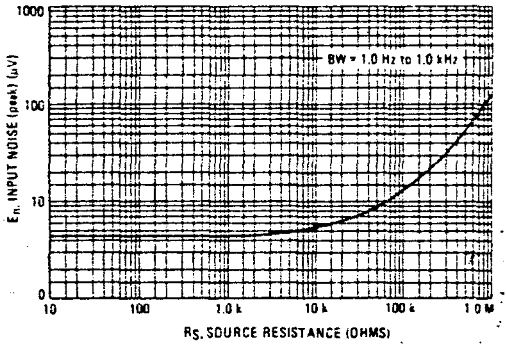


FIGURE 2 – RMS NOISE versus SOURCE RESISTANCE

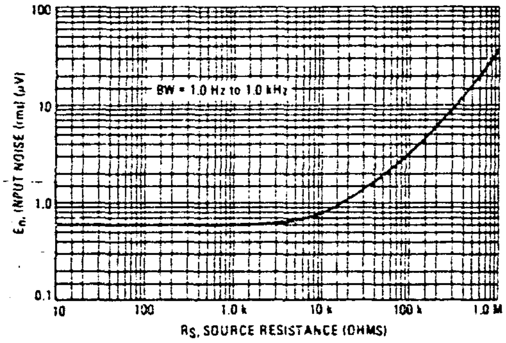


FIGURE 3 – OUTPUT NOISE versus SOURCE RESISTANCE

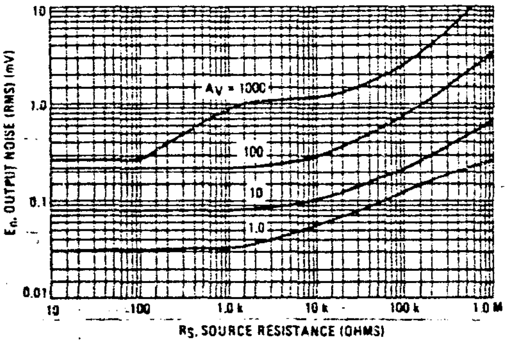


FIGURE 4 – SPECTRAL NOISE DENSITY

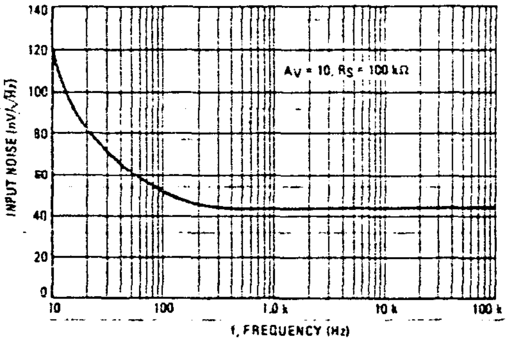
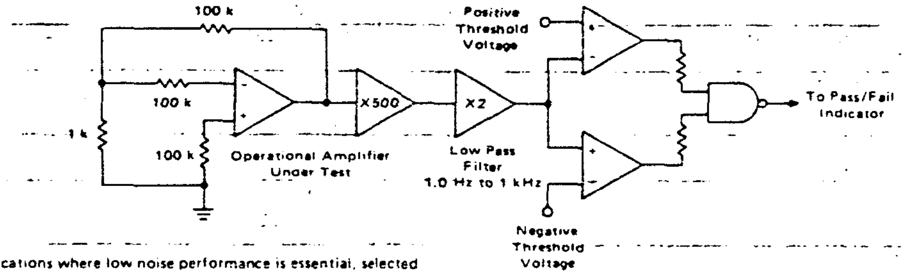


FIGURE 5 – BURST NOISE TEST CIRCUIT (N Suffixed Devices Only)



For applications where low noise performance is essential, selected devices denoted by an N suffix are offered. These units have been 100% tested for burst noise pulses on a special noise test system. Unlike conventional peak reading or RMS meters, this system was especially designed to provide the quick response time essential to burst (popcorn) noise testing.

The test time employed is 10 seconds and the 20 µV peak limit refers to the operational amplifier input thus eliminating errors in the closed-loop gain factor of the operational amplifier under test.

TYPICAL CHARACTERISTICS

(V_{CC} = +15 Vdc, V_{EE} = -15 Vdc, T_A = +25°C unless otherwise noted)

FIGURE 6 – POWER BANDWIDTH
(LARGE SIGNAL SWING versus FREQUENCY)

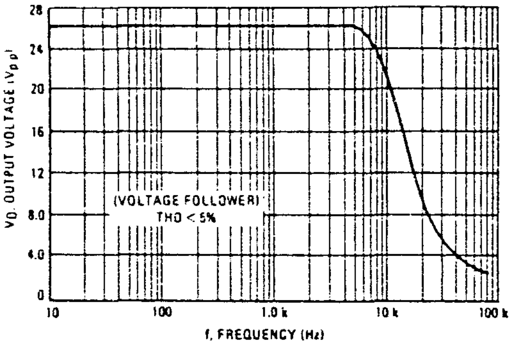


FIGURE 7 – OPEN LOOP FREQUENCY RESPONSE

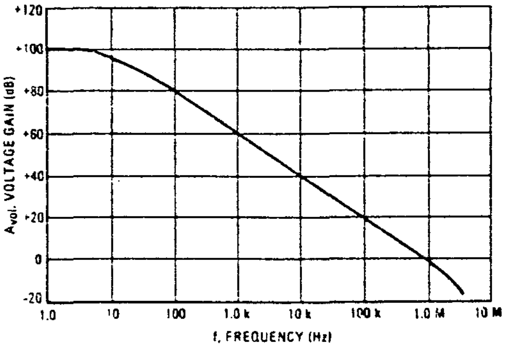


FIGURE 8 – POSITIVE OUTPUT VOLTAGE SWING versus LOAD RESISTANCE

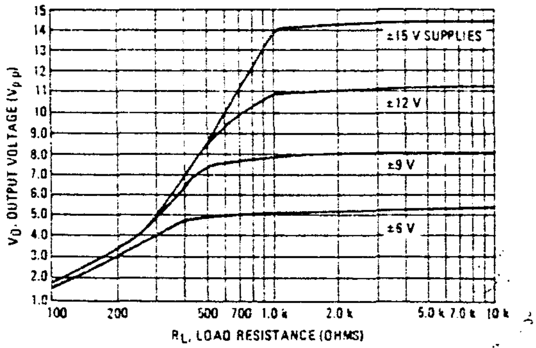


FIGURE 9 – NEGATIVE OUTPUT VOLTAGE SWING versus LOAD RESISTANCE

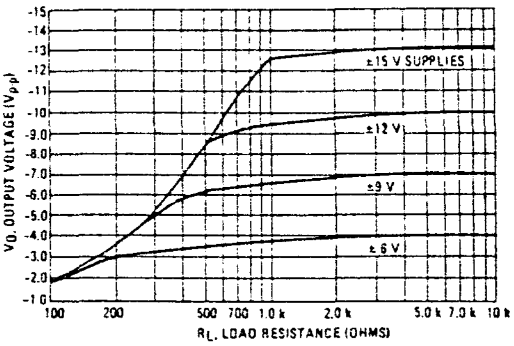


FIGURE 10 – OUTPUT VOLTAGE SWING versus LOAD RESISTANCE (Single Supply Operation)

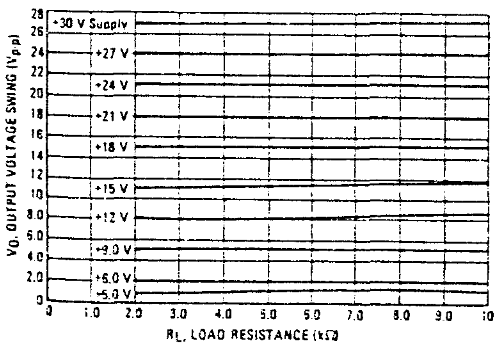


FIGURE 11 – SINGLE SUPPLY INVERTING AMPLIFIER

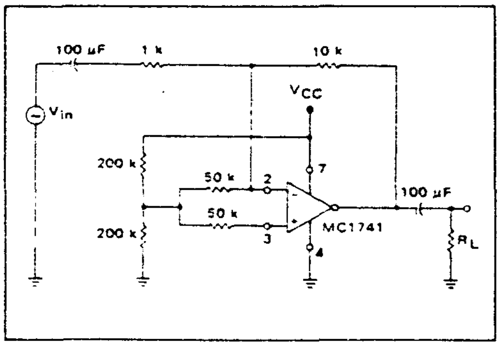


FIGURE 12 – NON-INVERTING PULSE RESPONSE

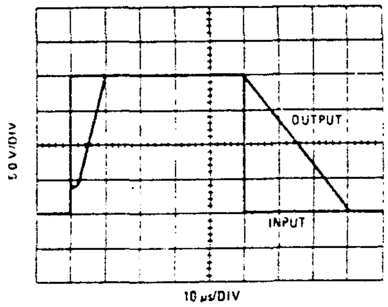


FIGURE 13 – TRANSIENT RESPONSE TEST CIRCUIT

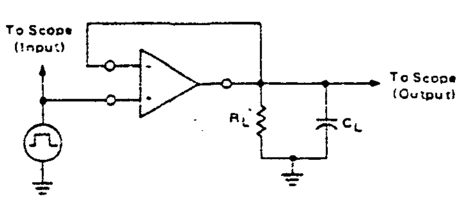
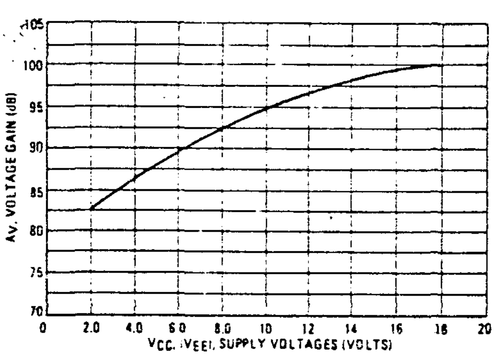


FIGURE 14 – OPEN LOOP VOLTAGE GAIN
versus SUPPLY VOLTAGE



ORDERING INFORMATION

Device	Alternate	Temperature Range	Package
MC1741CF, NCF	—	0°C to +70°C	Ceramic Flat
MC1741CG	LM741CD, µA741HC	0°C to +70°C	Metal Can
MC1741CL	LM741CD, µA741DC	0°C to +70°C	Ceramic DIP
MC1741CP1	LM741CN, µA741TC	0°C to +70°C	Plastic DIP
MC1741CP2, NCP1, NCP2	—	0°C to +70°C	Plastic DIP
MC1741CU,NCU	—	0°C to +70°C	Ceramic DIP
MC1741F,NF	—	−55°C to +125°C	Ceramic Flat
MC1741G,NG	—	−55°C to +125°C	Metal Can
MC1741L,NL	—	−55°C to +125°C	Ceramic DIP
MC1741U,NU	—	−55°C to +125°C	Ceramic DIP
MC1741NCG	—	0°C to +70°C	Metal Can
MC1741NCL	—	0°C to +70°C	Ceramic DIP

* 7. PRESUPUESTO.

PRESUPUESTO

UNIDADES	CONCEPTO	PESETAS UNIDAD	PESETAS TOTAL
92	Condensadores	60	5520
97	Resistencias	6	582
28	Potenciometros mini.	45	1260
4	Potenc. Chasis	300	1200
22	Conectores	50	1100
17	Zocalos	60	1020
18	Circuitos integrados	500	9000
1	Transistor (BD-901)	85	85
2	Diodos	25	50
1	Puente de diodo	250	250
1	Transformador 15+15 V. 1,5 A.	2200	2200
6	Placas Fotosensibilisadas	600	3600
25	Separadores	20	500
50	Tornillos y tuercas	2	100
10	Metros de cable	20	200
		Total	26667
	Montaje		10000
	% correspondiente a diseno		5000
		Total	41667

Este presupuesto esta hecho en base a la fabricacion de cien de estos sistemas moduladores. Con lo cual el importe total seria de:

Cuatro millones ciento sesenta y seis mil setecientas pesetas. (4.166.700,00 Pts.)

LA LAGUNA 30 de JUNIO de 1985.

Fdo.

NOTA :

Los precios dados a los componentes son valores medios para cada tipo.

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