ETH Quantumoptics

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V 1.0 - January 15th, 2011 QO-EL-0077

FG2206

Universal Function Generator

- **Amplitude and Offset tunable for all (Sine, Triangle and Rectangle) Waveforms**
- **Output Voltage can be as high as 70 Vpp (useful for scanning piezos)**
- **Built-in Clipping Detection**
- **Built-in Frequency Counter (with ATmega8)**
- **AM Modulation Input (controls Sine and Triangle only)**
- **FM Modulation Input (controls all Waveforms)**
- **Sync Output (TTL)**
- **min < 1 Hz, max > 100 kHz in 5 (widely) overlapping ranges (Standard Version)**
- **min < 1 Hz, max > 10 kHz in 4 (widely) overlapping ranges (High Voltage Version)**

Construction Manual

Contents

Functional Description

This Function Generator is built around the XR 2206 Monolithic Function Generator from Exar. It is capable of producing high quality sine, square and triangle waveforms of high-stability and accuracy.

The circuit uses either one of the timing capacitors C12, C8, C7, C6, C1 or C40. It therefore has five (widely overlapping) ranges. (C40 is reserve). In conjunction with R47 and R2 the Frequency may be adjusted. When FM is used, a voltage from 0...3V is injected and the change in frequency is proportonal to the change of voltage / R4.

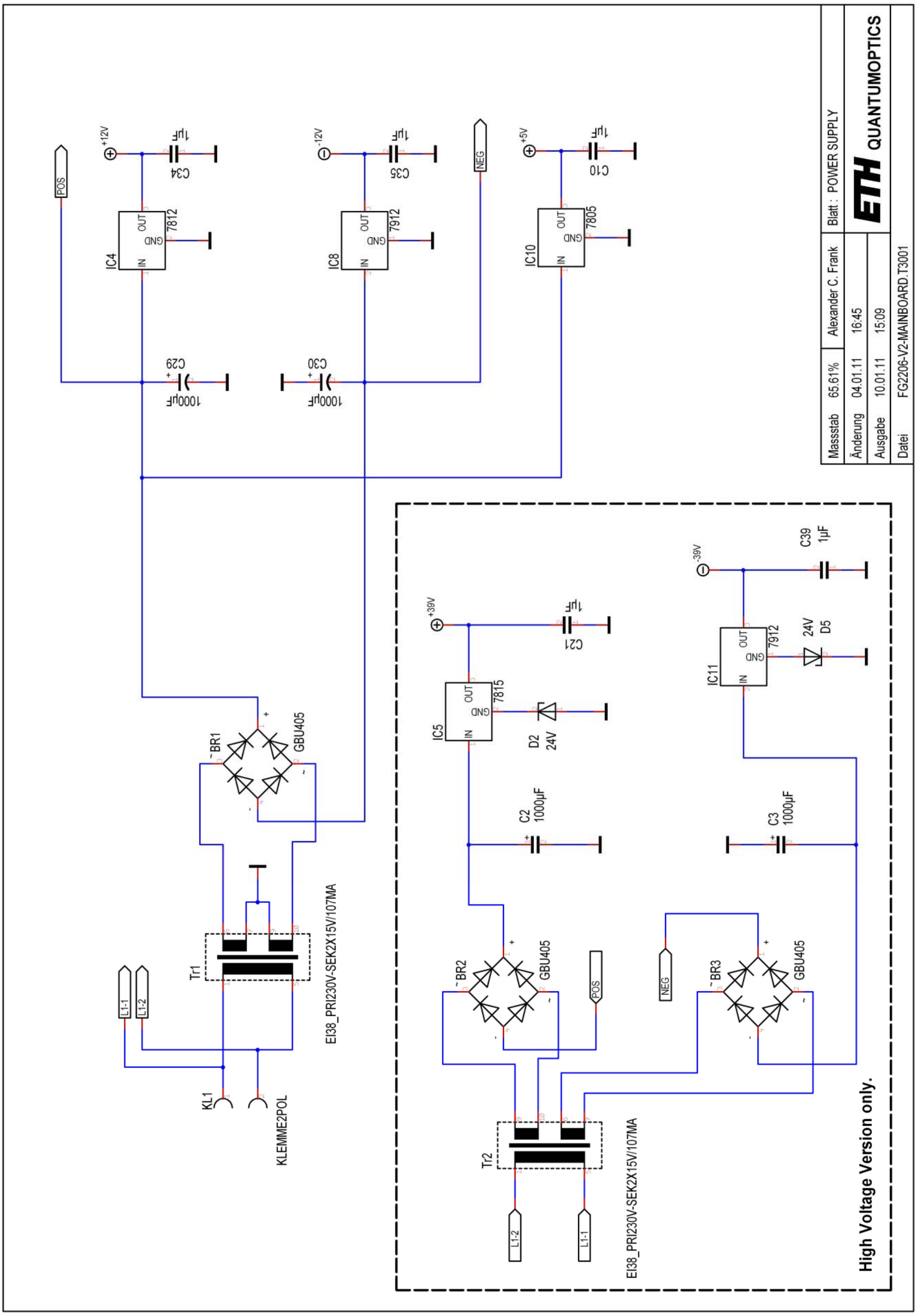
Whilst the amplitude of the square wave depends on the divider formed of R46, R20, R3 as well as R32 and D12 the amplitude of the sine and triangle are adjusteable in order to equal the square wave. (by R33 and R7).

A buffer follows the waveform-switch to decouple the load of R34 which determines the amplitude. IC13 is an active buffer to add a dc voltage upon the ac signal. The so called "Baseband" signal is now passed to the mainboard, where an AD 811 finally boosts the signal to 20 Vpp. Jumper J1 is set therefore, that the signal is passed back to the frontpanel for clipping detection. This is done with two rectifiers and two comparators. The comparator level is set to +9.21 V / -9.21 V which means that a voltage greater than +10V / lower than -10 V is able to trigger the comparator and switch on the corresponding LED.

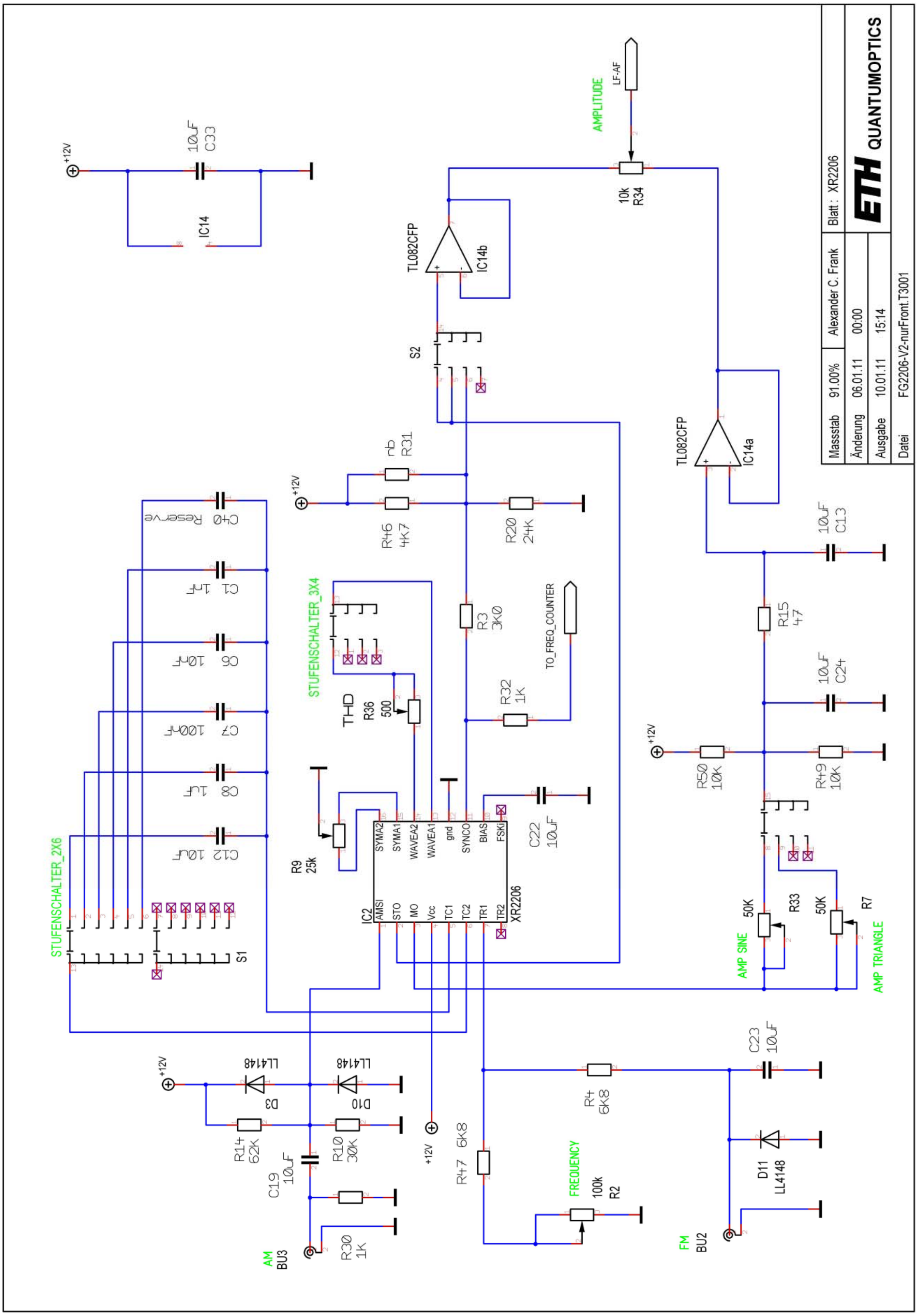
In case of a High Voltage Version, the Range switch is blocked to allow only frequencies < 10 kHz. The output of the AD 811 on the Mainboard is fed to the input of the OPA 452 which does additional amplification. In this case, jumper J1 has is set to pass the output of the OPA 452 back to the frontpanel, where a slightly modified clipping detector is monitoring the output.

The Frequency counter is realised with an ATMega8 running at 4 MHz. It is responsible for the counting as well as the multiplexing of the 7-Segment Display.

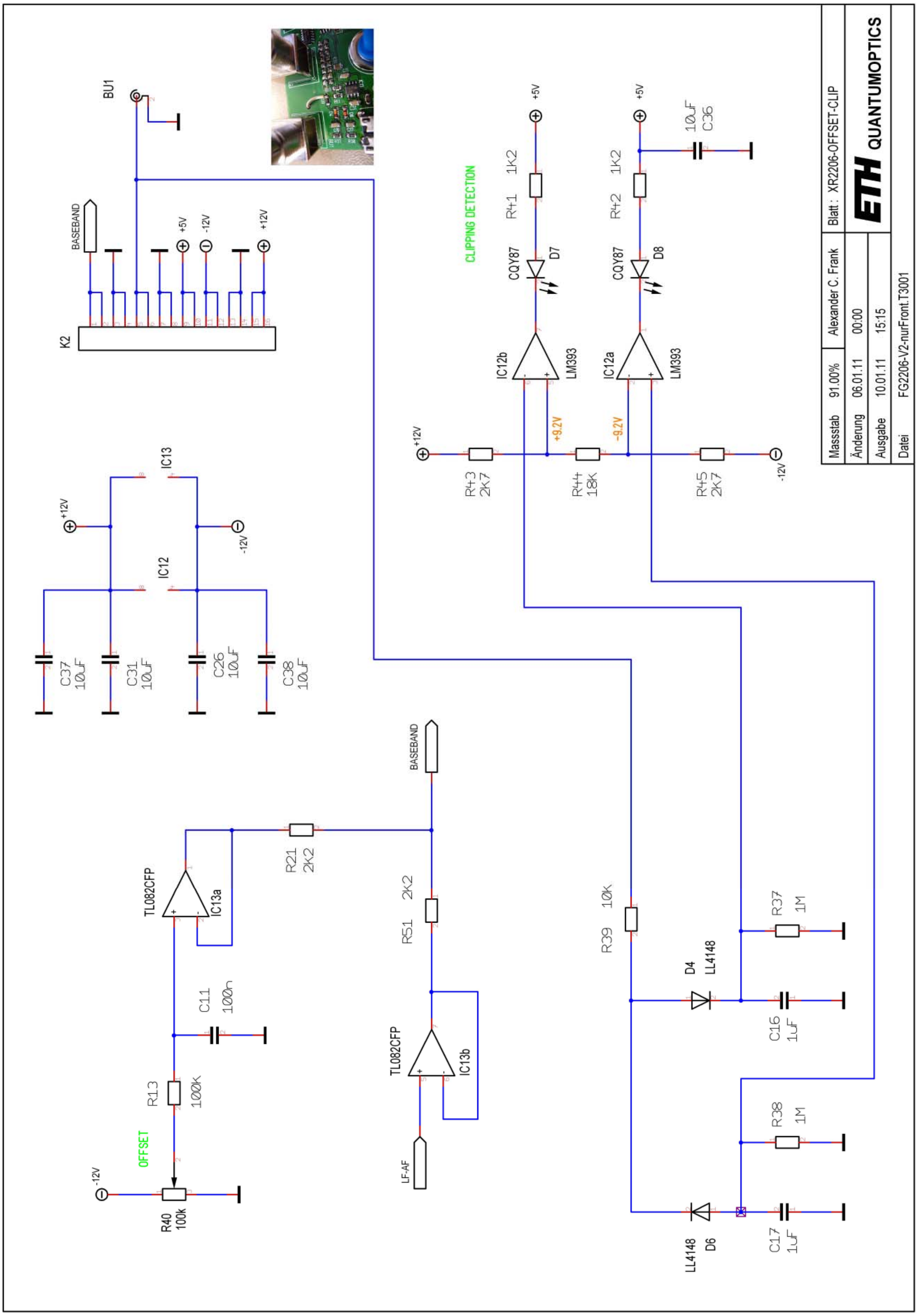
Power Supply



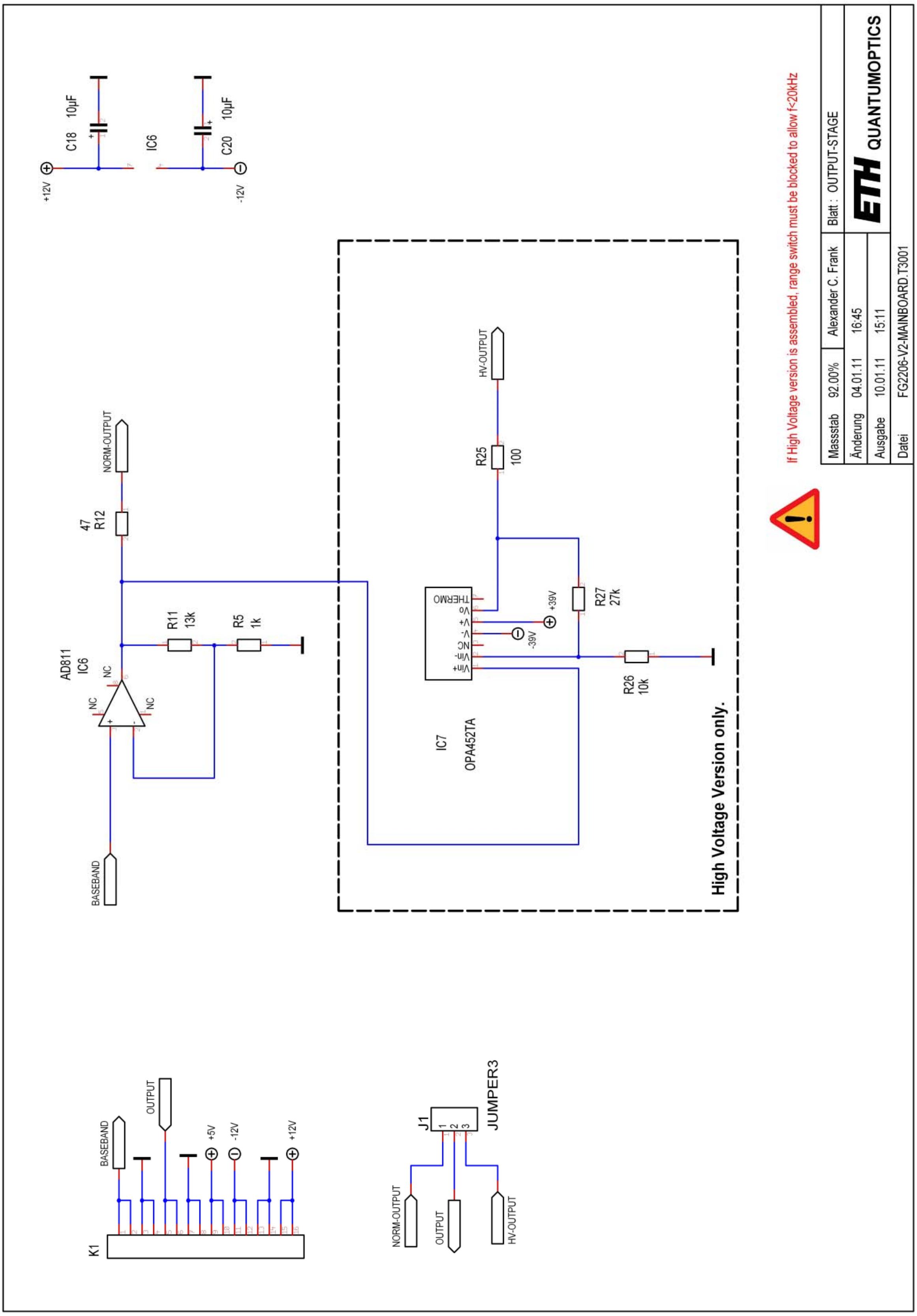
Function Generator



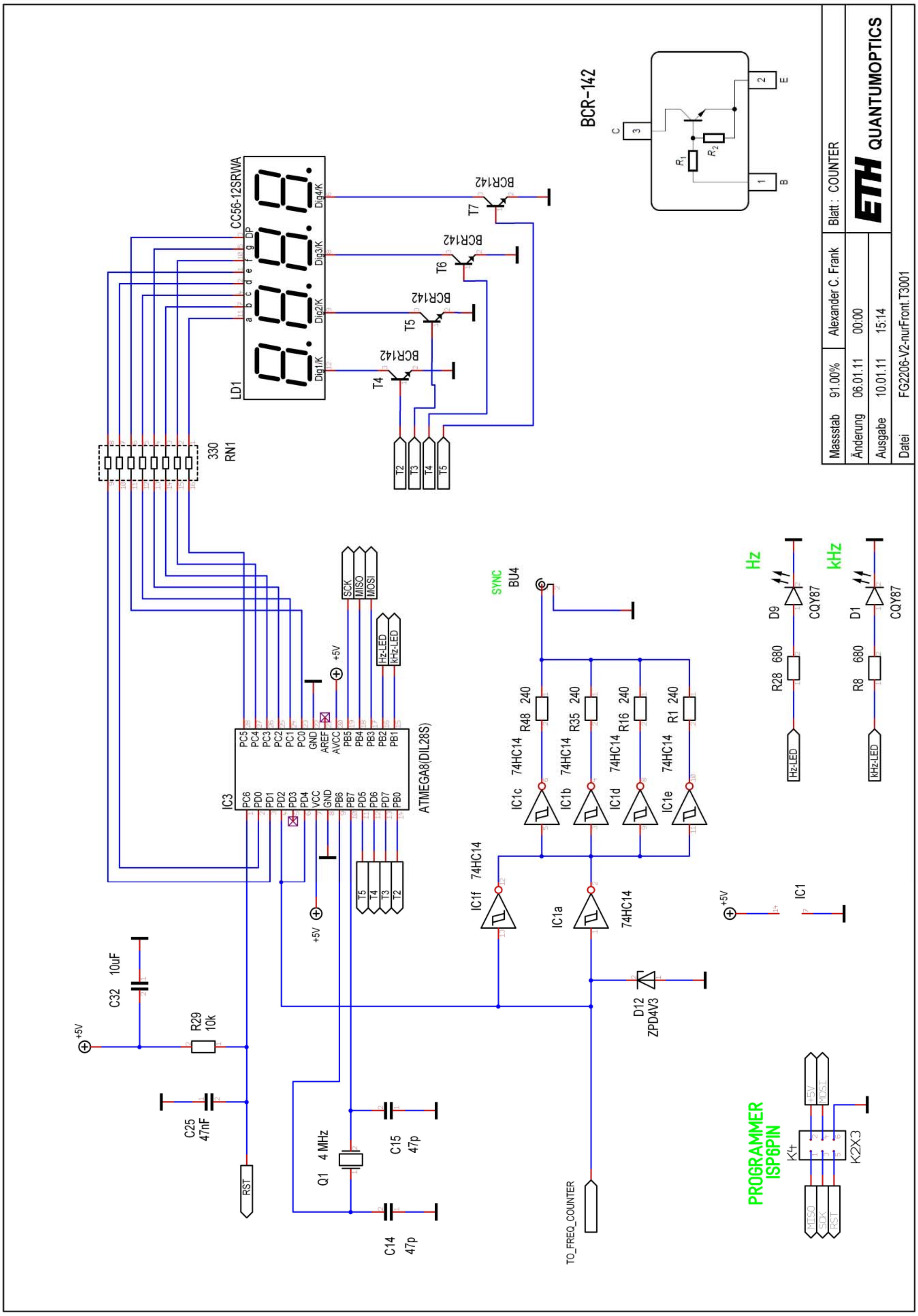
Clipping Detection



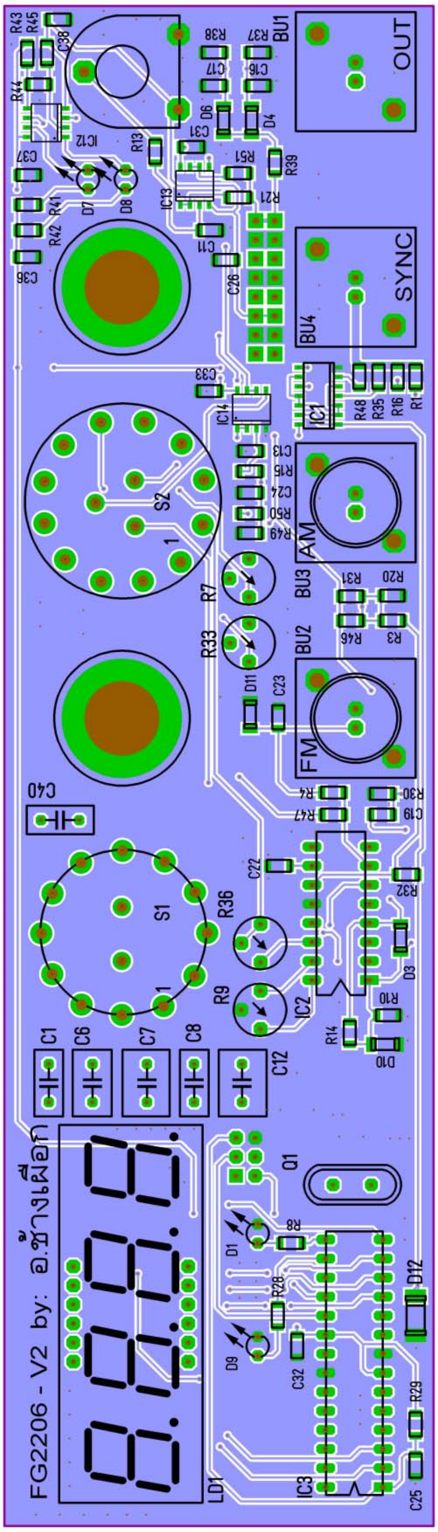
Final Amplifier

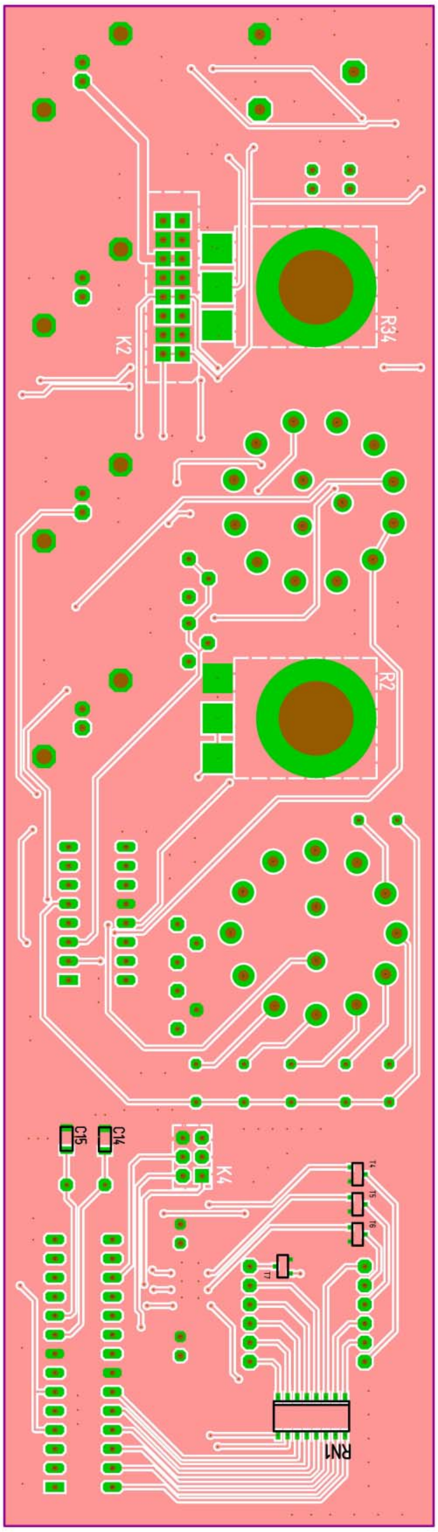


Frequency Counter

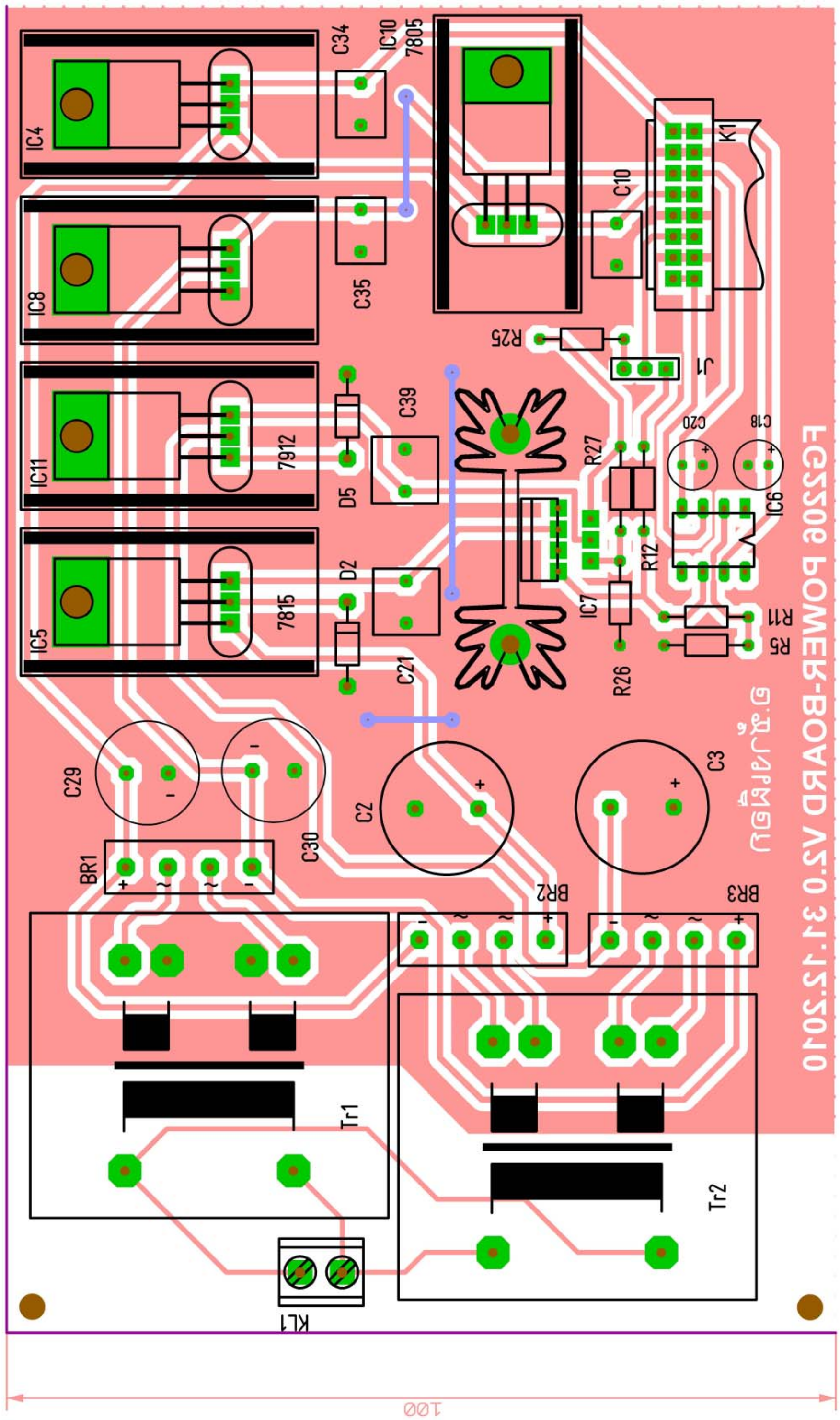


Placement : Frontpanel





Placement : Base PCB



BOM (Bill of Material) Mainboard

Pos	Name	Value	Case	Remark
1	BR1	GBU407	BRÜCKE6	
2	BR2	GBU407	BRÜCKE6	HV
3	BR3	GBU407	BRÜCKE6	HV
6	C2	1000µF/63V	D16R7,62_ELKO	HV
7	C3	1000µF/63V	D16R7,62_ELKO	HV
8	C10	1µF	8X8R5,08	
9	C18	10µF	D6R2,54_ELKO	
10	C20	10µF	D6R2,54_ELKO	
11	C21	1µF	8X8R5,08	
12	C29	1000µF/35V	C_ELKO_RM5,08_DM12,5	
13	C30	1000µF/35V	C_ELKO_RM5,08_DM12,5	
14	C34	1µF	8X8R5,08	
15	C35	1µF	8X8R5,08	
16	C39	1µF	8X8R5,08	
17	D2	24V	DO41	HV
18	D5	24V	DO41	HV
32	HEATSINK	KÜHLK13	KÜHLK13	
33	HEATSINK	KÜHLK13	KÜHLK13	
34	HEATSINK	KÜHLK13	KÜHLK13	
35	HEATSINK	KÜHLK13	KÜHLK13	
36	HEATSINK	KÜHLK13	KÜHLK13	HV
37	HEATSINK	KÜHLK13	KÜHLK13	HV
39	IC4	7812	TO220_LIEGEND	
40	IC5	7815	TO220_LIEGEND	
41	IC6	AD811	DIL8	
42	IC7	OPA452TA	TO220/7	
43	IC8	7912	TO220_LIEGEND	HV
44	IC10	7805	TO220_LIEGEND	
45	IC11	7915	TO220_LIEGEND	HV
46	J1	JUMPER3	1X03_BUCHSE	
47	K1	VERBINDER_2x8	VERBINDER_2X8	
48	KL1	KLEMME2POL	KLEMME2	
49	R5	1k	R4	
50	R11	13k	R4	
51	R12	47	R4	
52	R25	100	R4	
53	R26	10k	R4	
54	R27	27k	R4	
55	Tr1	EI38-SEK2X15V/107MA	TRAFO-EI38_1PRI-2SEK	
56	Tr2	EI38-SEK2X15V/107MA	TRAFO-EI38_1PRI-2SEK	HV

BOM (Bill of Material) Frontpanel

Pos	Name	Value	Case	Remark
3	BU1	BNC-BUCHSE_GERADE	BNC-BUCHSE_GERADE	
4	BU2	BNC-BUCHSE_GERADE	BNC-BUCHSE_GERADE	
5	BU3	BNC-BUCHSE_GERADE	BNC-BUCHSE_GERADE	
6	BU4	BNC-BUCHSE_GERADE	BNC-BUCHSE_GERADE	
7	C1	1nF	C2	MKS-2
8	C6	10nF	C2	MKS-2
9	C7	100nF	C2	MKS-2
10	C8	1uF	C2	MKS-2
11	C11	100n	1206	
12	C12	10uF	C2	MKS-2
13	C13	10uF	1206	
14	C14	47p	1206	
15	C15	47p	1206	
16	C16	1uF	1206	
17	C17	1uF	1206	
18	C19	10uF	1206	
19	C22	10uF	1206	
20	C23	10uF	1206	
21	C24	10uF	1206	
22	C25	47nF	1206	
23	C26	10uF	1206	
24	C27	470nF		
25	C28	100u		
26	C31	10uF	1206	
27	C32	10uF	1206	
28	C33	10uF	1206	
29	C36	10uF	1206	
30	C37	10uF	1206	
31	C38	10uF	1206	
32	C40	Reserve	C2	not used
33	D1	CQY87	LED_3MM_RM2,54	
34	D3	LL4148	MINIMELF	
35	D4	LL4148	MINIMELF	
36	D6	LL4148	MINIMELF	
37	D7	CQY87	LED_3MM_RM2,54	
38	D8	CQY87	LED_3MM_RM2,54	
39	D9	CQY87	LED_3MM_RM2,54	
40	D10	LL4148	MINIMELF	
41	D11	LL4148	MINIMELF	
42	D12	ZPD4V3	MELF	
55	R40	PT15LV	PT15LV	
57	IC1	74HC14	SO14	

58	IC2	XR2206	DIL16	
59	IC3	ATMEGA8(DIL28S)	DIL28S	
60	IC9	7805CT	TO-220	
61	IC12	LM393	SO8_SOT96-1	
62	IC13	TL082CFP	SO8_SOT96-1	
63	IC14	TL082CFP	SO8_SOT96-1	
64	K2	VERBINDER_2x8	VERBINDER_2X8	
65	K3	K1X02		
66	K4	K2X3	2X03_BUCHSE	ISP
67	LD1	CC56-12SRWA	CX56-12	distrelec 661271
68	Q1	4 MHz	HC49/U	
69	R1	240	1206	
70	R2	100k	POTI_ECW1J	
71	R3	3k0	1206	
72	R4	6k8	1206	
73	R7	50K	T7Y-47k	farnell: 114-1652
74	R8	680	1206	
75	R9	25k	T7Y-22k	farnell: 114-1651
76	R10	30k	1206	
77	R13	100k	1206	
78	R14	62k	1206	
79	R15	47	1206	
80	R16	240	1206	
81	R20	24k	1206	
82	R21	2k2	1206	
83	R28	680	1206	
84	R29	10k	1206	
85	R30	1k	1206	
86	R31	nb	1206	
87	R32	1k	1206	
88	R33	50K	T7Y-47k	farnell: 114-1652
89	R34	10k	POTI_ECW1J	
90	R35	240	1206	
91	R36	500	T7Y-470	farnell: 114-1644
92	R37	1M	1206	HV: 33k
93	R38	1M	1206	HV: 33k
94	R39	10k	1206	HV: 100k
95	R40	100k		
96	R41	1k2	1206	
97	R42	1k2	1206	
98	R43	2k7	1206	
99	R44	18k	1206	
100	R45	2k7	1206	
101	R46	4k7	1206	
102	R47	6k8	1206	
103	R48	240	1206	
104	R49	10k	1206	

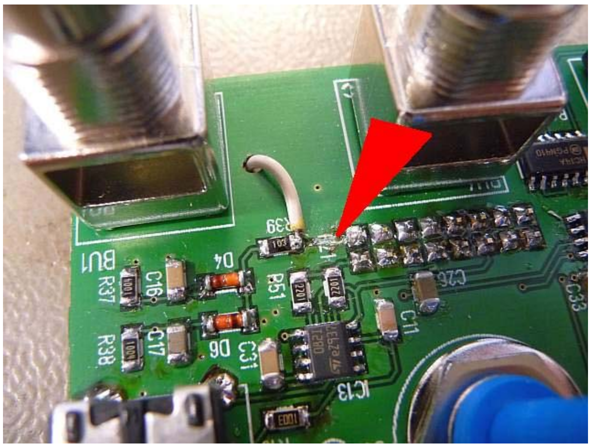
105	R50	10k	1206	
106	R51	2k2	1206	
107	RN1	330	SO16_SOT109-1	
108	S1	STUFENSCHALTER_2X6	DREH-2X6	
109	S2	STUFENSCHALTER_3X4	DREH-3X4	
110	T4	BCR142	SOT23/3	
111	T5	BCR142	SOT23/3	
112	T6	BCR142	SOT23/3	
113	T7	BCR142	SOT23/3	

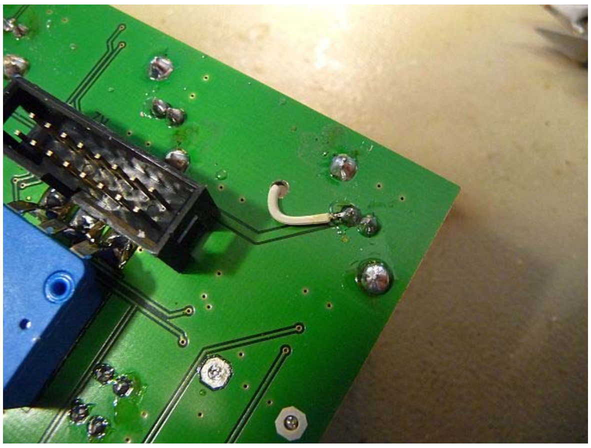
Notes:

1.) If you build the standard Version (100kHz, 20Vpp) it is not necessary to assemble the parts with the Remark "HV" (= High Voltage).

2.) If you build the High Voltage Version, you must change R39 from 10k to 100k. R37 and R38 from 1M to 33k. (Clipping Detector)

3.) In case you use the PCB from ELL, you must further make a changement of the layout. Cut the copper trace between R39 and K2 (Pin1,2). Solder a piece of wire from R39 to the output (on the back).





Setting up operation

As mentioned before, there are four points to calibrate.

Set the generator to "RECTANGLE"/ SQUAREWAVE and monitor the output on a scope.

In order to "see" something, set amplitude to about 50% and offset to about zero.

Measure the Voltage (peak-peak) of that signal.

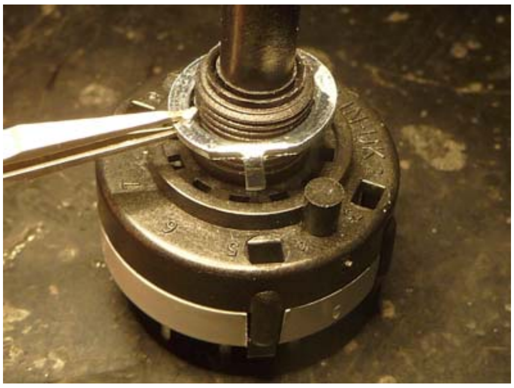
Now switch to TRIANGLE. Adjust the waveform with R9 and the Amplitude with R7 so that it has the same Amplitude as the rectangle/squarewave, measured before.

Now switch to SINE. Adjust the waveform with R36 and the Amplitude with R33 so that it has the same Amplitude as the rectangle/squarewave, measured before.

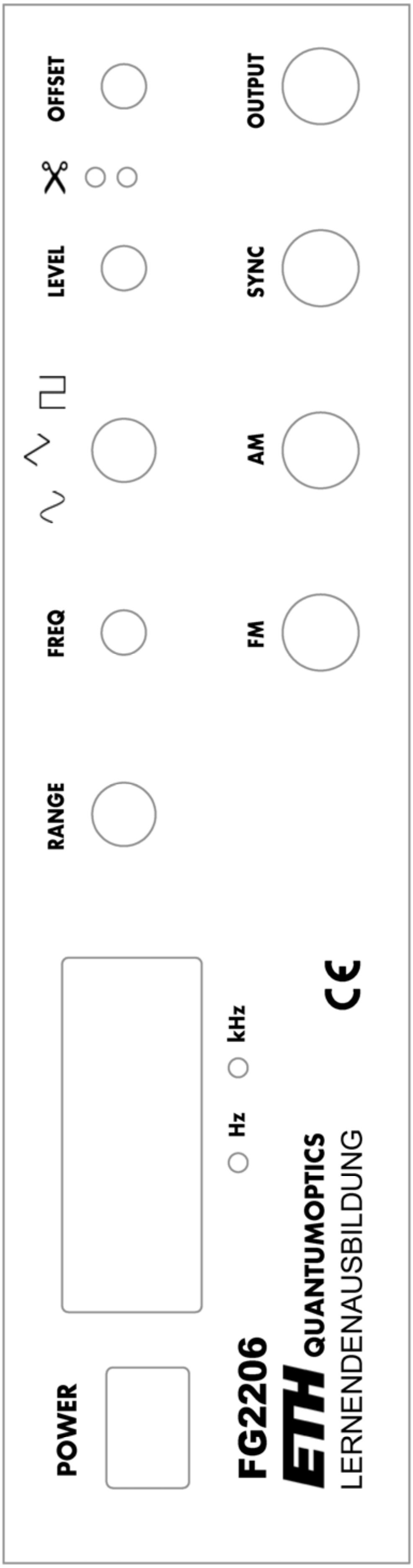
Make shure that the rotary switches can not be operated outside the designated range.

Turn them to the left mechanical stop. Place the limiting ring with the nose in position number 5 for the range switch and in position number 3 for the waveform switch.

Cut the bolt from the switch, so that the frontpanel rests planar on the switch.



Frontpanel


OFFSET
OUTPUT
LEVEL
SYNC
AM
FREQ
FM
RANGE
Hz
kHz
POWER
FG2206
ETH QUANTUMOPTICS
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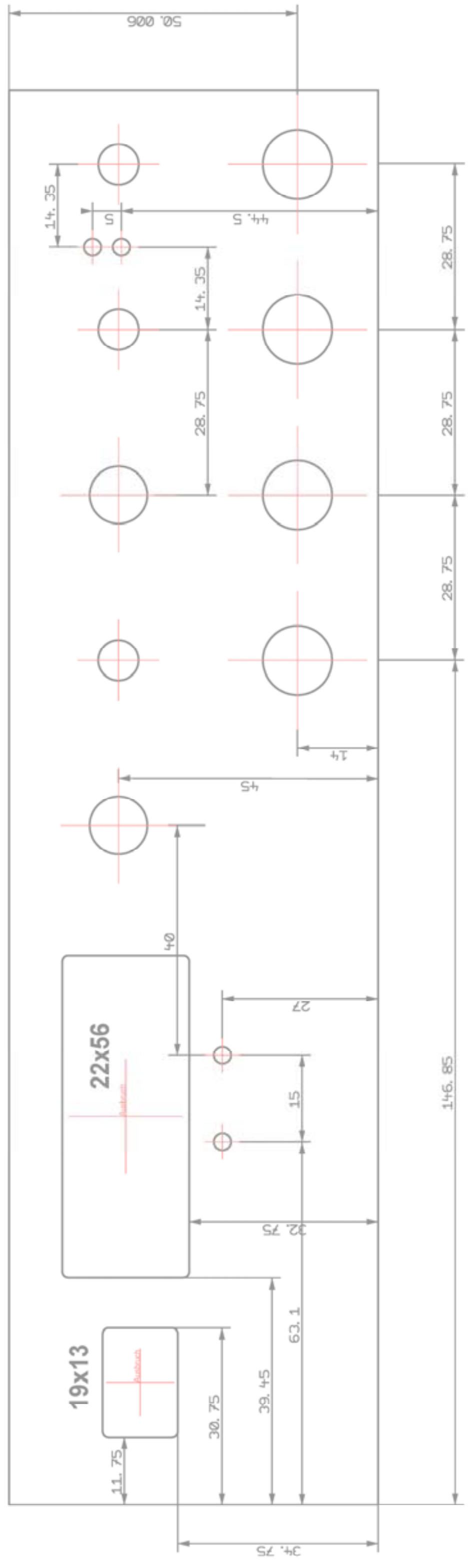

50.006
14.35
5
44.5
14.35
28.75
28.75
28.75
28.75
28.75
14
45
40
22x56
27
15
146.85
32.75
63.1
19x13
39.45
30.75
11.75
34.75

XR-2206
Monolithic Function Generator

February 2008-8

FEATURES

- Low-Sine Wave Distortion, 0.5%, Typical
- Excellent Temperature Stability, 20ppm/°C, Typ.
- Wide Sweep Range, 2000:1, Typical
- Low-Supply Sensitivity, 0.01%V, Typ.
- Linear Amplitude Modulation
- TTL Compatible FSK Controls
- Wide Supply Range, 10V to 26V
- Adjustable Duty Cycle, 1% TO 99%

APPLICATIONS

- Waveform Generation
- Sweep Generation
- AM/FM Generation
- V/F Conversion
- FSK Generation
- Phase-Locked Loops (VCO)

GENERAL DESCRIPTION

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 0.01Hz to more than 1MHz.

The circuit 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 20ppm/°C. The oscillator frequency can be linearly swept over a 2000:1 frequency range with an external control voltage, while maintaining low distortion.

ORDERING INFORMATION

Part No.	Package	Operating Temperature Range
XR-2206P	16 Lead 300 Mil PDIP	–40°C to +85°C
XR-2206CP	16 Lead 300 Mil PDIP	0°C to +70°C
XR-2206D	16 Lead 300 Mil JEDEC SOIC	0°C to +70°C

EXAR Corporation, 48720 Kato Road, Fremont, CA 94538 ◆ (510) 668-7000 ◆ (510) 668-7017

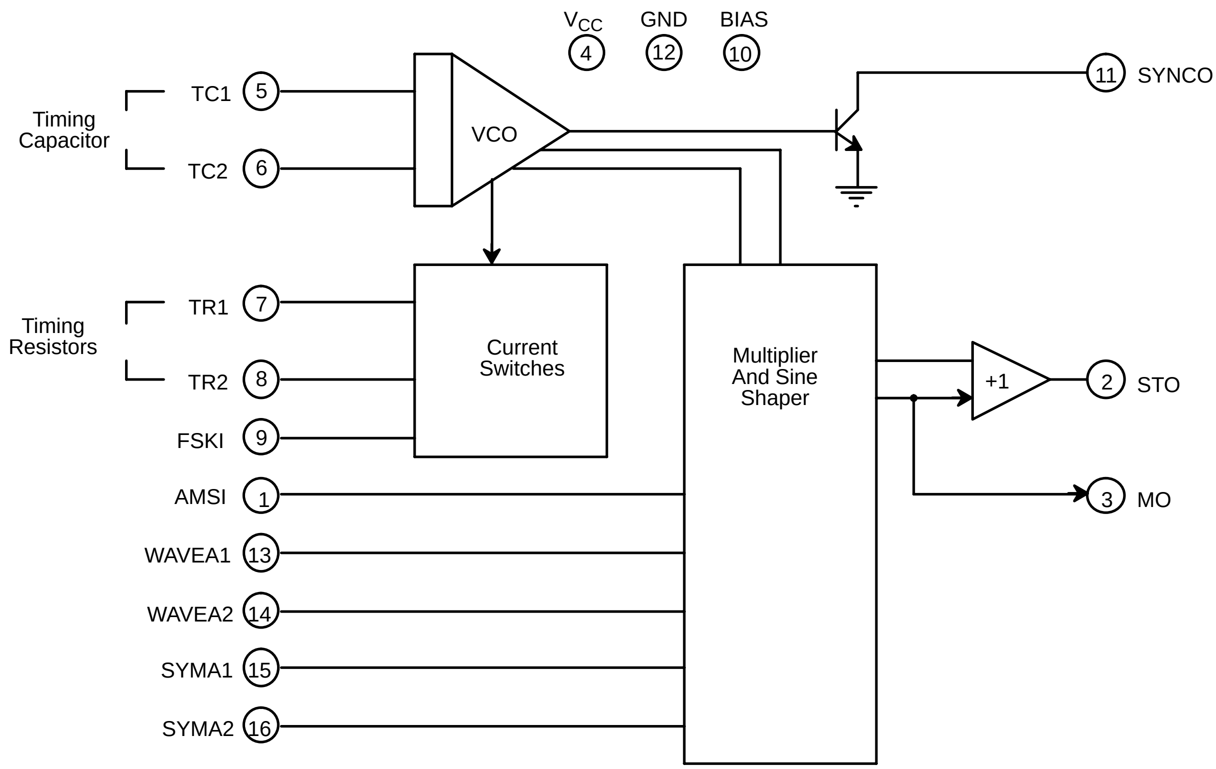
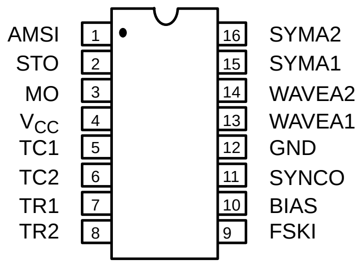
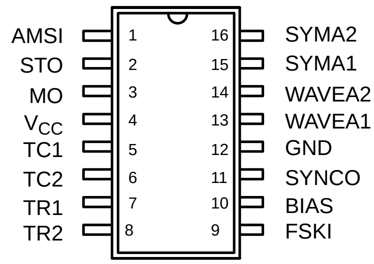


Figure 1. XR-2206 Block Diagram



16 Lead PDIP, CDIP (0.300")



16 Lead SOIC (Jedec, 0.300")

PIN DESCRIPTION

Pin #	Symbol	Type	Description
1	AMSI	I	**Amplitude Modulating Signal Input.**
2	STO	O	**Sine or Triangle Wave Output.**
3	MO	O	**Multiplier Output.**
4	V_{CC}		**Positive Power Supply.**
5	TC1	I	**Timing Capacitor Input.**
6	TC2	I	**Timing Capacitor Input.**
7	TR1	O	**Timing Resistor 1 Output.**
8	TR2	O	**Timing Resistor 2 Output.**
9	FSKI	I	**Frequency Shift Keying Input.**
10	BIAS	O	**Internal Voltage Reference.**
11	SYNCO	O	**Sync Output.** This output is a open collector and needs a pull up resistor to V_{CC}.
12	GND		**Ground pin.**
13	WAVEA1	I	**Wave Form Adjust Input 1.**
14	WAVEA2	I	**Wave Form Adjust Input 2.**
15	SYMA1	I	**Wave Symetry Adjust 1.**
16	SYMA2	I	**Wave Symetry Adjust 2.**

DC ELECTRICAL CHARACTERISTICS

Test Conditions: Test Circuit of *Figure 2* **Vcc = 12V, T_A = 25°C, C = 0.01μF, R_1 = 100kΩ, R_2 = 10kΩ, R_3 = 25kΩ**
Unless Otherwise Specified. S_1 open for triangle, closed for sine wave.

Parameters	XR-2206P			XR-2206CP/D			Units	Conditions
	Min.	Typ.	Max.	Min.	Typ.	Max.		
General Characteristics								
Single Supply Voltage	**10**		**26**	10		26	V	
Split-Supply Voltage	**±5**		**±13**	±5		±13	V	
Supply Current		12	**17**		14	20	mA	$R_1 \geq 10k\Omega$
Oscillator Section								
Max. Operating Frequency	**0.5**	1		0.5	1		MHz	C = 1000pF, R_1 = 1kΩ
Lowest Practical Frequency		0.01			0.01		Hz	C = 50μF, R_1 = 2MΩ
Frequency Accuracy		±1	**±4**		±2		% of f_o	$f_o = 1/R_1C$
Temperature Stability Frequency		±10	**±50**		±20		ppm/°C	$0°C \leq T_A \leq 70°C$ $R_1 = R_2 = 20k\Omega$
Sine Wave Amplitude Stability[2]		4800			4800		ppm/°C	
Supply Sensitivity		0.01	**0.1**		0.01		%/V	V_{LOW} = 10V, V_{HIGH} = 20V, $R_1 = R_2 = 20k\Omega$
Sweep Range	1000:1	2000:1			2000:1		$f_H = f_L$	f_H @ R_1 = 1kΩ f_L @ R_1 = 2MΩ
Sweep Linearity								
10:1 Sweep		2			2		%	f_L = 1kHz, f_H = 10kHz
1000:1 Sweep		8			8		%	f_L = 100Hz, f_H = 100kHz
FM Distortion		0.1			0.1		%	±10% Deviation
Recommended Timing Components								
Timing Capacitor: C	**0.001**		100	0.001		100	μF	*Figure 5*
Timing Resistors: R_1 & R_2	**1**		2000	1		2000	kΩ	
Triangle Sine Wave Output[1]								*Figure 3*
Triangle Amplitude		160			160		mV/kΩ	*Figure 2,* S_1 Open
Sine Wave Amplitude	**40**	60	80		60		mV/kΩ	*Figure 2*, S_1 Closed
Max. Output Swing		6			6		Vp-p	
Output Impedance		600			600		Ω	
Triangle Linearity		1			1		%	
Amplitude Stability		0.5			0.5		dB	For 1000:1 Sweep
Sine Wave Distortion								
Without Adjustment		2.5			2.5		%	R_1 = 30kΩ
With Adjustment		0.4	**1.0**		0.5	1.5	%	See *Figure 7* and *Figure 8*

Notes
[1] *Output amplitude is directly proportional to the resistance, R_3, on Pin 3. See Figure 3.*
[2] *For maximum amplitude stability, R_3 should be a positive temperature coefficient resistor.*
***Bold face parameters** are covered by production test and guaranteed over operating temperature range.*

DC ELECTRICAL CHARACTERISTICS (CONT'D)

Parameters	XR-2206P			XR-2206CP/D			Units	Conditions
	Min.	Typ.	Max.	Min.	Typ.	Max.		
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								
Amplitude		12			12		Vp-p	Measured at Pin 11.
Rise Time		250			250		ns	C_L = 10pF
Fall Time		50			50		ns	C_L = 10pF
Saturation Voltage		0.2	**0.4**		0.2	0.6	V	I_L = 2mA
Leakage Current		0.1	**20**		0.1	100	μA	V_{CC} = 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.

Notes
[1] Output amplitude is directly proportional to the resistance, R_3, on Pin 3. See Figure 3.
[2] For maximum amplitude stability, R_3 should be a positive temperature coefficient resistor.
***Bold face parameters** are covered by production test and guaranteed over operating temperature range.*

Specifications are subject to change without notice

ABSOLUTE MAXIMUM RATINGS

Power Supply 26V
Power Dissipation 750mW
Derate Above 25°C . . . . 5mW/°C
Total Timing Current 6mA
Storage Temperature . . . . -65°C to +150°C

SYSTEM DESCRIPTION

The XR-2206 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 VCO produces an output frequency proportional to an input current, which is set by a resistor from the timing terminals to ground. With two timing pins, two discrete output frequencies can be independently produced for FSK generation applications by using the FSK input control pin. This input controls the current switches which select one of the timing resistor currents, and routes it to the VCO.

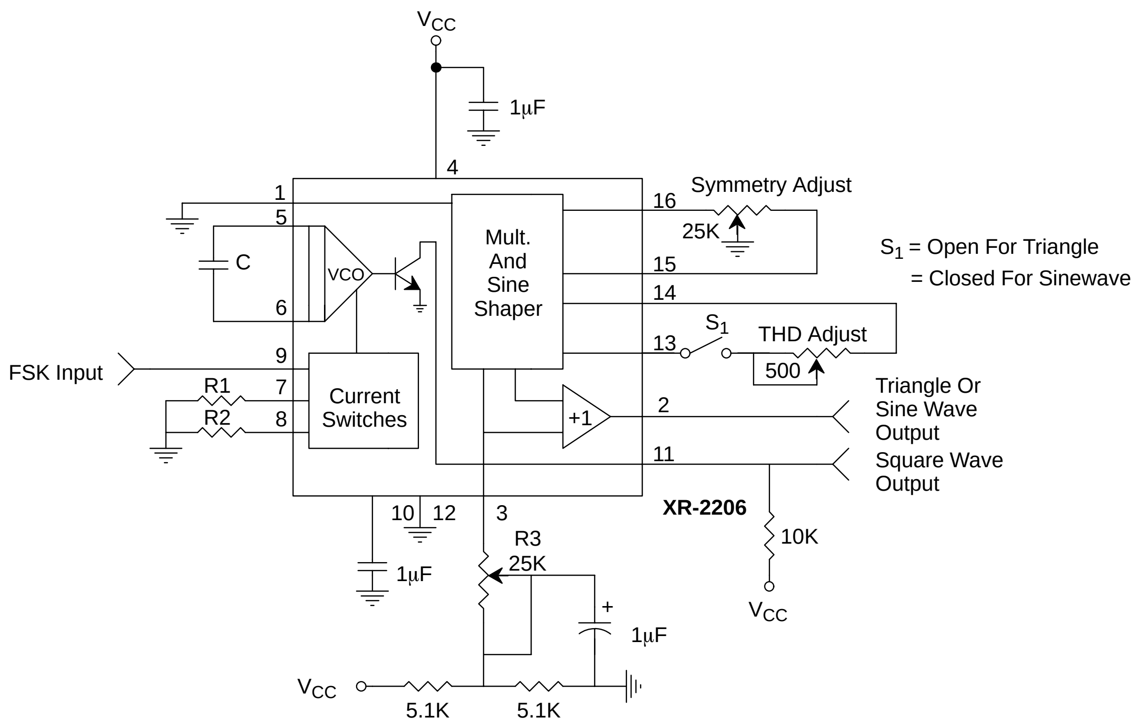


Figure 2. Basic Test Circuit

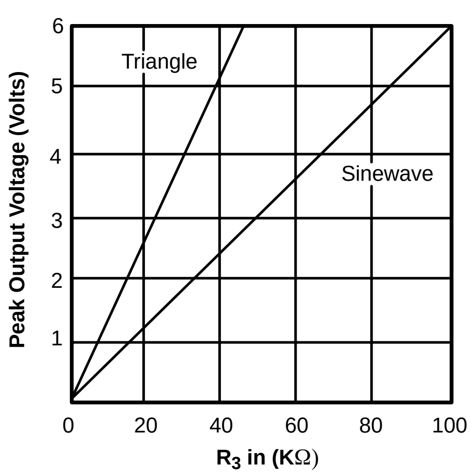


Figure 3. Output Amplitude as a Function of the Resistor, R3, at Pin 3

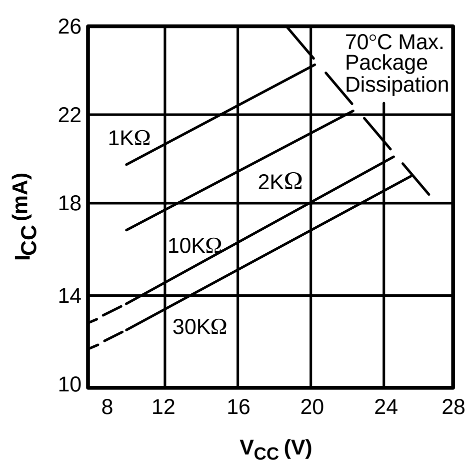


Figure 4. Supply Current vs Supply Voltage, Timing, R

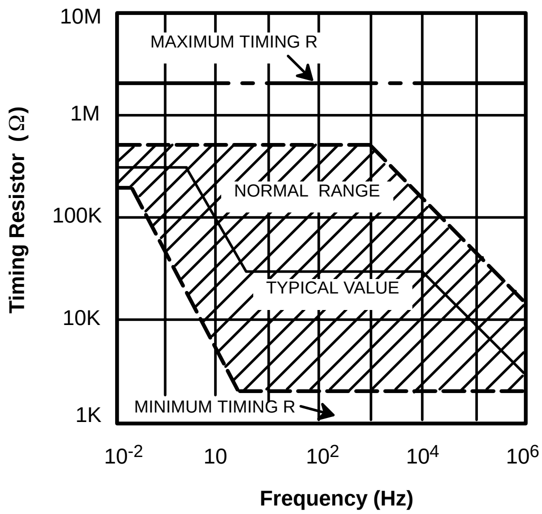


Figure 5. R versus Oscillation Frequency.

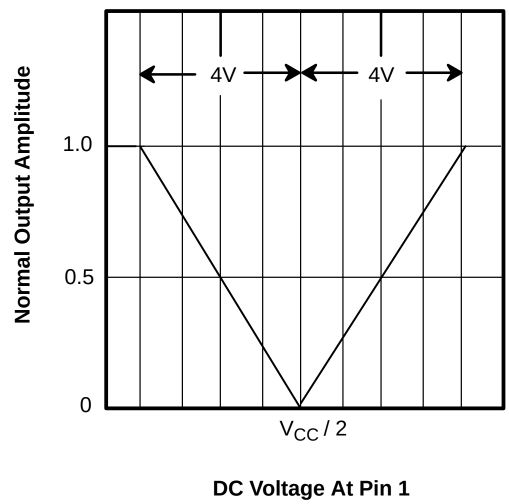


Figure 6. Normalized Output Amplitude versus DC Bias at AM Input (Pin 1)

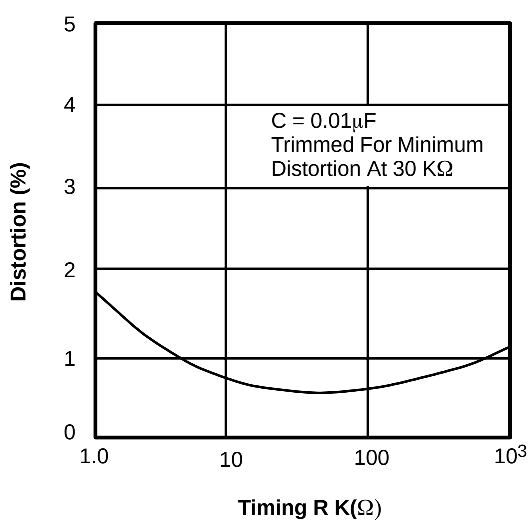


Figure 7. Trimmed Distortion versus Timing Resistor.

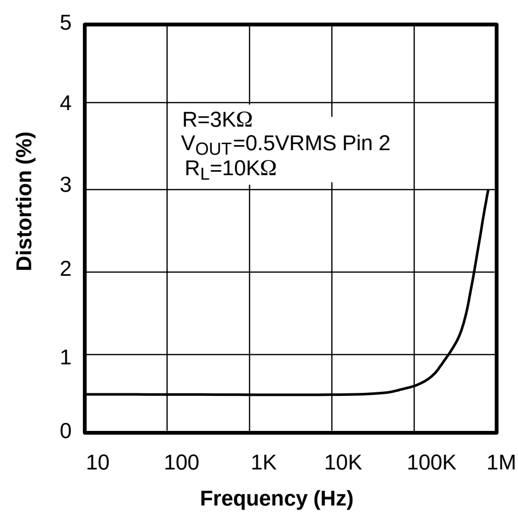


Figure 8. Sine Wave Distortion versus Operating Frequency with Timing Capacitors Varied.

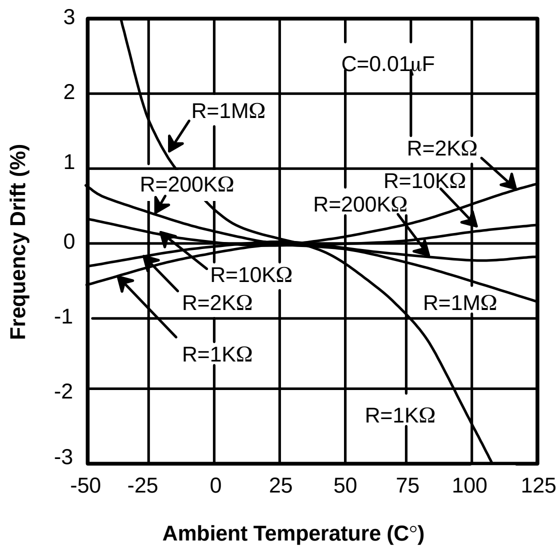


Figure 9. Frequency Drift versus Temperature.

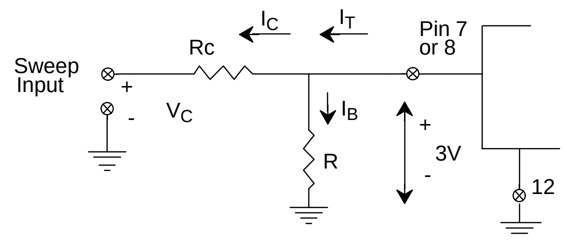


Figure 10. Circuit Connection for Frequency Sweep.

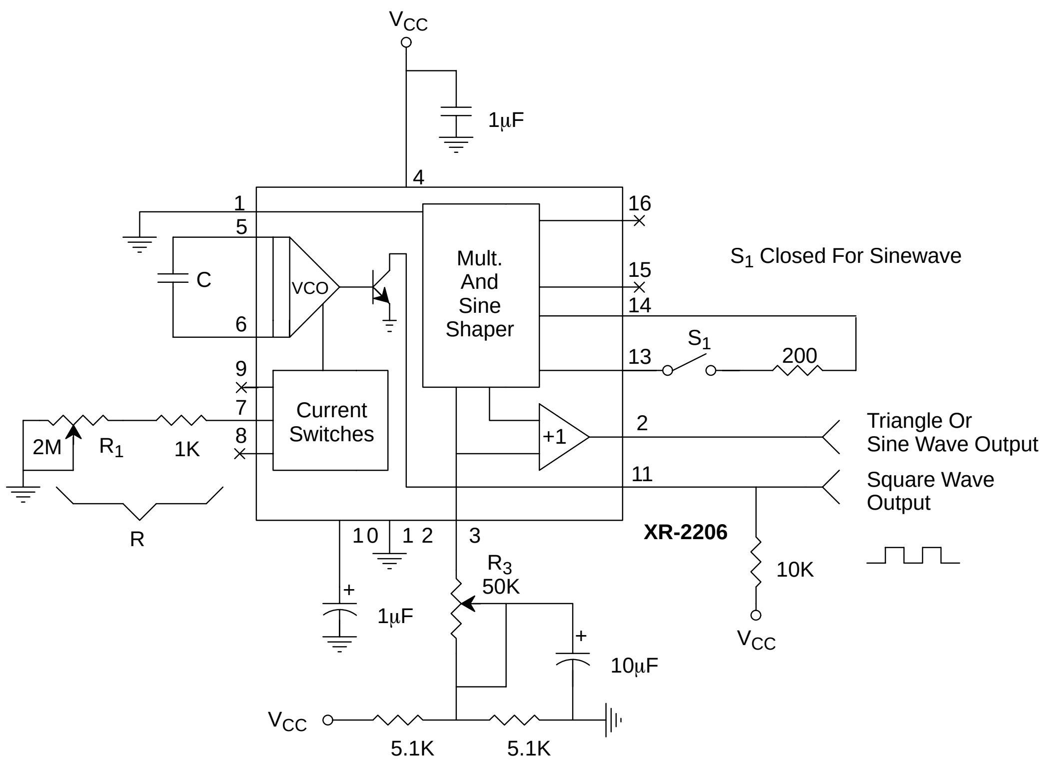


Figure 11. Circuit tor Sine Wave Generation without External Adjustment. (See *Figure 3* for Choice of R_3)

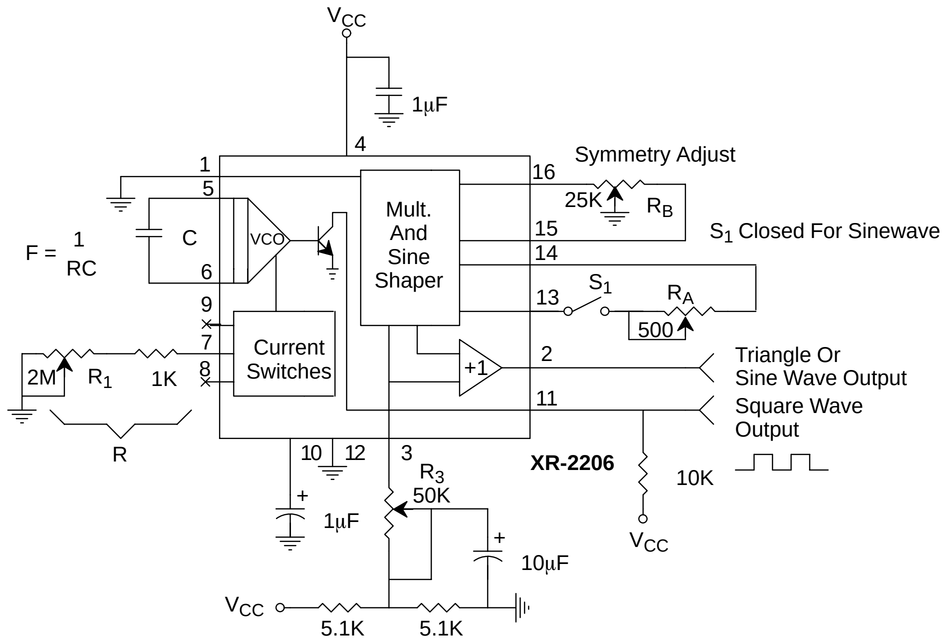


Figure 12. Circuit for Sine Wave Generation with Minimum Harmonic Distortion. (R_3 Determines Output Swing - See *Figure 3*)

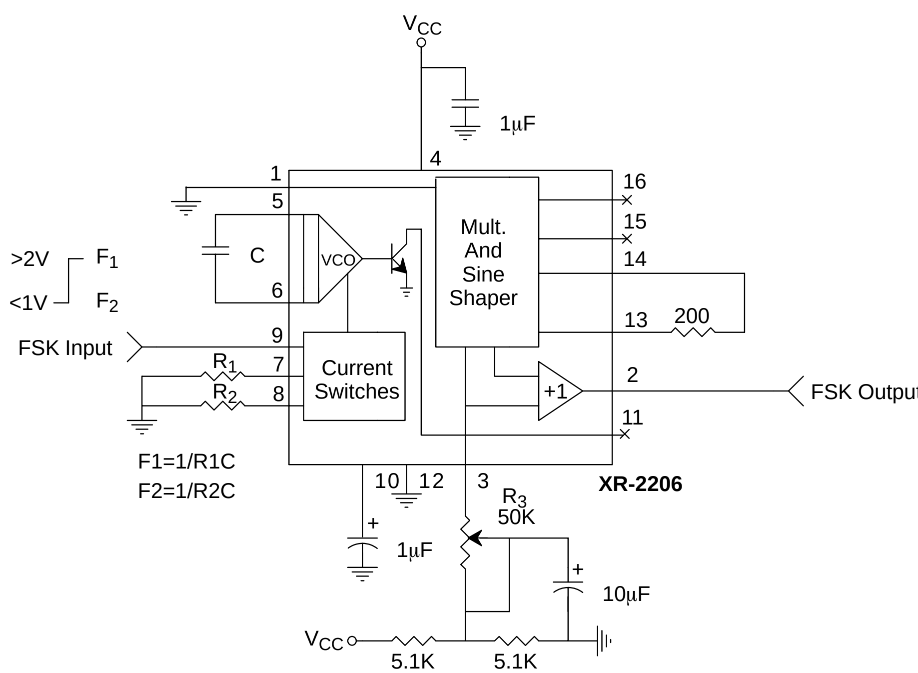


Figure 13. Sinusoidal FSK Generator

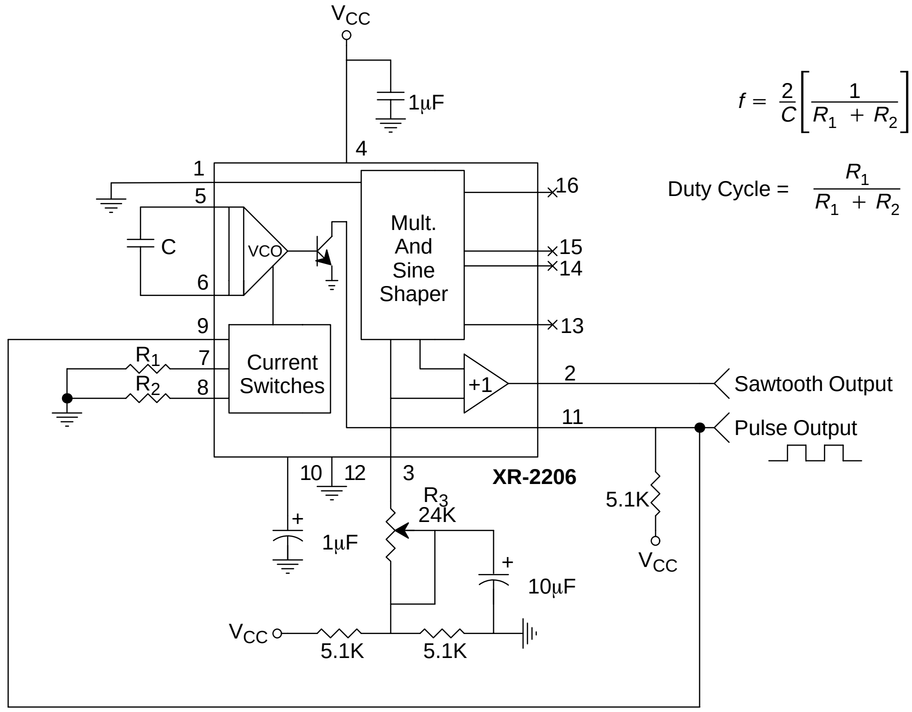


Figure 14. Circuit for Pulse and Ramp Generation.

Frequency-Shift Keying

The XR-2206 can be operated with two separate timing resistors, R_1 and R_2, connected to the timing Pin 7 and 8, respectively, as shown in *Figure 13.* Depending on the polarity of the logic signal at Pin 9, either one or the other of these timing resistors is activated. If Pin 9 is open-circuited or connected to a bias voltage $\geq$ 2V, only R_1 is activated. Similarly, if the voltage level at Pin 9 is $\leq$1V, only R_2 is activated. Thus, the output frequency can be keyed between two levels. f_1 and f_2, as:

$f_1 = 1/R_1C$ and $f_2 = 1/R_2C$

For split-supply operation, the keying voltage at Pin 9 is referenced to V^-.

Output DC Level Control

The dc level at the output (Pin 2) is approximately the same as the dc bias at Pin 3. In *Figure 11*, *Figure 12* and *Figure 13*, Pin 3 is biased midway between V+ and ground, to give an output dc level of $\approx V^+/2$.

APPLICATIONS INFORMATION

Sine Wave Generation

Without External Adjustment

Figure 11 shows the circuit connection for generating a sinusoidal output from the XR-2206. The potentiometer, R_1 at Pin 7, provides the desired frequency tuning. The maximum output swing is greater than $V^+/2$, and the typical distortion (THD) is < 2.5%. If lower sine wave distortion is desired, additional adjustments can be provided as described in the following section.

The circuit of *Figure 11* can be converted to split-supply operation, simply by replacing all ground connections with V^-. For split-supply operation, R_3 can be directly connected to ground.

With External Adjustment:

The harmonic content of sinusoidal output can be reduced to -0.5% by additional adjustments as shown in *Figure 12.* The potentiometer, R_A, adjusts the sine-shaping resistor, and R_B provides the fine adjustment for the waveform symmetry. The adjustment procedure is as follows:

1. Set R_B at midpoint and adjust R_A for minimum distortion.
2. With R_A set as above, adjust R_B to further reduce distortion.

Triangle Wave Generation

The circuits of *Figure 11* and *Figure 12* can be converted to triangle wave generation, by simply open-circuiting Pin 13 and 14 (i.e., S_1 open). Amplitude of the triangle is approximately twice the sine wave output.

FSK Generation

Figure 13 shows the circuit connection for sinusoidal FSK signal operation. Mark and space frequencies can be independently adjusted by the choice of timing resistors, R_1 and R_2; the output is phase-continuous during transitions. The keying signal is applied to Pin 9. The circuit can be converted to split-supply operation by simply replacing ground with V^-.

Pulse and Ramp Generation

Figure 14 shows the circuit for pulse and ramp waveform generation. In this mode of operation, the FSK keying terminal (Pin 9) is shorted to the square-wave output (Pin 11), and the circuit automatically frequency-shift keys itself between two separate frequencies during the positive-going and negative-going output waveforms. The pulse width and duty cycle can be adjusted from 1% to 99% by the choice of R_1 and R_2. The values of R_1 and R_2 should be in the range of 1kΩ to 2MΩ.

PRINCIPLES OF OPERATION

Description of Controls

Frequency of Operation:

The frequency of oscillation, f_o, is determined by the external timing capacitor, C, across Pin 5 and 6, and by the timing resistor, R, connected to either Pin 7 or 8. The frequency is given as:

$$f_0 = \frac{1}{RC}\ Hz$$

and can be adjusted by varying either R or C. The recommended values of R, for a given frequency range, as shown in *Figure 5.* Temperature stability is optimum for 4kΩ < R < 200kΩ. Recommended values of C are from 1000pF to 100µF.

Frequency Sweep and Modulation:

Frequency of oscillation is proportional to the total timing current, I_T, drawn from Pin 7 or 8:

$$f = \frac{320 I_T(mA)}{C(\mu F)}\ Hz$$

Timing terminals (Pin 7 or 8) are low-impedance points, and are internally biased at +3V, with respect to Pin 12. Frequency varies linearly with IT, over a wide range of current values, from 1µA to 3mA. The frequency can be controlled by applying a control voltage, V_C, to the activated timing pin as shown in *Figure 10.* The frequency of oscillation is related to VC as:

$$f = \frac{1}{RC}\left(1 + \frac{R}{R_C}\left(1 - \frac{V_C}{3}\right)\right) Hz$$

where V_C is in volts. The voltage-to-frequency conversion gain, K, is given as:

$$K = \partial f / \partial V_C = -\frac{0.32}{R_C C}\ \ Hz/V$$

CAUTION: *For safety operation of the circuit, I_T should be limited to $\leq$ 3mA.*

Output Amplitude:

Maximum output amplitude is inversely proportional to the external resistor, R_3, connected to Pin 3 (see *Figure 3*). For sine wave output, amplitude is approximately 60mV peak per kΩ of R_3; for triangle, the peak amplitude is approximately 160mV peak per kΩ of R_3. Thus, for example, R_3 = 50kΩ would produce approximately 13V sinusoidal output amplitude.

Amplitude Modulation:

Output amplitude can be modulated by applying a dc bias and a modulating signal to Pin 1. The internal impedance at Pin 1 is approximately 100kΩ. Output amplitude varies linearly with the applied voltage at Pin 1, for values of dc bias at this pin, within 14 volts of $V_{CC}/2$ as shown in *Figure 6.* As this bias level approaches $V_{CC}/2$, the phase of the output signal is reversed, and the amplitude goes through zero. This property is suitable for phase-shift keying and suppressed-carrier AM generation. Total dynamic range of amplitude modulation is approximately 55dB.

CAUTION: *AM control must be used in conjunction with a well-regulated supply, since the output amplitude now becomes a function of* V_{CC}.

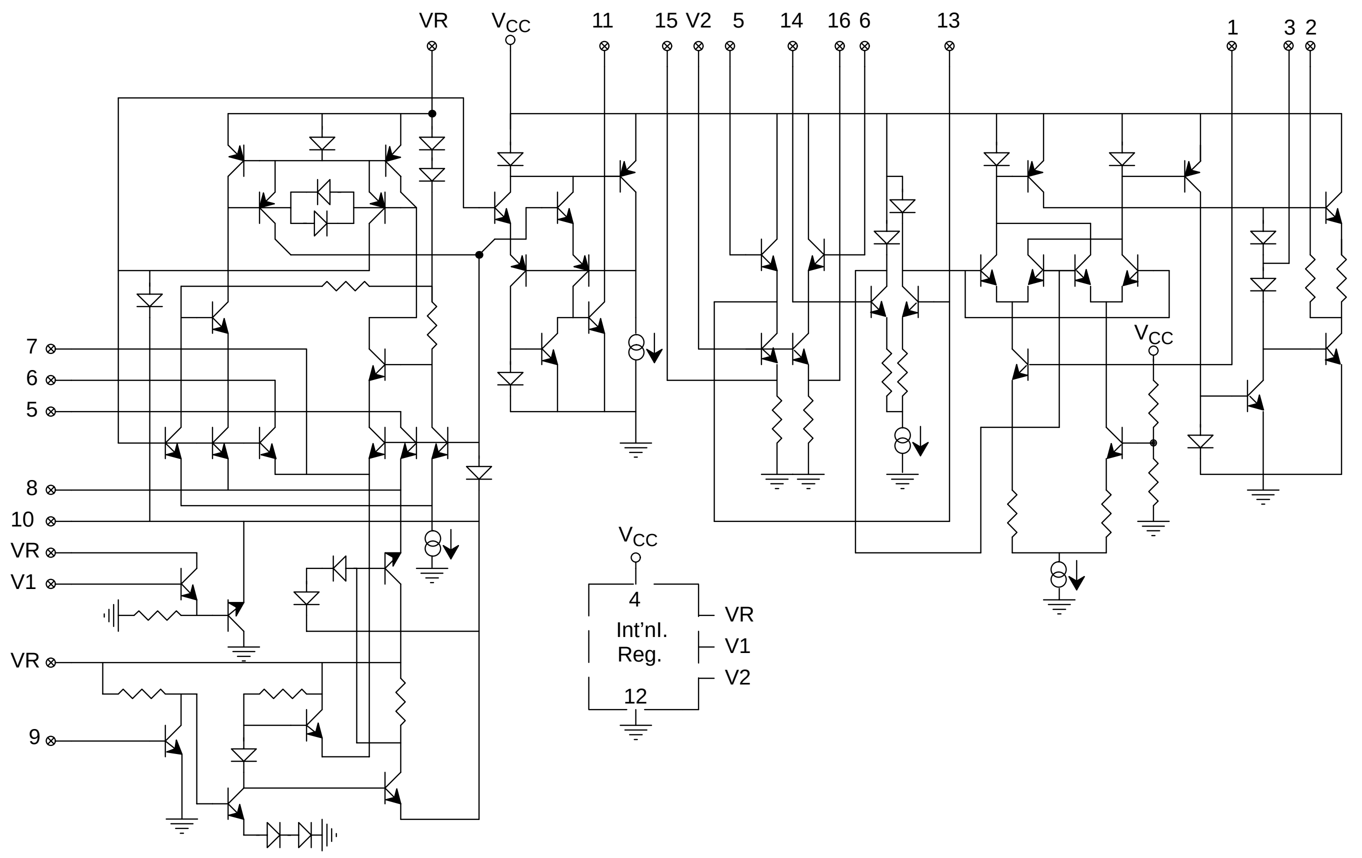
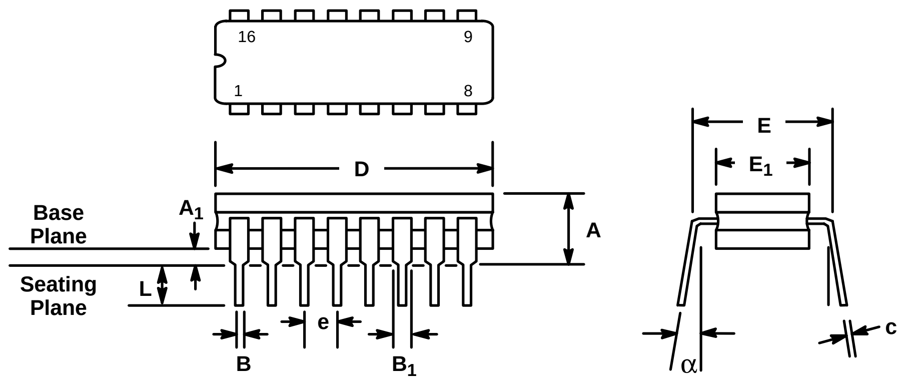


Figure 15. Equivalent Schematic Diagram

16 LEAD CERAMIC DUAL-IN-LINE
(300 MIL CDIP)

Rev. 1.00

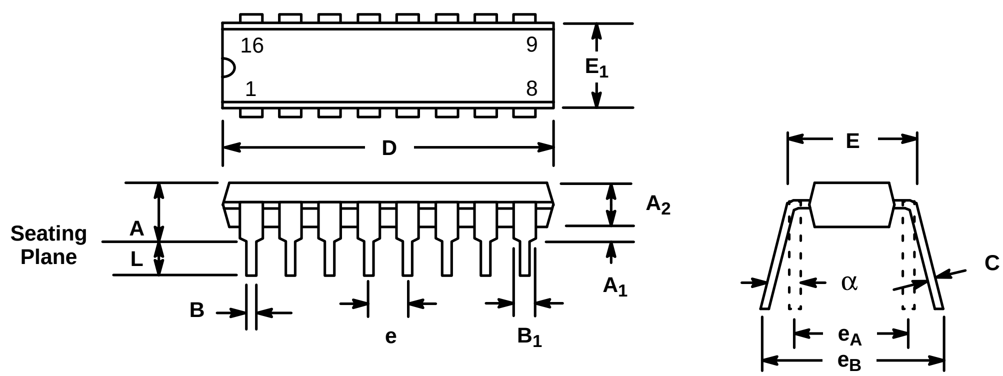


SYMBOL	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.100	0.200	2.54	5.08
A_1	0.015	0.060	0.38	1.52
B	0.014	0.026	0.36	0.66
B_1	0.045	0.065	1.14	1.65
c	0.008	0.018	0.20	0.46
D	0.740	0.840	18.80	21.34
E_1	0.250	0.310	6.35	7.87
E	0.300 BSC		7.62 BSC	
e	0.100 BSC		2.54 BSC	
L	0.125	0.200	3.18	5.08
α	0°	15°	0°	15°

Note: The control dimension is the inch column

16 LEAD PLASTIC DUAL-IN-LINE
(300 MIL PDIP)

Rev. 1.00

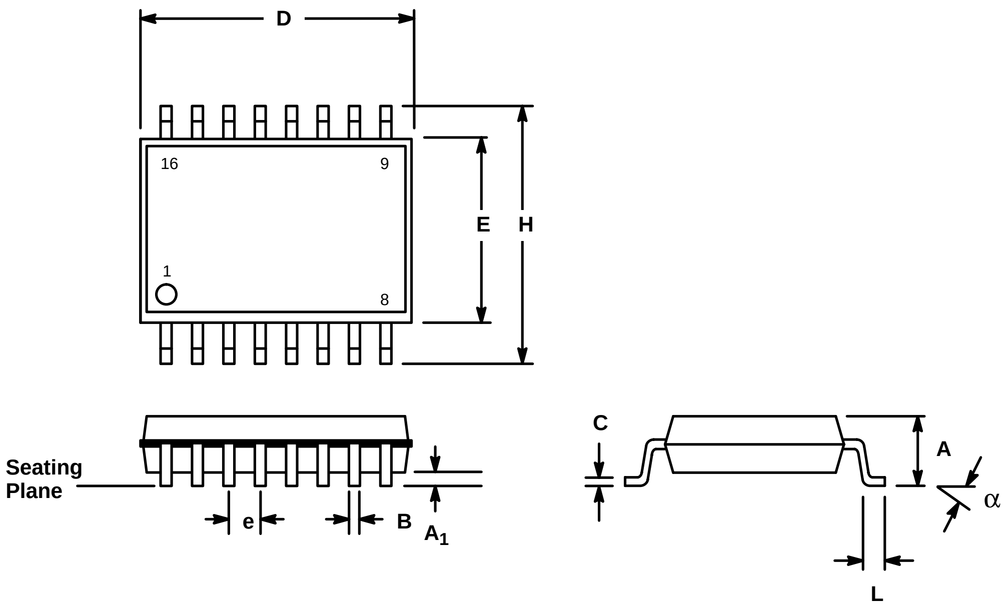


SYMBOL	INCHES MIN	INCHES MAX	MILLIMETERS MIN	MILLIMETERS MAX
A	0.145	0.210	3.68	5.33
A_1	0.015	0.070	0.38	1.78
A_2	0.115	0.195	2.92	4.95
B	0.014	0.024	0.36	0.56
B_1	0.030	0.070	0.76	1.78
C	0.008	0.014	0.20	0.38
D	0.745	0.840	18.92	21.34
E	0.300	0.325	7.62	8.26
E_1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
e_A	0.300 BSC		7.62 BSC	
e_B	0.310	0.430	7.87	10.92
L	0.115	0.160	2.92	4.06
α	0°	15°	0°	15°

Note: The control dimension is the inch column

16 LEAD SMALL OUTLINE (300 MIL JEDEC SOIC)

Rev. 1.00



SYMBOL	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.093	0.104	2.35	2.65
A_1	0.004	0.012	0.10	0.30
B	0.013	0.020	0.33	0.51
C	0.009	0.013	0.23	0.32
D	0.398	0.413	10.10	10.50
E	0.291	0.299	7.40	7.60
e	0.050 BSC		1.27 BSC	
H	0.394	0.419	10.00	10.65
L	0.016	0.050	0.40	1.27
α	0°	8°	0°	8°

Note: The control dimension is the millimeter column

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TAN-005

High-Quality Function Generator System with the XR-2206

June 1997-3

INTRODUCTION

Waveform or function generators capable of producing AM/FM modulated sine wave outputs find a wide range of applications in electrical measurement and laboratory instrumentation. This application note describes the design, construction and performance of such a complete function generator system suitable for laboratory usage or hobbyist applications. The entire function generator is comprised of a single XR-2206 monolithic IC and a limited number of passive circuit components. It provides the engineer, student, or hobbyist with a highly versatile laboratory instrument for waveform generation, at a very small fraction of the cost of conventional function generators available today.

GENERAL DESCRIPTION

The basic circuit configuration and the external components necessary for the high-quality function generator system is shown in *Figure 1.* The circuit shown is designed to operate with either a 12V single power supply, or with 16V split supplies. For most applications, split-supply operation is preferred since it results in an output dc level which is nearly at ground potential.

The circuit configuration of *Figure 1* provides three basic waveforms: sine, triangle and square wave. There are four overlapping frequency ranges which give an overall frequency range of 1Hz to 100KHz. In each range, the frequency may be varied over a 100:1 tuning range.

The sine or triangle output can be varied from 0 to over 6V (peak to peak) from a 600Ω source at the output terminal.

A squarewave output is available at the sync output terminal for oscilloscope synchronizing or driving logic circuits.

TYPICAL PERFORMANCE CHARACTERISTICS

The performance characteristics listed are not guaranteed or warranted by EXAR Corporation. However, they represent the typical performance characteristics measured by EXAR's application engineers during the laboratory evaluation of the function generator system shown in *Figure 1.* The typical performance specifications listed below apply only when all of the recommended assembly instructions and adjustment procedures are followed:

(a) **Frequency Ranges:** The function generator system is designed to operate over four overlapping frequency ranges:

1Hz	to	100Hz
10Hz	to	1KHz
100Hz	to	10KHz
1KHz	to	100KHz

The range selection is made by switching in different timing capacitors.

(b) **Frequency Setting:** At any range setting, frequency can be varied over a 100:1 tuning range with a potentiometer (see R13 of *Figure 1.*)

(c) **Frequency Accuracy:** Frequency accuracy of the XR-2206 is set by the timing resistor R and the timing capacitor C, and is given as:

$$f = 1/RC$$

The above expression is accurate to within 15% at any range setting. The timing resistor R is the series combination of resistors R4 and R13 of *Figure 1.* The timing capacitor C is any one of the capacitors C3 through C6, shown in the figure.

(d) **Sine and Triangle Output:** The sine and triangle output amplitudes are variable from 0V to 6Vpp. The amplitude is set by an external potentiometer, R12 of *Figure 1.* At any given amplitude setting, the triangle output amplitude is approximately twice as high as the sinewave output. The internal impedance of the output is 600Ω.

EXAR Corporation, 48720 Kato Road, Fremont, CA 94538 ◆ (510) 668-7000 ◆ FAX (510) 668-7017

(e) **Sinewave Distortion:** The total harmonic distortion of sinewave is less than 1% from 10Hz to 10KHz and less than 3% over the entire frequency range. The selection of a waveform is made by the triangle/sine selector switch, S2.

(f) **Sync Output:** The sync output provides a 50% duty cycle pulse output with either full swing or upper half swing of the supply voltage depending on the choice of sync output terminals on the printed circuit board (see *Figure 1.*)

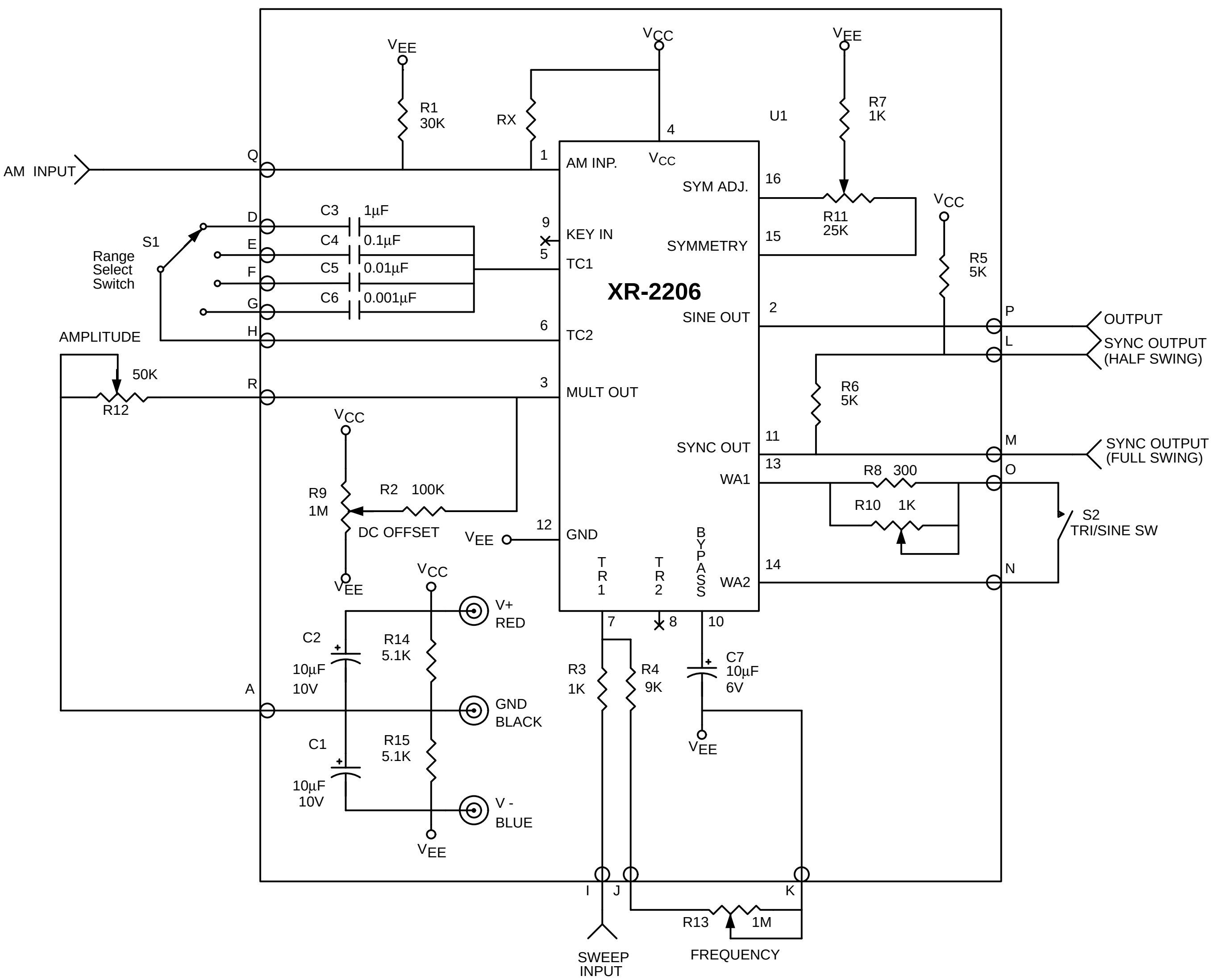


Figure 1. Circuit Connection Diagram for Function Generator (See (i) for Single Supply Operation)

g) **Frequency Modulation (External Sweep):** Frequency can be modulated or swept by applying an external control voltage to sweep terminal (Terminal I of *Figure 1.*) When not used, this terminal should be left open circuited. The open circuit voltage at this terminal is approximately 3V above the negative supply voltage and its impedance is approximately 1000Ω.

(h) **Amplitude Modulation:** The output amplitude varies linearly with modulation voltage applied to AM input (terminal Q of *Figure 1.*) The output amplitude reaches its minimum as the AM control voltage approaches the half of the total power supply voltage. The phase of the output signal reverses as the amplitude goes through its minimum value. The total dynamic range is approximately 55dB, with AM control voltage range of 4V referenced to the half of the total supply voltage. When not used, AM terminal should be left open-circuited.

(i) **Power Source: Split Supplies:** +/-6V, or single supply: +12V. Supply Current 15mA (see *Figure 2*). For single supply operation bias resistors, R14 and R15 should be added, the GND point left floating and V-tied to ground.

EXPLANATION OF CIRCUIT CONTROLS

Switches

Range Select Switch, S1: Selects the frequency range of operation for the function generator. The frequency is inversely proportional to the timing capacitor connected across Pins 5 and 6 of the XR-2206 circuit. Nominal capacitance values and frequency ranges corresponding to switch positions of S1 are as follows:

Position	Nominal Range	Timing Capacitance
1	1Hz to 100Hz	1μF
2	10Hz to 1KHz	0.1μF
3	100Hz to 10KHz	0.01μF
4	1Hz to 100kHz	0.001μF

If additional frequency ranges are needed, they can be added by introducing additional switch positions.

Triangle/Sine Waveform Switch, S2: Selects the triangle or sine output waveform.

Trimmers and Potentiometers

DC Offset Adjustment, R9: The potentiometer used for adjusting the dc offset level of the triangle or sine output waveform.

Sinewave Distortion Adjustment, R10: Adjusted to minimize the harmonic content of sinewave output.

Sinewave Symmetry Adjustment, R11: Adjusted to optimize the symmetry of the sinewave output.

Amplitude Control, R12: Sets the amplitude of the triangle or sinewave output.

Frequency Adjust, R13: Sets the oscillator frequency for any range setting of S1. Thus, R13 serves as a frequency dial on a conventional waveform generator and varies the frequency of the oscillator over an approximate 100 to 1 range.

Terminals

A. Negative Supply -6V
B. Ground
C. Positive Supply +6V
D. Range 1, timing capacitor terminal
E. Range 2, timing capacitor terminal
F. Range 3. timing capacitor terminal
G. Range 4, timing capacitor terminal
H. Timing capacitor common terminal
I. Sweep Input
J. Frequency adjust potentiometer terminal
K. Frequency adjust potentiometer negative supply terminal
L. Sync output (1/2 swing)
M. Sync output (full swing)
N. Triangle/sine waveform switch terminals
O. Triangle/sine waveform switch terminals
P. Triangle or sinewave output
Q. AM input
R. Amplitude control terminal

PARTS LIST

The following is a list of external circuit components necessary to provide the circuit interconnections shown in *Figure 1.*

Capacitors:

C1, C2, C7	Electrolytic, 10µF, 10V
C3	Mylar, 1µF, nonpolar, 10%
C4	Mylar, 0.1µF, 10%
C5	Mylar, 0.01µF, 10%
C6	Mylar, 1000pF, 10%

Resistors:

R1	30KΩ, 1/4 W, 10%
R2	100KΩ, 1/4 W, 10%
R3, R7	1KΩ, 1/4 W, 10%
R4	9KΩ, 1/4 W, 10%
R5, R6	5KΩ, 1/4 W. 10%
R8	300KΩ,1/4 W, 10%
RX	62KΩ, 1/4 W, 10% (RX can be eliminated for maximum output)

The following two resistors are used in single supply applications:

R14, R15	5.1KΩ, 1/4 W 10%

Potentiometers:

R9	Trim, 1MΩ, 1/4 W
R10	Trim, 1KΩ, 1/4 W
R11	Trim, 25KΩ, 1/4 W

The following additional items are recommended to convert the circuit of *Figure 1* to a complete laboratory instrument:

Potentiometers:

R12	Amplitude control, linear, 50KΩ
R13	Frequency control, audio taper, 1MΩ

Switches:

S1	Rotary switch, 1-pole, 4 positions
S2	Toggle or slide, SPST

Power Supply:

Dual supplies 16V or single +12V

Batteries or power supply unit

(See *Figure 2 (a)* and *Figure 2 (b)*.)

Miscellaneous:

Knobs, solder, wires, terminals, etc.

BOARD LAYOUT

Care should be given to the layout of the board, to prevent noise from the supplies from affecting the XR-2206 performance.

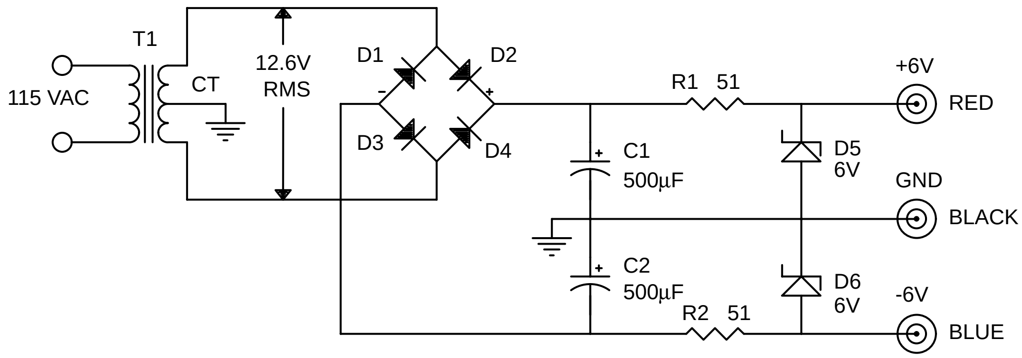
Any simple power supply having reasonable regulation may be used. *Figure 2* gives some recommended power supply configurations.

Precaution: Keep the lead lengths small for the range selector switch. This will reduce stray capacitance.

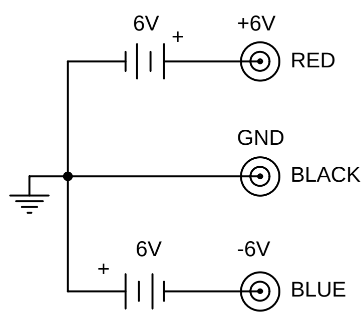
ADJUSTMENT PROCEDURE

When assembly is completed and you are ready to put the function generator into operation, make sure that the polarity of power supply and the orientation of the IC unit are correct. Then apply the dc power to the unit.

To adjust for minimum distortion, connect the scope probe to the triangle/sine output. Close S2 and adjust the amplitude control to give non-clipping maximum swing. Then adjust R10 and R11 alternately for minimum distortion by observing the sinusoidal waveform. If a distortion meter is available, you may use it as a final check on the setting of sine-shaping trimmers. The minimum distortion obtained in this manner is typically less than 1% from 1Hz to 10KHz and less than 3% over the entire frequency range.



(a) Zener Regulated Supply



(b) Battery Power Supply

T1: Filament Transformer (Primary 115V Secondary 12.6 VCT 0.5A)

D1 - D4: 1N4001 or Similar

D5, D6: 1N4735 or Similar

R1, R2: 51Ω, 1/2W, 10%

Figure 2. Recommended Power Supply Configurations

Notes

Notes