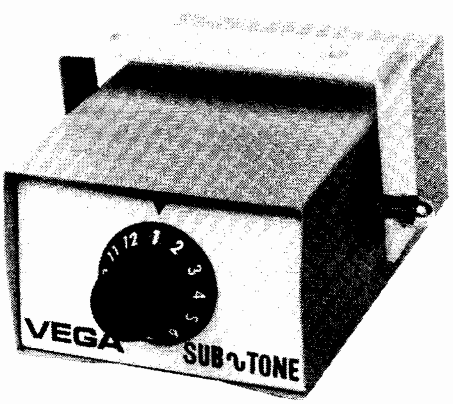
SERIES 280 SUB~TONE® CONTINUOUS TONE CONTROL/SQUELCH ENCODERS AND ENCODER/DECODERS PRODUCT DESCRIPTION AND INSTALLATION INFORMATION

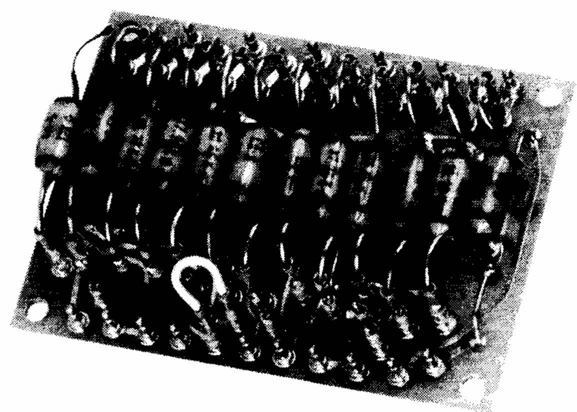
MODEL 281 TUNEABLE CTCSS ENCODER

MODEL 282 TUNEABLE CTCSS ENCODER/DECODER



MODEL 283 2 TO 12 TONE CTCSS ENCODER

MODEL 284 2 TO 12 TONE CTCSS ENCODER/DECODER



MODEL 9005102 THROUGH 9005112 MULTI-FREQUENCY SELECTOR ASSEMBLY

VEGA ELECTRONICS

A DIVISION OF COMPUTER EQUIPMENT CORPORATION

SUB~TONE ADVANCED CONTINUOUS TONE SQUELCH FEATURES

All electronic continuous tone-controlled squelch encoders and encoder/decoders exceed all applicable EIA CTCSS standards.

Continuously tunable throughout entire 33-tone channel 67 to 251Hz frequency range via a self-contained 20-turn precision trim pot.

No need for plug-in unreliable reeds or frequency control networks.

Compatible with G. E. 'Channel Guard', Motorola 'Private Line', RCA 'Quiet Channel', and other two-way radio manufacturers' CTCSS systems.

Addition of multi-frequency selector assembly adapts basic single-frequency models for switched two-to-twelve tone capability.

Select desired radio repeater, dispatcher or remote control function with multi-frequency SUB~TONE.

SUB~TONE is the most economical multi-frequency CTCSS approach known.

Product line includes circuit board models for radio inboard mounting plus attractively styled encased models for under dash or table-top mounting.

Silicon operational circuits maintain high performance under severe land-mobile environments.

INTRODUCTION

Vega SUB~TONE continuous tone squelch maintains a radio system silenced to annoying interference. SUB~TONE is easily adapted to any FM two-way radio system regardless of make or age. Each transmitter in the radio system is modulated by a precise low-frequency tone generated by a SUB~TONE encoder or encoder/decoder. Each protected receiver in the system is squelched by a SUB~TONE decoder. Interference is not heard, but the decoder unsquelches the receiver when a signal modulated by the correct tone frequency is received. The operator may defeat tone protection at any time by activating a mike hook switch or 'monitor' switch.

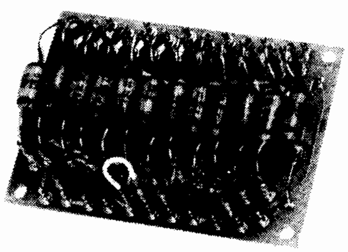
Selective signaling or control is achieved by equipping the SUB~TONE encoder with a multi-frequency selector assembly. The operator, via a rotary or pushbutton switch, selects the transmitted tone frequency. At the receiving end of the system each controlled device is equipped with a SUB~TONE decoder tuned to one of the unique encode frequencies.

A SUB~TONE encoder/decoder may also be adapted for switched multi-frequency operation by the addition of a multi-frequency selector assembly. Both encode and decode frequencies are identical as both are controlled by the same active filter circuit. Encoder and decoder boards can be grouped for a multi-function access or co-op repeater tone panel. SUB~TONE and Vega Pulse-Tone or Page~Alert can be combined in a single system package. Vega's Applications Engineering Department is staffed to provide customer support services for special requirements.

SUB~TONE MODELS

MODEL 281 - Encoder circuit board measures 2" x 2.75" x .9" high; is supplied with universal mounting bracket, mounting hardware and three-foot interconnect cable terminated in stripped and tinned leads. A popular economy application is one-way tone protection where all models are equipped to transmit but not receive tone, and only the dispatcher or repeater receiver is decoder protected.

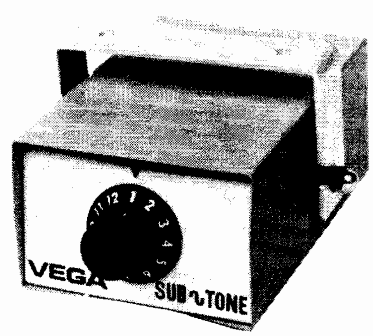
MODEL 282 - Encoder/decoder circuit board measures 3.25" x 3.50" x .9" high; is supplied with universal mounting bracket, mounting hardware and three-foot interconnect cable terminated in stripped and tinned leads. The circuit automatically switches from a receiver protecting decoder to a tone generating encoder when the transmitter is keyed. The encoder section need not be used for an application requiring a decoder only.



9005102 - through 9005112 - (Two-frequency) through (twelve-frequency) multi-frequency selector assembly adapts a 281 or 282 circuit board for switched multi-frequency operation. The board measures 2" x 2.75" x .9" high; is supplied with universal mounting bracket, mounting hardware and three-foot interconnect cable terminated in stripped and tinned leads. It may also be ordered already mounted and interconnected to a 281 encoder. Each frequency is controlled by a plug-on precision resistor. The low output impedance amplifier is strappable for either flat or 6 db/octave de-emphasis response. A rotary or pushbutton frequency selector switch must be ordered separately if not customer supplied. A multi-frequency selector assembly employing a precision trim pot to control each frequency is available on special order.

MODEL 283 - Multi-frequency encoder is housed in attractively styled case that is suitable for dashboard or table-top mounting. Frequency is controlled via a front panel two-to-twlve position rotary switch. Internal electronics consists of a 281 encoder circuit board interconnected to a 90051XX multi-frequency selector assembly. The Model 283 is supplied with mounting hardware and a three-foot interconnect cable terminated in stripped and tinned leads.

MODEL 284 - Multi-frequency encoder/decoder is identical to Model 283 except that a 282 encoder/decoder circuit board is employed instead of the 281.



9005160 - Metal case houses and protects a 281 or 282 circuit board when outboard mounting is required due to insufficient mounting space within the radio case.

ELECTRICAL SPECIFICATIONS

SUPPLY VOLTAGE RANGE	10 to 18V DC positive or negative ground	FREQUENCY RANGE	Continuously tunable from 67 to 251Hz
CURRENT DRAIN	Approximately 15ma @ 13V	FREQUENCY STABILITY	± .25% over specified voltage and operating temperature range
OPERATING TEMPERATURE RANGE	-30° to $+70^{\circ}$ C.		

ENCODER SPECIFICATIONS

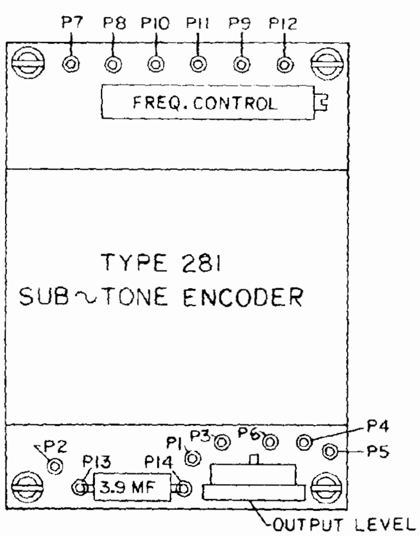
TONE OUTPUT LEVEL	Continuously adjustable from 0 to 1.6V RMS	HARMONIC DISTORTION	THD less than 2%
OUTPUT LEVEL STABILITY	±2db over specified voltage and operating temperature range	TURN-ON TIME	Less than 30 milliseconds (For encoder/decoder models)

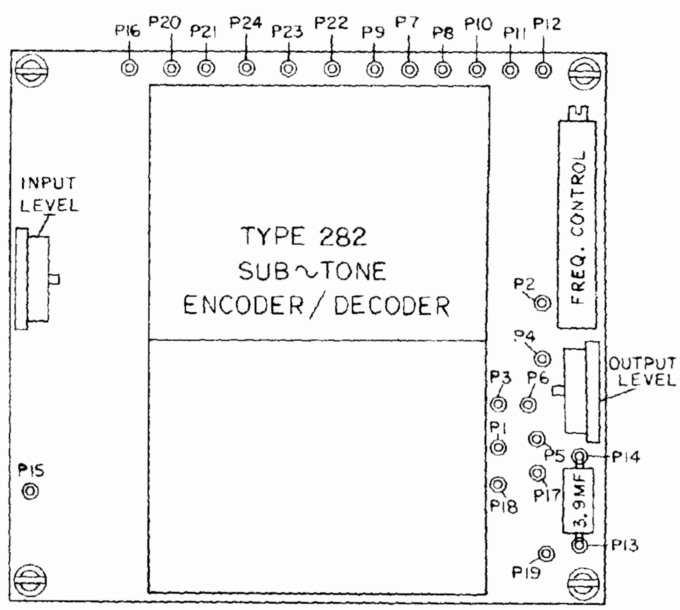
DECODER SPECIFICATIONS

INPUT SENSITIVITY	Adjustable from 30mv to 1V	SELECTIVITY	Active bandpass filter 'Q' is approximately 100 with 'High Q' jumper in, or 50 with 'Low Q' jumper in. Tone received on adjacent EIA CTCSS channels will not activate decoder
INPUT IMPEDANCE	Greater than 200k		
DYNAMIC RANGE	After input level control initially set, circuit will tolerate a tone input level variation of ±12db	TURN-ON (Unsquelch) TIME	Less than 200 milliseconds

DECODER DC CONTROL OUTPUT	Transistor collector switches (saturates) to within 1V of the decoder negative buss when correct tone frequency is received. Collector load current must not exceed 15ma and collector voltage with respect to the (-) buss must not exceed +20V, -1V.

Top View Pictorial Showing Pin Locations





INSTALLATION

Avoid mounting equipment in high temperature or strong magnetic or RF field areas. Do not mount in close proximity to RF or audio power output tubes or power transformers. Interconnect to associated radio equipment, per table and notes below. Application bulletins covering recommended interconnection to specific radios are available upon request and will be supplied with the SUB~TONE order.

INTERCONNECTIONS BETWEEN RADIO AND SUB-TONE ENCODER OR ENCODER/DECODER

				FOR NEGATIVE GROUND SYSTEM	FOR POSITIVE GROUND SYSTEM
ENCODER OR ENCODER SECTION OF ENCODER/DECODER	P2	RED	(+)	Connect to switched and fused continuous (+) 13v.DC supply. See Note 1.	Connect to transmitter audio ground (mike low or mike shield in most cases). See Note 2.
	P1	BLACK	(–)	Connect to transmitter audio ground (mike low or mike shield in most cases). See Note 2.	Connect to switched and fused continuous (-)13v. DC supply. See Note 1.
	P6		TONE OUT HIGH	Connect to transmitter phase modulator or crystal modulator tone input. See Note 3.	Connect to transmitter phase modulator or crystal modulator tone input. See Note 3.
	P5	RED SLEEVE	TONE OUT LOW	Connect to same point as black lead.	Connect to same point as red lead.
DECODER SECTION OF ENCODER/DECODER	P16	BLACK SLEEVE	TONE IN HIGH	Connect to receiver discriminator. See Note 4.	Connect to receiver discriminator. See Note 4.
			TONE IN LOW	Connect to ground point near receiver discriminator.	Connect to ground point near receiver discriminator.
	P15	ORANGE	KEYED +	Connect to keyed transmitter positive supply voltage. See Note 5.	Connect to keyed transmitter positive supply voltage. See Note 5.
	P17	BLUE	D.C.CONTROL OUT	Connect to receiver audio/squelch circuit or to device being controlled. See Note 6.	Connect to receiver audio/squelch circuit or to device being controlled. See Note 6.
	P19	GREEN	– HOOK SWITCH	Connect to ground through mike hook-switch or through MONITOR switch.	Connect to same point as black lead.
	P18	YELLOW	+ HOOK SWITCH	Connect to same point as red lead.	Connect to ground through mike hook-switch or through MONITOR switch.

NOTES:

1. For a 12V vehicle, connect to the battery supply on the radio side of the power fuse and ON-OFF switch. For a solid state base station, connect to the radio's 12 to 15V regulated supply. For a vacuum tube base station, connect to the radio's 12 to 15V regulated supply. For a vacuum tube base station or 6V vacuum tube mobile, derive power from a continuous 200 - 300V B+ line, through an 8,000 Ohm, 20 Watt wirewound series resistor and a 12V one-watt 5% shunt zener diode.

2. Ground-loop noise may be induced into the circuit if this lead is returned to any other ground point.

3. For application information, see "Typical Questions and Answers" on Page 9.

4. Connect directly to discriminator before de-emphasis network and before signal passes through coupling capacitors. As an alternate, connect to same tone take-off point that radio manufacturer recommends for his tone squelch equipment.

5. Voltage on the orange lead must not exceed +20V or -5V with respect to the black lead (negative buss). Keyed voltage may be supplied from a 200 - 300V transmit B+ line, provided that a 100K two-watt resistor is connected in series with the orange lead.

6. In most cases the blue lead can directly electronically control the receiver's audio or squelch circuits. A low-level audio amplifier transistor's base bias or emitter current may be switched, or cathode current of a low-level vacuum tube audio amplifier may be controlled. Blue lead voltage with respect to the negative buss must not exceed +20V or -1V. In most cases where electronic control is applied, a minimum resistance of 220 Ohm should be placed in series with the blue lead to limit high capacitive inrush current surges. The blue lead may be used to drive a 1,000 Ohm minimum-resistance coil of a dry-reed relay. Connect the blue lead to one side of the relay coil, connect the other side of the relay coil to the plus buss (same point that red lead is connected to).

CIRCUIT BOARD STRAPPING

All interconnect cable, jumper and reversible output capacitor connections to the SUB~TONE circuit boards are made via circuit board pins and mating quick-disconnect wire lead receptacles.

The tone output coupling capacitor connected between P-13 and P-14 must not be reverse polarized. Refer to block diagram of the encoder or encoder/decoder for capacitor polarity. All units shipped from the factory have capacitor positive connected to P-13. The DC voltage at P-13 is +5V with respect to the negative buss. If there is DC voltage present on the transmitter tone input line, connect a 1MF capacitor in series with the red-sleeved shielded cable center conductor, observing correct capacitor polarity and voltage rating.

Optimum 282 encoder/decoder "Q" strapping depends on operating frequency range. For EIA tone channels between 67.0 and 94.8Hz, connect the jumper between low "Q" terminals P-20 and P-21. For EIA tone channels between 100.0 and 250.3Hz, connect the jumper between high "Q" terminals P-22 and P-23.

For multi-frequency applications, correct polarity for the output coupling capacitor connected between P-113 and P-114 of the multi-frequency selector assembly must be determined. DC voltage at P-113 is +5 volts with respect to the negative buss. Refer to the multi-frequency intra-connections block diagram. All units shipped from the factory have capacitor positive connected to P-113.

Frequency response of the multi-frequency selector assembly output amplifier is controlled by a jumper. If tone is injected at the transmitter phase modulator, connect jumper between P-115 and P-116. If tone directly modulates the crystal via a voltage variable capacitor, connect the jumper between P-116 and P-117.

ADJUSTMENTS

Operating frequency is controlled by a precision 20 turn trimmer potentiometer. A precise frequency adjustment will be made at the factory if the requirement is specified on the order. Accurate field adjustment can be made by feeding an encoding SUB~TONE unit to a crystal controlled time base frequency counter with ten second count (0.1Hz readability) and reading the frequency directly. A counter capable of period measurement may be employed since period is equal to the reciprocal of frequency (P=1/F). Take all readings to four significant figures and set counter for ten period averaging. A list of standard EIA CTCSS frequencies with respective periods to four places will be found on Page 8. Another approach, but one subject to possible great error, is to compare an encoding SUB~TONE unit requiring frequency adjustment against a reference CTCSS encoder via an oscilloscope Lissajous pattern. This approach is not recommended unless frequency of the reference encoder was recently varified to be within 0.1% of the specified frequency.

To set transmitter FM tone deviation, connect an FM deviation meter to the transmitter. If the crystal is directly modulated, couple a frequency meter to the transmitter. Cover the microphone to prevent noise pickup. Key the transmitter and adjust the SUB~TONE output level control for a transmitted FM tone deviation of 0.8KHz, or the deviation recommended by the radio manufacturer. Interaction between tone deviation, voice deviation, and RF frequency controls may be noted. Simultaneously adjust tone level, voice deviation, and crystal frequency controls until desired results are obtained.

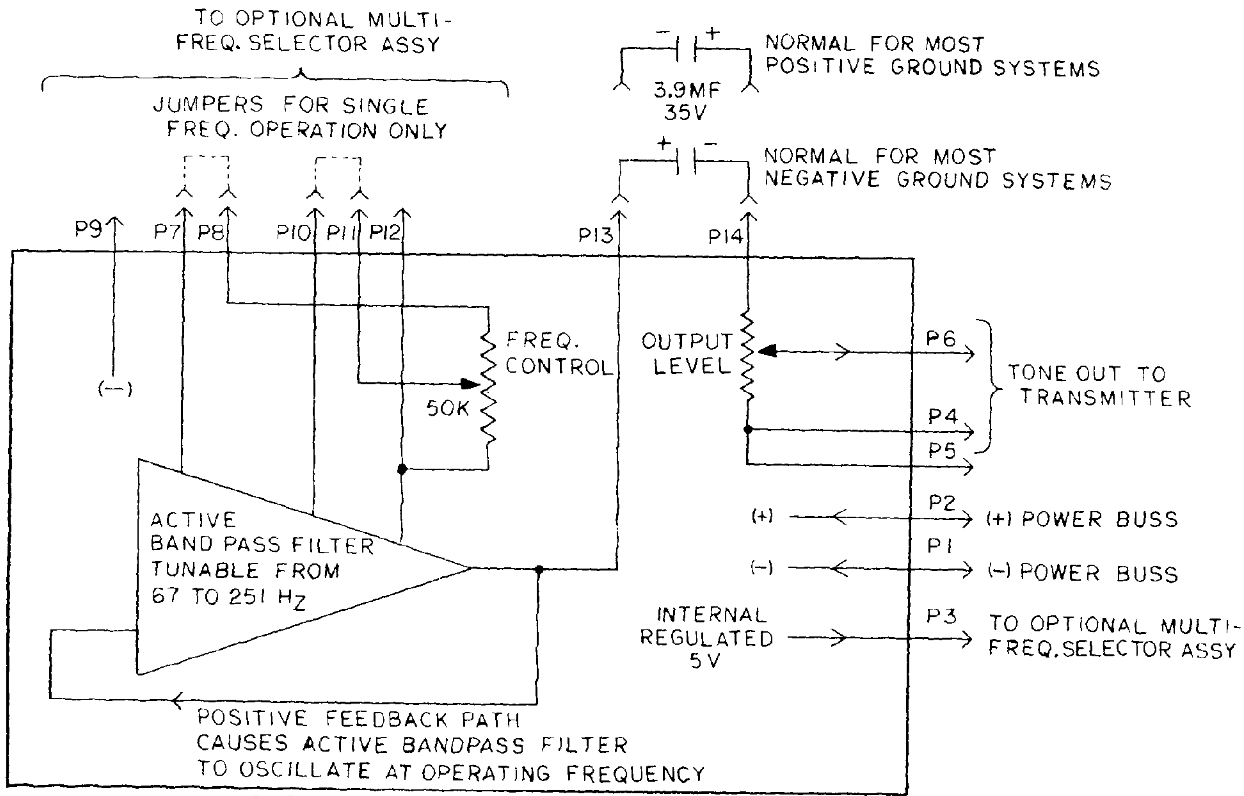
To set the encoder/decoder input level control, connect the hot lead of a high-impedance AC VTVM or Solid State AC voltmeter to P-24. Connect the meter common lead to ground. While receiving a strong transmission that is tone modulated, set the SUB~TONE input level control for a meter reading of 1.2V RMS.

SPECIAL MULTI-FREQUENCY CONSIDERATIONS

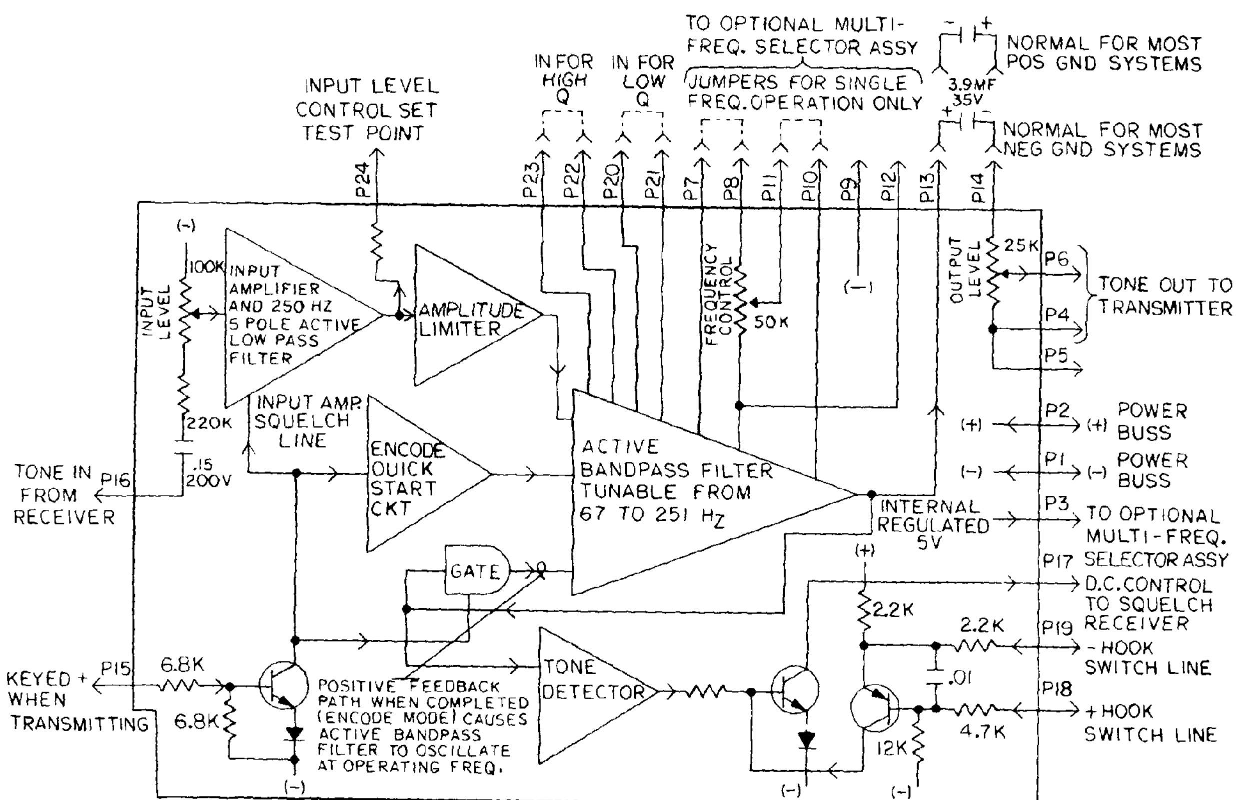
Leads that connect to the frequency selector switch must not be tight laced or sleeved. Lead length must not exceed one foot and should be kept as short as possible. The lead interconnecting P-10 with P-110 must be shielded with braid connecting to P-9.

Each frequency is individually controlled by a plug-on precision resistor on the 90051XX multi-frequency selector assembly. All frequencies are simultaneously trimmed by the frequency control on the associated 281 or 282 circuit board. This control is normally factory set and sealed for multi-frequency applications.

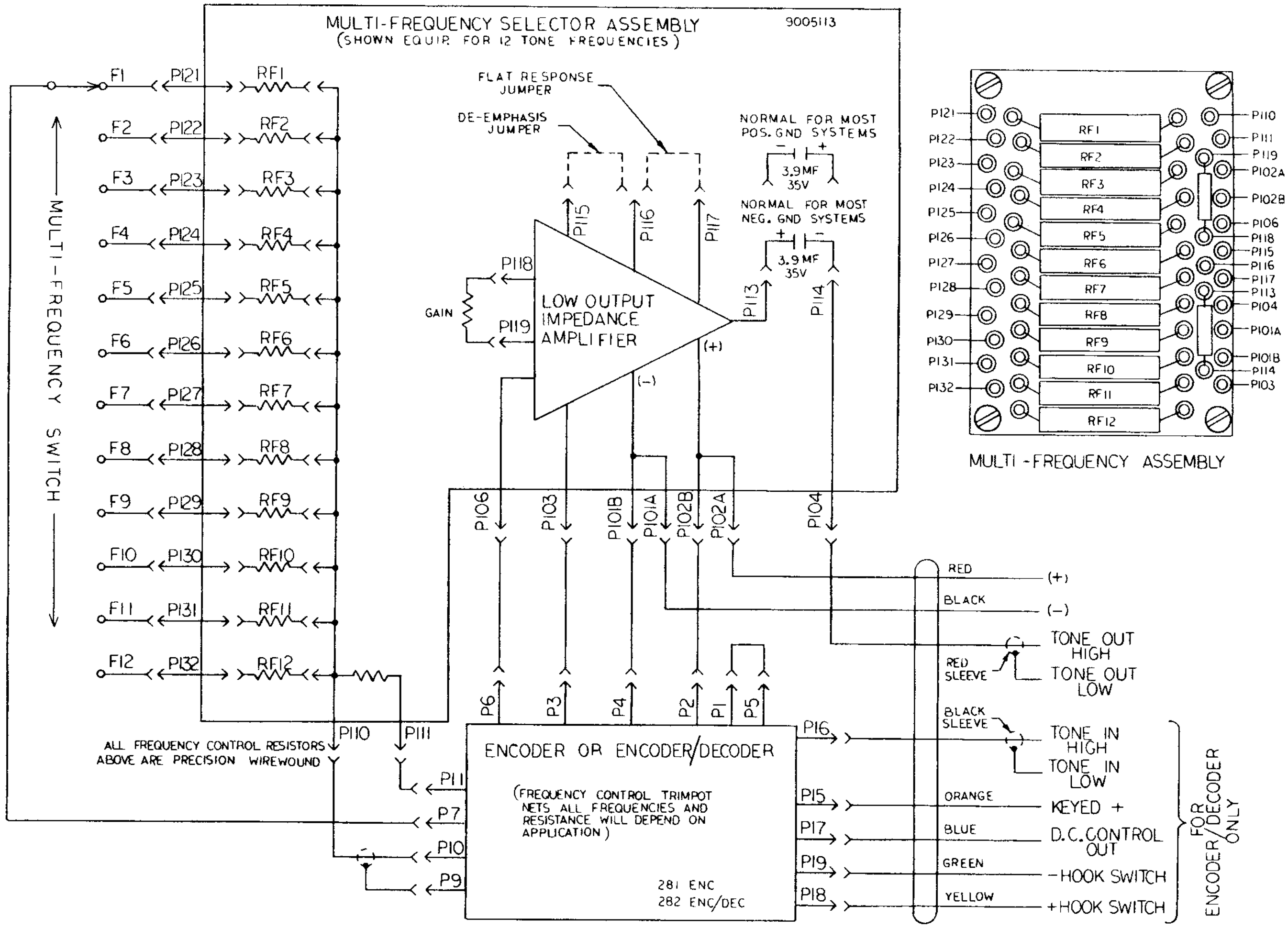
If SUB~TONE equipment is mounted at the dashboard and the radio is in the trunk, then carrying tone over this distance may pose a problem. Electrical noise will be avoided by using shielded cables to carry the tone signals. In some cases, spare leads in the radio equipment control cable may be used as the shunting effect of the multi-frequency selector assembly low-output impedance amplifier will suppress capacitively coupled noise. An adjacent lead in the cable carrying a high pulsating current may still inductively couple noise into the circuit. This noise is generally of a high-frequency nature and can be low-pass filtered before it reaches the transmitter modulator. The Vega Applications Engineering Department has accumulated considerable experience in this area and will be pleased to assist in special system planning.



SUB∿TONE ENCODER



SUB∿TONE ENCODER/DECODER



MULTI-FREQUENCY SUB~TONE INTRACONNECTIONS

EIA GROUP A FREQUENCY (Hz)	EIA GROUP A PERIOD (ms)	EIA GROUP B FREQUENCY (Hz)	EIA GROUP B PERIOD (ms)
67.0	14.93	71.9	13.91
77.0	12.99	82.5	12.12
85.5	11.30	94.8	10.55
100.0	10.00	103.5	9.662
107.2	9.328	110.9	9.017
114.8	8.711	118.8	8.418
123.0	8.130	127.3	7.855
131.8	7.587	136.5	7.326
141.3	7.077	146.2	6.840
151.4	6.605	156.7	6.382
162.2	6.165	167.9	5.956
173.8	5.754	179.9	5.559
186.2	5.371	192.8	5.187
203.5	4.914	210.7	4.746
218.1	4.585	225.7	4.431
233.6	4.281	241.8	4.136
250.3	3.995		

STANDARD EIA CTCSS TONE FREQUENCIES WITH MATCHING PERIODS THAT CAN BE MEASURED ON A PERIOD READING FREQUENCY COUNTER

TYPICAL QUESTIONS AND ANSWERS ON CTCSS

Q. **Is it difficult to modulate the radio transmitter with sub-audible tone?**

A. No, but it is far more difficult than modulating the transmitter with voice alone. Almost all FM transmitters are phase rather than direct frequency modulated. A true frequency modulator connected to directly vary frequency of the crystal has a flat FM deviation versus modulation frequency response.

A characteristic of all phase modulators is that sensitivity of the modulator increases directly with audio frequency. The transmitter frequency deviation is a function of the rate of change of phase. The modulator has an inherent 6 db per octave pre-emphasis characteristic.

The lower the tone frequency, the more the tone level required to drive the phase modulator. There is a limit to the amplitude of tone that can be applied. The limiting point is where distortion, both caused by overload of the phase modulator and by the non-linear characteristic of sinusoidal phase modulation, becomes objectionable. It is the non-linear characteristic of phase modulation that is not generally understood. The phaser diagram in Figure 1 represents the basic phase modulated signal which consists of carrier and modulation vectors. Length of the modulation vector is controlled by amplitude of the modulating voltage and the rate of change of phase is controlled by modulating frequency. Note that the resultant vector moves back and forth across the carrier reference phase at the modulation rate. The phase shift is a trigonometric function of the modulation and carrier vectors. It can be seen that a change in length of the modulation vector will not necessarily produce a proportional change in phase angle. Distortion is quite low at very low phase excursions, say $\pm 5^\circ$, but, as phase shift is increased with resultant attainment of greater FM deviation, the distortion also increases. 90° can be approached but never reached.

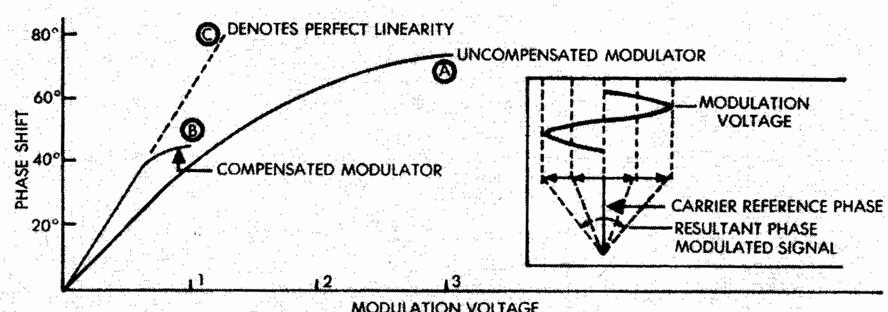


FIGURE 1

Line A in Figure 1 shows the results obtained with a phase modulator that produces a modulation vector whose length is proportional to tone amplitude. Distortion becomes excessive above approximately $\pm 25^\circ$ phase shift. The standard Miller effect modulator employed in some two-way radios capitalizes on non-linear transconductance to compensate for the non-linearity inherent in phase modulation. Curve B is a typical example of results obtained by this technique.

There is a definite limit to the amount of deviation that can be squeezed out of a phase-modulated FM transmitter at subaudible tone frequencies. Driving the system into the non-linear range not only produces harmonic distortion but also severe intermodulation of voice by tone if both are applied to the same modulator. Although the fundamental tone frequency may be too low to hear, it will produce a gurgling effect on the voice.

As a summary of the above, phase modulation distortion is reduced and FM deviation is increased as tone frequency is increased. Transmitter FM deviation is increased by the frequency multiplication within the transmitter. A rule of thumb empirically derived to predict the approximate peak FM tone deviation at acceptable distortion that can be squeezed out of a typical transmitter is: maximum peak FM deviation in $Hz = \pm .45M\ Ft$ where M is the transmitter multiplication factor and Ft is the tone frequency in Hz. As an example, a transmitter multiplication factor of 24 and a tone frequency on 100 Hz would yield a maximum deviation of $\pm .45 \times 24 \times 100 = \pm 1080$ Hz. This empirical formula should only be used as a guide as exact results will depend upon the particular radio equipment involved.

Some transmitters can be equipped with a voltage variable capacitor diode to directly frequency modulate the crystal. The crystal modulator approach has distinct advantages in that, as mentioned above, the device is insensitive to modulating frequency. Lower tone frequencies can be used with success. Even if some non-linear distortion is introduced, there will be no gurgling effect on voice as speech and tone are fed to separate modulators. Field design and construction of a crystal modulator is not recommended as this could violate FCC Type acceptance rules. Some radio manufacturers have a type-accepted modulator kit available for their own transmitters. Direct modulation of the crystal is recommended over injection of tone into the phase modulator if the appropriate modulator kit can be conveniently obtained.

Q. What is the best SUB~TONE frequency to use?

A. The choice of frequency will depend upon the particular application involved. For low band (30-50MHz) transmitters, use of the lower subaudible tone frequencies is not recommended if tone is fed to the phase modulator as low band transmitters generally employ a low frequency multiplication factor. From the empirical formula in the preceding section, no more than 540 Hz of deviation can be squeezed out of a low band transmitter with a multiplication factor of 12 and 100 Hz tone. There is no limit on the use of lower tone frequencies if a crystal modulator is employed.

For high band and UHF applications, it may also be advisable to avoid the lower frequencies if tone will be injected at the phase modulator. Although distortion will be less severe because of the higher transmitter frequency multiplication factor, the tendency toward greater distortion at the lower tone frequencies still prevails. If congested channel conditions dictate the need for lower tone frequencies, they need not be ruled out but caution must be exercised. Again the use of a crystal modulator is recommended.

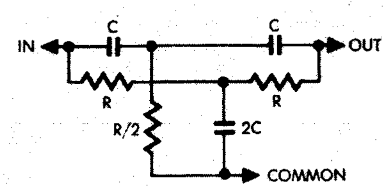
Frequencies above 180 Hz should be avoided if at all possible. These higher frequencies easily modulate the transmitter but they are difficult to filter out of the receiver audio amplifier and can cause an annoying buzz in the loud-speaker. The use of de-emphasis in the receiver with its boosting of lower frequencies greatly accentuates the problem. Some of the newer, more expensive receivers employ extensive filtering to rapidly cut off receiver amplifier response below 300 Hz. Older receivers may have no provision at all for filtering tone. Another disadvantage of the higher tone frequencies is that voice energy is more dominant than at the lower frequencies. High energy voice components can cause tone squelch falsing if they happen to fall within the decoder's bandpass. The tendency toward voice falsing is reduced as the tone frequency is reduced.

The conclusion to be drawn from the above is that frequencies in the middle of the CTCSS range are preferable, i.e., those frequencies between approximately 100 and 180 Hz. This does not mean that lower or higher frequencies cannot be used but the system designer must be cognizant of the problems that may be encountered in choosing these extremes. The importance of co-ordination with other users on the channel cannot be over-emphasized. To choose a frequency and then find that someone else is already operating on that same tone channel could prove both costly and embarrassing.

Q. How can the annoying tone feed through be filtered out of the receiver audio amplifier?

A. A 6 or 8 db reduction can be achieved simply by changing the receiver de-emphasis components. The 6 db per octave de-emphasis circuit boosts the low end and reducing the amount boost will reduce the sub-audible tone feedthrough. Speech quality will be affected by the reduction of low end boost. The trick is to remove only that amount of boost that does not materially add tinniness to voice quality.

If the above approach does not satisfactorily solve the problem, then a twin-T filter of the type shown in Figure 2 may be employed. The proper component values will depend upon impedance of the particular radio discriminator circuit. R equal to 200K is a good compromise for most high impedance discriminators. Rejection of greater than 20 db can be achieved with 5% tolerance components. Since the twin-T notch filter's slope may extend above 300 Hz, the receiver's normal de-emphasis circuit should be left alone if the twin-T is employed. If both de-emphasis reduction and twin-T filtering were employed, severe degradation to the speech low frequency response could occur.



$$F = \frac{1}{2\pi RC}$$ R IN OHMS, C IN FARADS

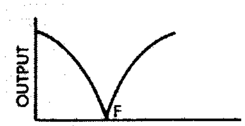


FIGURE 2

Q. How should the SUB~TONE encoder connect into the transmitter?

A. The encoder must either connect directly to the phase modulator or to a modulator at the crystal. The subaudible tone must not be fed through the transmitter's speech amplifier. The speech amplifier frequency response is rapidly attenuated below 300 Hz and the FM deviation limiter will produce severe tone plus voice intermodulation distortion.

Figure 3 shows recommended connections to a typical phase modulator circuit. Tone may be either series fed at the bottom of the FM deviation control or shunt fed through a mixing resistor. The series fed method is recommended as voice and tone channels have minimum loading on each other. If it is inconvenient to connect to the bottom of the control or if the control's resistance is less than 100,000 ohms, the alternate shunt connection may be employed if the phase modulator has gain to spare.

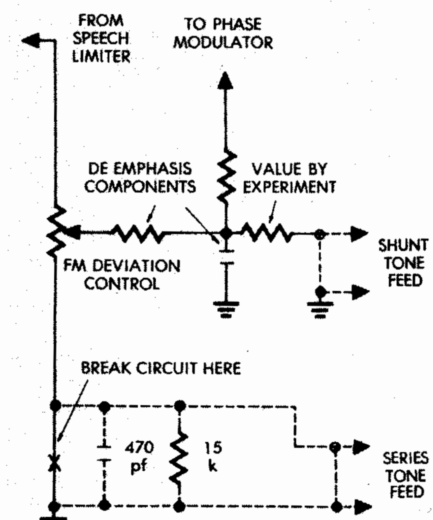


FIGURE 3

NOTES