OPERATING & MAINTENANCE INSTRUCTION MANUAL

MODEL 222

"NRSC" (AM) AUDIO PROCESSOR

INOVONICS
INCORPORATED

USER'S RECORD

Model 222 - Serial No. ......
Date Purchased ....
Warranty Card Returned? .....
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INSTRUCTION MANUAL

MODEL 222

PREEMPHASIS / LOWPASS
BROADCAST AUDIO PROCESSOR
(NRSC STANDARD)

June, 1987

INOVONICS INCORPORATED

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I FUNCTIONAL DESCRIPTION

Introduction

Inovonics' Model 222 is an audio processor intended exclusively for AM broadcasting applications. It can stand alone between the audio console and the transmitter for conservative limiting-only program control, or may be used in conjunction with a level compressor or an existing AM audio processing system for more "aggressive" results.

The unit also provides compliance with the Voluntary AM Transmission Standard established by the U.S. National Radio Systems Committee (NRSC). In addition to the adjustable-asymmetry peak control function, it incorporates the specified 75-microsecond "truncated" preemphasis characteristic with independent high frequency "preemphasis protection" limiting, as well as a sharp 10kHz lowpass filter with proprietary overshoot control.

The 222 is capable of supporting other transmission standards as well. Options include a 75-microsecond / 9kHz version for European Medium Wave broadcasting, and a 150-microsecond / 5kHz version for International Shortwave service.

The 222 uses feedforward Pulse Width Modulation (PWM) for colorless control over program dynamics and equalization. This also permits a good deal more gain reduction to be utilized, without audible degradation, than permitted by more conventional feedback-mode VCA designs.

This Manual is divided into several sections which present the features and design philosophies of, and installation and operating instructions for, the Inovonics 222. Since much of the information is expressed in text, rather than in tabular form, it is recommended that the user at least skim Sections I through III before placing the unit in service.

Background

Development of the 222 was inspired by ongoing work toward improving the quality of AM (medium wave) broadcasting in the United States. During recent years, U.S. radio listenership has migrated increasingly toward the VHF-FM broadcast band as low-cost portable and automobile FM receivers became readily available.

In 1985, the National Radio Systems Committee (NRSC), sponsored jointly by the Electronic Industries Association (EIA) and the National Association of Broadcasters (NAB), formally addressed the general issue of "AM Improvement." The Committee's work, undertaken on the mutual behalf of radio broadcasters and of receiver manufacturers, culminated in the adoption of the "NRSC Standard" of January 10, 1987. The Standard calls for 75-microsecond transmission preemphasis (and complementary receiver deemphasis) curves to suppress noise, and a 10kHz, sharp-cutoff lowpass characteristic to reduce interference between adjacent-channel stations.

As of this writing, the NRSC Standard is being implemented through strictly voluntary compliance. A growing majority of AM broadcasters appear to recognize the potential "NRSC benefit" by expressing their eagerness to comply with the Committee's recommendations.

Implementation Implications

The "truncated" 75-microsecond preemphasis characteristic is easily achieved with a simple R/C network. Figure 1 graphs the required curve with its single "zero" (+3dB) at 2122Hz, and "pole" (-3dB with respect to the 6dB/octave rising response) at 8700Hz. What a simple program preemphasis network does not take into consideration, however, is its effect on modulation. If the network follows the peak controller, limited high frequency program energy will be boosted to undoubtedly exceed the 100% modulation limit. If, on the other hand, the network precedes the limiter, the overall program level will "duck" as accentuated high frequency peaks are reduced.

To prevent the modulation sacrifice inherent in either case, some form of independent high frequency limiting must be used. "Preemphasis protection" limiters are common in FM broadcasting systems which employ a similar 75-microsecond curve; these use split-band gain control or voltage-controlled filters to separately limit the program energy within the preemphasized portion of the spectrum.

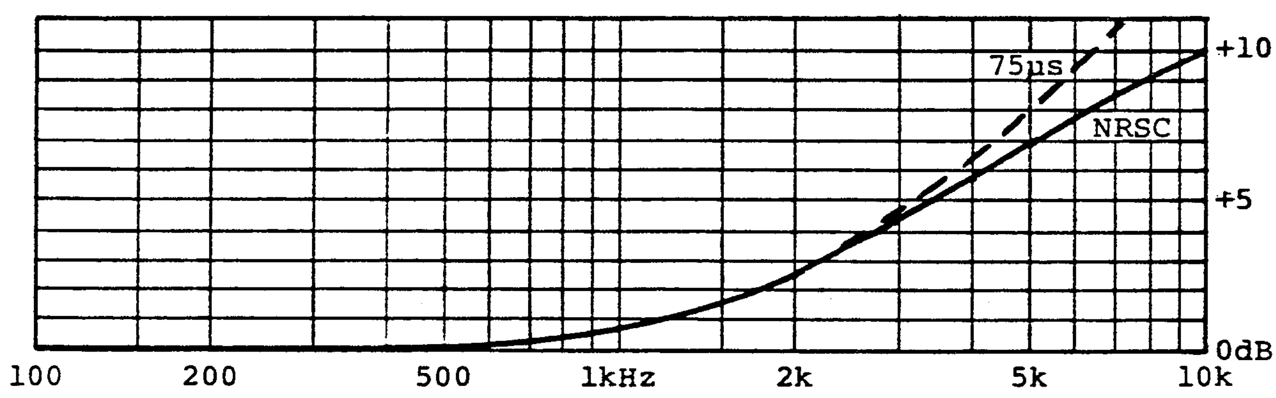


Figure 1 - NRSC PREEMPHASIS CURVE

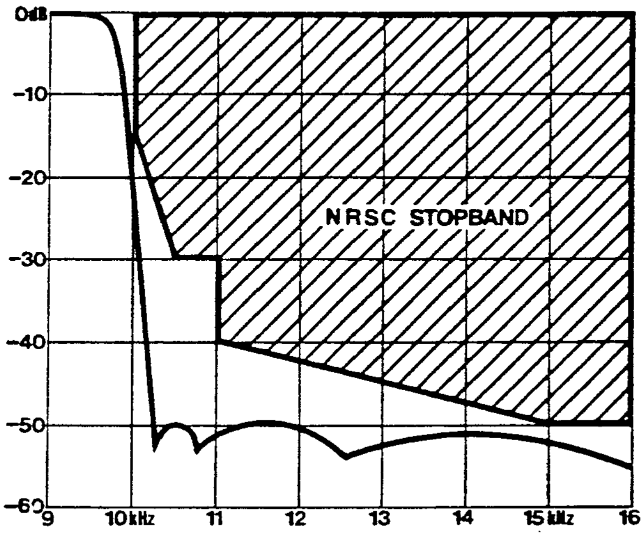


Figure 2

NRSC STOPBAND SPECIFICATION AND FILTER RESPONSE

The NRSC Stopband Specification is shown in figure 2, along with the lowpass filter response of the 222. The required 10kHz lowpass function implies a very sharp-cutoff filter, and filters of this type invariably exhibit a certain amount of output amplitude overshoot and "ringing." Thus some provision must again be included to guard against this potential source of overmodulation. Simply placing the filter before the final limiter or clipper is hardly sufficient since the fast-limited or clipped filter overshoots will again contain frequency components beyond the 10kHz cutoff.

The better FM stereo generators incorporate some form of lowpass filter overshoot control. These techniques may be borrowed, provided that they prove sufficient for the sharper cutoff characteristic of the NRSC lowpass specification.

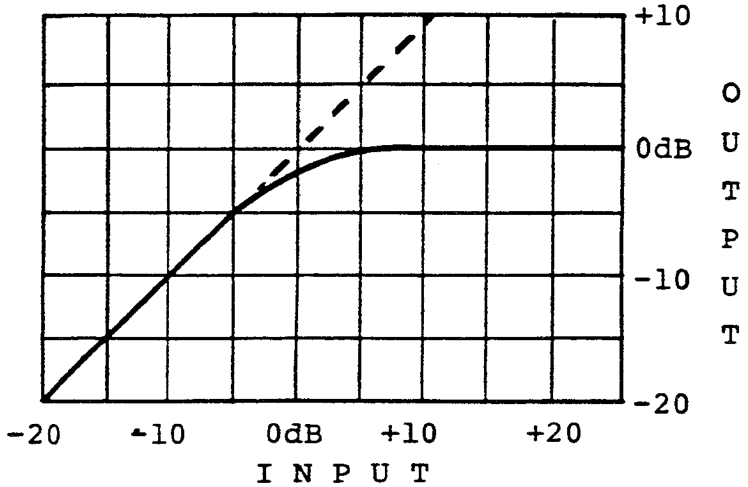
Peak Limiter

The input Peak Limiter section of the 222 restricts program amplitude excursions to a peak level which represents 100% negative, and 100%-to-130% positive carrier modulation. When the 222 is fed from an existing processing system which already includes tight peak control, the redundant built-in limiter may be switched OFF.

The Limiter section accomplishes its gain reduction (G/R) with a feedforward technique using Pulse Width Modulation. A brief "tutorial" on PWM is included with the CIRCUIT DESCRIPTIONS in Section V. An advantage of feedforward gain control over the more conventional feedback methods is the ability to tailor the input-to-output gain-reduction transfer characteristic for smoother-sounding processor action, especially noticeable during heavy limiting.

Figure 3 graphs the in/out function of the Model 222 Limiter, showing a "soft knee" with an area of increasing-ratio compression prior to the final, "infinite" limiting ratio.

Attack time of the internal Peak Limiter is virtually instantaneous. The release function has a dual time constant, with a rapid initial realease (for fast program peaks) to an averaged "platform" value, and a slower release for the integrated, average value of peak reduction.



<u>Figure 3</u>

LIMITER TRANSFER CURVE

(INPUT vs OUTPUT)

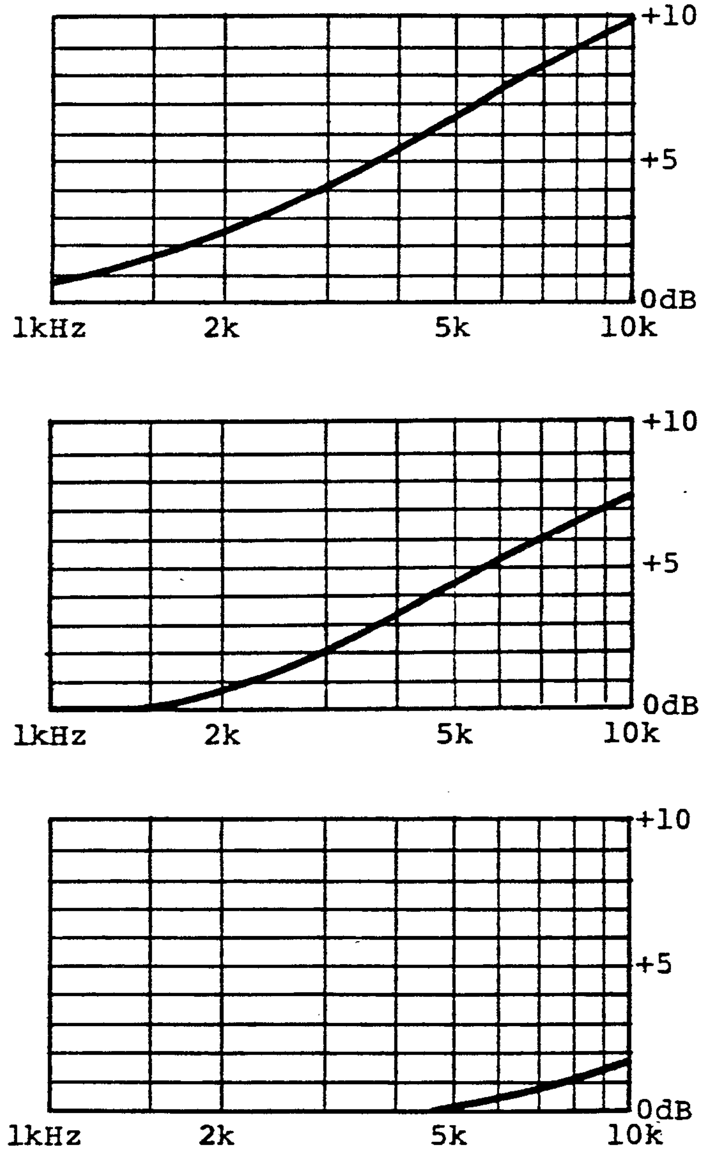
"<u>Adaptive</u>" <u>Preemphasis</u>

To "protect" that part of the spectrum which is subject to the 75-microsecond preemphasis, and thus avoid high frequency overmodulation, independent high frequency limiting is afforded in the form of a variable, "sliding-turnover" preemphasis circuit, also using feedforward PWM.

The value of the preemphasized high frequency energy is added to that of the previously-limited broadband program. The preemphasis turnover frequency, normally 2122Hz, adaptively shifts <u>up</u> to keep the energy sum at 100%. Examples of the actual preemphasis curve under different program signal conditions are graphed in Figure 4 on the next page.

Attack and release time constants of this circuit are very fast, in keeping with the high-frequency-only nature of the controlled part of the spectrum. This helps keep the preemphasis protection limiter unobtrusive in its action and maintain the full specified preemphasis, consistent with keeping total carrier modulation at 100%.

As the protection limiter is an integral part of the active preemphasis circuit, it is defeated only when preemphasis is turned OFF.



4a - NEGLIGIBLE HIGH FREQUENCY PROGRAM ENERGY. (FULL PREEMPHASIS)

4b - INPUT SIGNAL WITH 3kHz COMPONENT AT -2VU LEVEL.

4c - INPUT SIGNAL WITH 5kHz COMPONENT AT 0VU LEVEL.

Figure 4 - EXAMPLES OF ADAPTIVE PREEMPHASIS

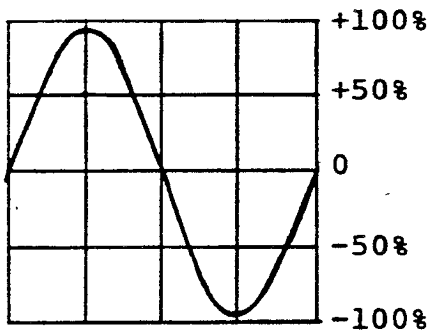
Lowpass Filter and Overshoot Compensator

The primary lowpass filter in the Inovonics 222 is a 9-pole "elliptic" type which easily meets the NRSC stopband specification as shown in Figure 2. The filter is of conventional high-stability, "FDNR" active design.

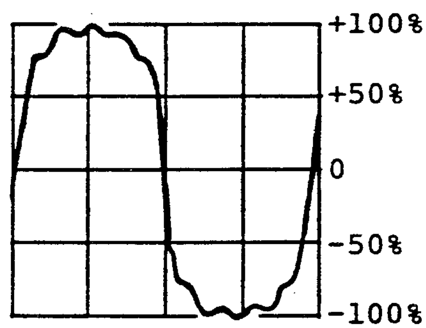
A fast peak clipper is placed immediately ahead of the filter to catch whatever program peaks might evade program peak limiting. The positive clipping threshold is adjustable between +100% (symmetrical with the negative) and +130%. This is concurrent with an identical offset in the Peak Limiter thresholds. Though in actual operation the clipper is rarely called-on for more than a dB or two of clipping, it does establish an absolute signal ceiling value which corresponds to full carrier modulation.

Presented with a complex-waveform program input signal, any sharp-cutoff lowpass filter will exhibit output amplitude excursions (overshoots) which exceed any ceiling value established at the filter input. Even a filter design which is "fully phase-corrected" will overshoot. This is due to the filter's normal and, in fact, desired elimination of higher-order frequency components which, themselves, help define the instantaneous peak value of the signal.

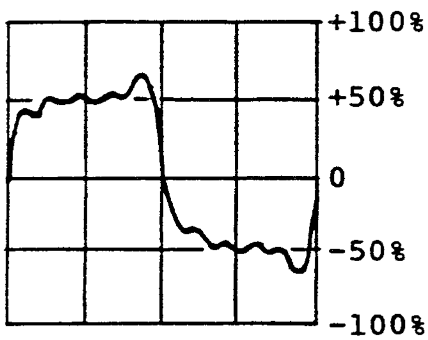
Unlike "brute force" methods of overshoot control which often feature cascaded filter/clipper combinations, the proprietary compensation scheme (patent applied for) used in the Model 222 preconditions the program signal at the filter input so that overshoots at the output are negligible. Thus no complicated isolation, re-filtering and re-introduction of actual filter overshoots is required as in some other methods of compensation. 222 filter topography remains straight-forward, and compensation circuitry relatively simple. A front-panel "O.S. COMP" LED indicates any compensation circuit action. Filter output waveforms for a variety of input signals are shown in figure 5.



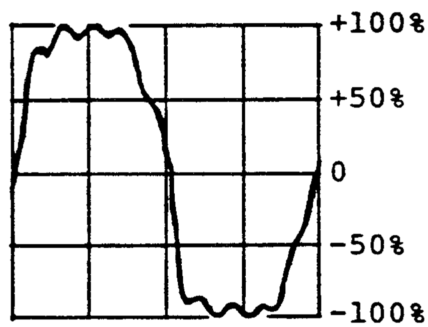
5a - FILTER OUTPUT WITH 1kHz SINEWAVE APPLIED AT 97% EQUIV. MODULATION.



5b - FILTER OUTPUT WITH 1kHz SINEWAVE APPLIED AT 300% EQUIV. MODULATION.



5c - FILTER OUTPUT WITH 1kHz SQUAREWAVE APPLIED AT 50% EQUIV. MODULATION.



5d - FILTER OUTPUT WITH 1kHz SQUAREWAVE APPLIED AT 100% EQUIV. MODULATION.

Figure 5 - OVERSHOOT-COMPENSATED LOWPASS FILTER OUTPUT

Since the filter is, indeed, the final element in the signal path, the specified cutoff characteristic is assured under any condition or degree of previous signal processing.

Asymmetrical Modulation

As previously noted, both the Peak Limiting and Clipping functions of the Inovonics 222 will support asymmetrical carrier modulation. Program material which is non-symmetrical by nature, such as the human voice and some solo musical instruments, will be passed by the 222 to utilize the "advantage" afforded by the asymmetrical carrier modulation permitted by governent regulations. However, the 222 will not create asymmetry by force-clipping negative program waveform excursions.

Also, the Peak Limiter section of the 222 has no provision for selective-inversion of the program signal to insure a predominance of positive peaks. It is assumed that if this feature is desired, it will be provided by a more sophisticated processor ahead of the Model 222.

Nevertheless, to the extent that positive-going asymmetry is present in the program source, the 222 can be adjusted to yield positive output peaks up to 130% of the negative, though +125% is generally the legal limit. In the interest of conformance with the NRSC Stopband Specification, the transmitter should not be driven into modulation non-linearity in an effort to force a full +125% modulation.

"PROOF" Mode

When the three front-panel selector switches are turned OFF, Limiting, Preemphasis, Preemphasis-Protection Limiting and the Lowpass Filter and Overshoot Compensator are switched out of the signal path, and the "PROOF" indicator lights. Any of the three functions may be independently defeated as well.

Stereo Operation

Two Model 222 units are required for stereo operation. A rear-panel "phono" jack permits interconnection to slave the broadband Peak Limiter gain-reduction functions.

Since the 222 is placed immediately ahead of the transmitter, the two units are necessarily operated in the stereo "sum and difference" modes.

Particular care has been excercised in the manufacture and final test of the Model 222 to ensure that any two Processors will exhibit identical amplitude and phase response for proper stereo tracking, even when serial numbers differ widely.

Specifications

Tabulated below are performance specifications of the Model 222 which are neither expressed in the text of the Manual nor implied in the attendant drawings.

Frequency Response (preemphasis defeated):
+/-1dB, 10Hz-9.7kHz;
In "PROOF": +/-0.5dB, 10Hz-15kHz.

Noise: Better than 75dB below 100% modulation.

Distortion: Less than 0.2% THD, 10Hz-9.7kHz with Peak Limiter OFF; less than 1% THD, 200Hz-9.7kHz with Peak Limiter ON.

Input: Active-balanced, 10k-bridging; accepts nominal line levels between -15dBmV and +15dBmV.

Output: Active-balanced, 600-ohm resistive source; delivers 0 to +15dBm into 600-ohm loads.

Power Requirement: 105-130 or 205-255VAC, 50/60Hz; 8 Watts.

Size and Weight: 1-3/4" x 19" x 8" (1U); 8 lbs.

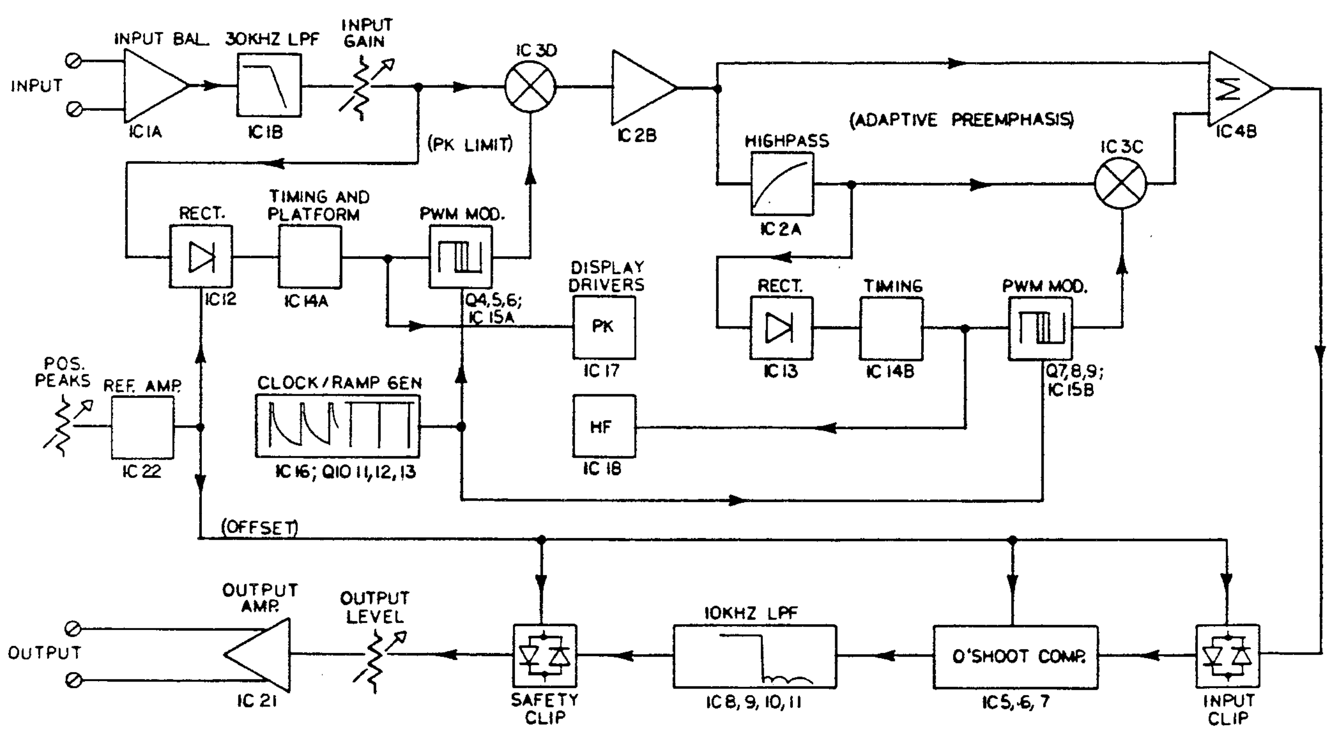


Figure 6 - BLOCK DIAGRAM, MODEL 222

II INSTALLATION

Unpacking and Inspection

Upon receipt of the equipment, inspect carefully for shipping damage. Should any such damage be observed, notify the carrier at once; if not, proceed as outlined below. It is recommended that the original shipping carton and packing materials be saved should future reshipment become necessary. In the event of return for Warranty repair, shipping damage sustained as a result of improper packing for return may invalidate the Warranty.

> IT IS VERY IMPORTANT that the Warranty Registration Card found at the front of this manual be completed and returned. Not only does this assure coverage of the equipment under terms of the Warranty, and provide some means of trace in the case of lost or stolen gear, but the user will automatically receive specific SERVICE OR MODIFICATION INSTRUCTIONS should they be issued by the factory.

Mounting

The Inovonics 222 is packaged to mount in a standard 19-inch equipment rack and requires only 1-3/4 inches (1U) of vertical rack space. The 222 generates negligible heat and, itself, is unaffected by wide variations in ambient operating temperature.

AC Power

Unless specifically ordered for export shipment, the 222 is delivered for operation from 125V, 50/60Hz AC mains power. The back-panel designation next to the fuseholder will confirm both the mains voltage selected and the value of the fuse to be used.

Mains voltage reselection is easily made with the top cover removed. A plug-on jumper strip next to the power transformer may be installed in either of two positions for the two nominal mains voltages. A silkscreened legend next to the connector clearly indicates its orientation. A proper fuse must always be installed, and the appropriate back-panel voltage designation marked to indicate the input power requirement.

The detachable power cord supplied with the Processor is fitted with a North-American-standard male connector. The individual cord conductors are supposedly color-coded in accordance with CEE standards: BROWN="hot," BLUE=neutral, GREEN/YELLOW=ground. If this turns out not to be the case, we offer our apologies (cord vendors vary) and advise that U.S. color coding applies: BLACK="hot," WHITE=neutral, GREEN=ground.

RFI

Though the 222 has been designed to operate in the proximity of broadcast transmitters, care should be exercised in locating the unit away from abnormally high RF fields.

In some installation situations, an RF ground loop may be formed between the input or output cable shield grounds and the AC power cord ground. Use of a "ground-lifting" AC adapter should remedy the problem. Nevertheless, the chassis must somehow be returned to earth ground for safety.

LINE INPUT and Range Selection

The Model 222 has an electronically-balanced (transformer-less), bridging LINE INPUT (10k-ohms or greater). This is brought out to the rear-panel barrier strip and includes a chassis ground connection for the cable shield. The terminals marked "+" and "-" remain in-phase with LINE OUTPUT terminals similarly identified.

Should the equipment which feeds the Processor require output loading, a 600-ohm terminating resistor may be placed across the 222 input terminals.

The 222 accepts "zero-reference" input program levels between -15 and +15dBmV. This 30dB input level range is divided into two 15dB segments selected with a pair of jumpers located on the circuit board just behind the barrier strip. Figure 7 shows the two input level range jumper placement options.

LOW LEVEL RANGE (-15 to 0dBm)

HIGH LEVEL RANGE (0 to +15dBm)

Figure 7 - INPUT LINE LEVEL RANGE SELECTION

As shipped, the 222 is jumpered for input levels between 0 and +15dBmV. This is the "HIGH" range, identified by the letter "H" silkscreened in two places beside the level range jumper connector. For input levels between -15 and 0dBmV, the two jumpers must be moved to the "L" ("LOW" range) positions.

LINE OUTPUT

The LINE OUTPUT of the 222 terminates at the rear-panel barrier strip along with a ground terminal for the cable shield. The output is electronically-balanced (transformerless), but is not load-sensing. It is intended to feed the balanced input of the transmitter.

If a single-ended unbalanced output is required, only the "+" and "GND" terminals should be used. Do NOT ground the "-" side of the LINE OUTPUT.

The characteristic, resistive output impedance of the 222 is 600 ohms. When terminated in a similar resistance, the output level will drop 6dB below the unloaded value. The output is variable between 0 and +15dBm into a balanced, 600-ohm load.

The LINE OUTPUT is designated "+" and "-" for program phase considerations, and is in-phase with the similarly-designated LINE INPUT terminals. The Processor output should be connected so that a positive-going waveform at the "+" output terminal yields positive carrier modulation.

Stereo Interconnect

To ensure compliance with the NRSC Specification, the 222 Processor must directly feed the main (AM) input to the transmitter. In a stereo installation, this is the L+R "sum" signal from the matrix. A second 222 Processor must then be placed in the L-R "difference" channel to maintain identical frequency/ phase response and gain for separation considerations.

When two units are used for stereo, a shielded phono-connector patch cord is connected between the two STEREO INTERCONNECT jacks on the back panel, slaving the two Peak Limiters to preserve separation. Gain Reduction (G/R) will be identical in both units, and will be based on the higher value of G/R performed by either.

No similar provision is included for slaving the Preemphasis Protection (high frequency) Limiters. Their very fast response minimizes the audibility of dynamic separation loss at the high end of the spectrum.

III SETUP AND OPERATION

Setup of the Inovonics 222 is simple and straightforward. It is most easily done once connected in the program signal chain and "on air," thus requiring only a program feed and the station Modulation Monitor for installation and adjustment.

Auxiliary Processing

The Model 222 may be used as a stand-alone, "basic" processor between the audio console and the transmitter. In fact, the "floating platform" release characteristic approximates the action of an additional slow Compressor or AGC ahead of the fast Peak Limiter. When the 222 is used alone, results will be "conservative," but very "clean" and "open."

It is anticipated, however, that most users will elect to place some type of average-level compressor ahead of the 222 for more "aggressive" processing. This may be a broadband or a multiband unit, and may or may not contain an integral peak controller. If pre-processing does provide tight peak control, the user may choose whether or not to defeat the Peak Limiter in the 222.

Since the Model 222 was designed to satisfy the technical specification of the NRSC Standard, and thus to impart minimal subjective effect of its own, the user should first become satisfied with the results afforded by any other processing before placing the 222 in service. The only exception is with respect to "brightness," or high-end boost. Since the 222 does preemphasize the high frequencies according to the NRSC "truncated" 75-microsecond curve (Figure 1, Page 4), any high-end equalization in the program signal chain should be cut back by an amount corresponding to this boost.

INPUT GAIN Set

STEP 1 Be sure that the LINE INPUT and LINE OUTPUT are properly connected, observing signal polarity as indicated under the appropriate headings on Pages 12 and 13.

STEP 2 Turn the PEAK LIMITING, PREEMPHASIS and LOWPASS FUNCTION panel switches ON, and all controls fully counterclockwise.

STEP 3 With a typical program signal feeding the unit, advance the INPUT GAIN control for a proper indication of Peak Limiter gain reduction (G/R).

A. If the 222 is used alone in the signal path, adjust INPUT GAIN for an average value of 6dB G/R, with peaks occasionally reaching -12dB.

B. When auxiliary processing already provides fast peak control, adjust INPUT GAIN to a point where the -2dB G/R indicator stays ON most of the time, and the -6dB G/R indicator seldom, if ever, flashes. (See the Indications of - - notation below.)

C. If adjustment of INPUT GAIN is not within the range of the panel control, refer to the procedure for input range selection on Page 12.

OUTPUT LEVEL Set

STEP 1 Check that the POS. PEAKS control is fully counterclockswise.

STEP 2 Advance the OUTPUT LEVEL control for negative peak modulation of 90-95% as indicated by the station Mod-Monitor.

STEP 3 Advance the POS. PEAKS control for positive peak modulation of as much as +125% as indicated by the Mod-Monitor.

Indications of Improper Operation

If the Peak Limiter G/R display conditions described in INPUT GAIN, STEP 1, B, above, cannot be met, this indicates that a preceding peak controller does not adequately "hold" program peaks. If this is the case, the 222 Peak Limiter should be kept ON. Otherwise it may be turned OFF at the user's option.

In typical operation, the 222 will display a good deal of High Frequency Limiter activity. Occasional indications of -12dB G/R are common with program material played directly from Compact Discs or "dance mix" single records. However, consistent indications of -6 to -12dB high frequency G/R suggest excessive top-end boost ahead of, and in addition to, the NRSC curve. In the interest of compliance with the intent of the NRSC Standard, high-end equalization should be less aggressive than what has become customary in AM broadcasting.

Stereo System Setup

The procedure for installing two Model 222 Processors for stereo operation is given on Page 13. The "sum" unit, connected in the L+R signal path at the main (AM) input of the transmitter, may be adjusted in the normal stereo mode exactly as outlined for a single unit in monophonic operation. Following this, the "difference" Processor is statically aligned for identical operation.

An audio generator and an AC voltmeter are required for this procedure.

STEP 1 With L+R program feeding the "sum" processor, but with the "difference" Processor disconnected, follow the INPUT GAIN and OUTPUT LEVEL setting procedures for proper mono transmission.

STEP 2 Disconnect the "sum" Processor from the program feed and from the transmitter, and connect the audio generator to the Processor input.

STEP 3 Apply a 500Hz test signal to the preadjusted "sum" Processor at a level which causes the -6dB G/R indicator to just come on.

STEP 4 With the AC voltmeter, measure and record the output level from the "sum" unit.

STEP 5 Without changing the level from the audio generator, disconnect it from the "sum" Processor and apply the signal to the input of the "difference" unit.

STEP 6 Advance the INPUT GAIN control of the "difference" Processor until the -6dB indicator just comes on.

STEP 7 Monitor the output level of the "difference" Processor with the AC voltmeter and adjust the OUTPUT LEVEL control for the same reading as previously noted at the output of the "sum" unit. The POS. PEAKS control on the "difference" Processor should be left fully counterclockwise.

The "sum" Processor may now be reinstalled at the L+R, "main" input to the transmitter, and the "difference" unit at the corresponding point in the L-R signal path.

This procedure assumes similar signal levels at both matrix inputs of the AM stereo generator or exciter. The OUTPUT LEVEL of the "difference" Processor may be trimmed for best stereo separation with one stereo channel driven.

IV CALIBRATION

Clock Adjustment

The Model 222 pulse-width-modulation circuits operate at a switching frequency of 152kHz. This frequency is common to similar circuits in other Inovonics processors, and was initially chosen as a multiple (8X) of the FM pilot.

Test point TP2, clearly marked in the silkscreened legend of the circuit board, is the squarewave output of the 152kHz clock. This point may be monitored with a frequency counter using a low-capacitance 'scope probe, and R101 adjusted for the exact frequency; however, Processor operation will not be compromised with errors as great as +/-10%.

The other "TPs" (1,3,4,5) monitor other points in the PWM circuitry. These are identified in the Circuit Descriptions Section, next to Figure 11 on Page 23.

Lowpass Filter Tuning

The 10kHz lowpass filter is a 9-pole, elliptic-function design with four "Frequency-Dependent Negative Resistance" (FDNR) active elements, each tunable to its specific resonant "null" frequency.ppp

This filter configuration is inherently very stable, and precision components have been used to assure drift-free operation indefinitely. Though the filter should never need retuning, a procedure is nevetheless outlined below.

The equipment required is a stable audio generator, a frequency counter, and general-purpose oscilloscope with a low-capacitance probe.

STEP 1 (SETUP) Set the PEAK LIMITING and PREEMPHASIS switches "OFF," and the LOWPASS FUNCTION switch "ON." Connect the output of the audio generator to the LINE INPUT of the 222, and to the input of the frequency counter as well. With the 'scope, monitor the output of the filter buffer stage, IC19A. A convenient point is the right-hand end of 10k resistor R132, the second resistor above IC19, second row to the right of the power transformer.

STEP 2 Apply 1kHz at a level that yields a 6-volt peak-to-peak (p-p) sinewave at the monitor point.

STEP 3 Increase the generator frequency to 10,330Hz and downrange the 'scope to observe the residual signal. Adjust R60 for a null at this frequency.

STEP 4 Reset the generator to 10,790Hz and adjust R54 for a null.

STEP 5 Reset the oscillator to 12,490Hz and adjust R66 for a null.

STEP 6 Reset the oscillator to 19,950Hz and adjust R48 for a null.

Overshoot Comp. Adjust

Adjustment of the overshoot compensation circuit must always follow the lowpass filter tuning procedure. Setup is the same as called out in the preceding STEP 1. Figures 8a through 8f depict signal waveforms for the various STEPS of the procedure. These appear on the next page.

STEP 1 (SETUP DOUBLE-CHECK) Audio gen. to LINE IN and counter, 'scope to right-hand end of R132. PK LIM and PREEMPH "OFF," LOWPASS "ON." Also, turn the front-panel POS. PEAKS control and calibration pot R34 fully counter-clockwise. Turn cal. pot R26 a quarter-turn up from full counterclockwise.

STEP 2 Set the generator to 100Hz and increase the level until the observed waveform just starts to flatten at about 8 volts p-p (Fig. 8a).

STEP 3 Increase the generator output level by about 10dB. Using the 'scope vertical attenuators, adjust the squared waveform for exactly 6 graticule divisions p-p (Fig. 8b).

STEP 4 Increase the generator frequency to approx. 1900Hz, fine-tuning for the highest p-p waveform amplitude (Fig. 8c).

STEP 5 While continuing to retune the generator to maintain highest p-p amplitude, advance R26 to a point where the left-hand peak is the same value below +/-3 divisions as the right-hand peak is above +/-3 divisions (Fig. 8d).

STEP 6 Retune the generator to approx. 3200Hz, fine-tuning for the highest p-p amplitude in the monitored waveform. While continuing to finetune the generator, advance R34 to <u>reduce</u> the waveform amplitude level to exactly +/-3 divisions p-p (Fig. 8e).

STEP 7 Carefully fine-adjust R26 and R34 so that the maximum amplitudes at approximately 3200Hz and at 1900Hz match at +/-3 divisions p-p. (Figs. 8e and 8f).

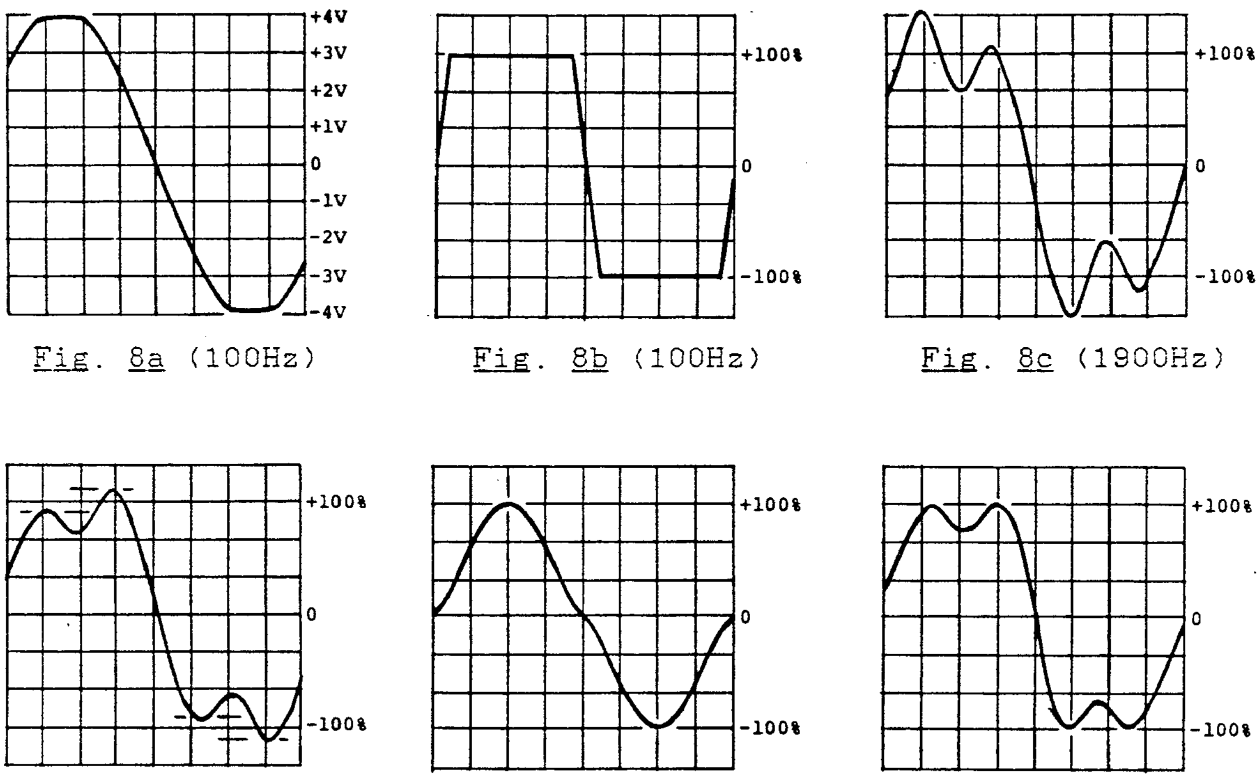


Fig. 8a (100Hz) Fig. 8b (100Hz) Fig. 8c (1900Hz)

Fig. 8d (1900Hz) Fig. 8e (3200Hz) Fig. 8f (1900Hz)

Figure 8 - OVERSHOOT COMP. ADJUSTMENT WAVEFORMS

Stereo Matching

During final test, all Model 222 Processors are calibrated against a "house" standard to ensure best L/R separation when used in "matrix mode" for stereo. Should field recalibration become necessary, two stereo units must first be identically aligned per the forgoing procedures, then "mutually-calibrated," one-against-the-other, for a match in phase response.

This is best done using a dual-trace oscilloscope in the "add-and-invert" mode to display the <u>difference</u> between the two processing channels. STEPS for this procedure are provided on the following page.

STEP 1 (SETUP) Connect the audio generator to both LINE INPUTS of the two Processors, and monitor the right-hand end of both R132s with the two 'scope probes. Turn the PK LIM and PREEMPH "OFF," LOWPASS "ON."

STEP 2 Apply 100Hz at a level which yields a 3-volt p-p sinewave at the two monitor points. Trim INPUT GAIN on one unit or the other to match the levels.

STEP 3 Downrange the vertical attenuators of both 'scope channels to 0.2 volts/div. This should put the observed waveforms just off-scale. Invert one 'scope channel and "add" the signals. Using the A or B channel vernier attenuator, null the residual "sum."

STEP 4 Increase the generator frequency to 1kHz. Readjust the 'scope vernier attenuator to again null the residual. Next, <u>carefully</u> adjust R26 in <u>one</u> of the Processors to try to increase the null depth. Turn the control only a <u>few degrees</u> in either direction, while simultaneously trimming the 'scope attenuator to maintain a best null. If the null <u>can</u> be improved with R26, adjust the one Processor for <u>only one-half</u> the improvement. Adjust R26 in the <u>other</u> unit in the <u>opposite direction</u> to reach maximum null depth.

STEP 5 Increase the generator frequency to 5kHz. Trim the 'scope vernier attenuator to maximize the null, and in a manner similar to STEP 4, but adjusting R48 in both units, optimize null depth at 5kHz.

V CIRCUIT DESCRIPTIONS

This section details the circuitry of the Inovonics 222. These circuit discussions refer to the three pages of Schematic Diagrams contained in the Appendix, Section VI.

The first part of this Section covers the general subject of Pulse Width Modulation (PWM) and its implementation in the Model 222. Signal path circuitry discussions follow.

About Pulse Width Modulation

PWM is utilized exclusively for Peak Limiter gain control and the "adaptive" variable preemphasis in the Inovonics 222. This quasi-digital approach is certainly one of the simplest, and among the few truly "colorless" means of varying the amplitude of an analog signal with a DC control voltage.

Consider an audio signal which can be turned on and off with a toggle switch. When the switch is ON, attenuation is zero. When OFF, attenuation is infinite. If we satisfy the Nyquist sampling theory and toggle this switch at a rate at least twice that of the highest audio frequency, linear signal attenuation becomes directly proportional to the OFF time.

ON	OFF	dB ATTEN
100%	0%	0dB
50%	50%	6dB
25%	75%	12dB
10%	90%	20dB
1%	99%	40dB
0%	100%	(infinite)

This technique gets a bit touchy at small duty cycles (40dB or more attenuation), relegating it to uses which do not require a great amount of gain reduction. PWM thus lends itself well to audio processing applications because it is easily implemented and very predictable over the modest 30dB range required.

The "clock" (switching) frequency in the Model 222 is 152kHz. Since this is well above the Nyquist rate, no elaborate anti-aliasing filters are needed, either in the signal input path or to remove the switching frequency from the output signal.

PWM Generation

Gain control and variable preemphasis in the 222 operate in a feedforward mode rather than in the more common feedback configuration. This necessitates a conversion function to cause a dB of output signal decrease for each dB that the input signal increases to keep the output level constant over a wide input signal range.

Put into linear (voltage), rather than in log (dB) terms, the function can be expressed simply as X = 1/Y. Figure 9 graphs this, with X representing circuit gain (reduction) required to hold a 1 - 10-volt input signal, Y, at a constant, 1-volt output.

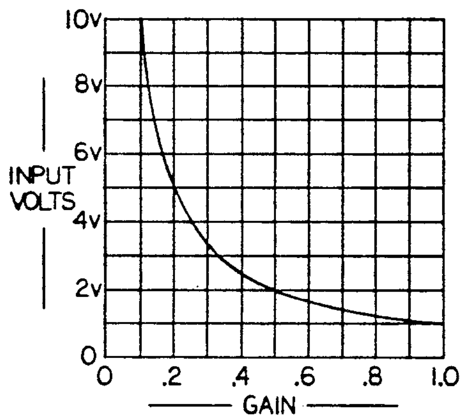


Figure 9

VOLTAGE TRANSFER FUNCTION

If we assume a linear relationship between PWM "OFF" time and signal gain reduction, the 1/Y expression translates directly to the duty cycle: 0.1 = 10% "ON," and 1.0 = 100% "ON."

In this implementation, however, we must add a "threshold" level, below which circuit gain will remain at full value. Just above threshold the function will conform to the desired "soft knee" characteristic (see Figure 3, Page 6), and above this gentle transition the X = 1/Y expression will fully apply. The desired "composite" is graphed in Figure 10.

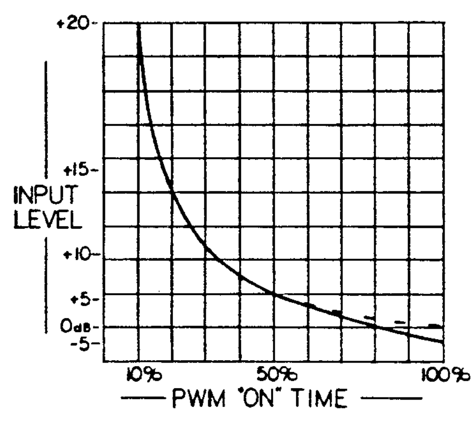


Figure 10

PWM DUTY CYCLE

VS. INPUT LEVEL

Clock and Ramp Generator

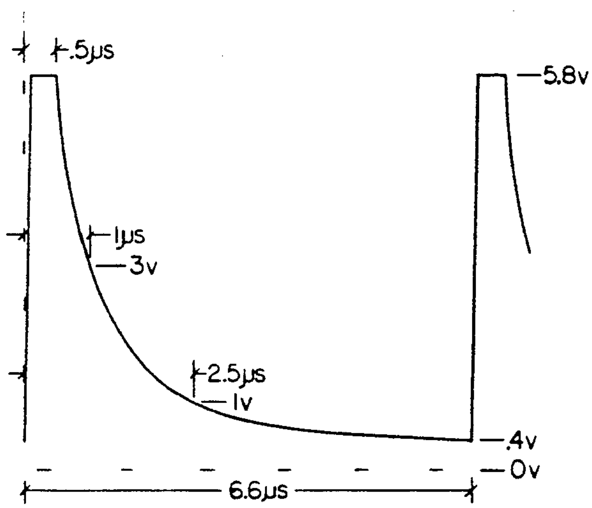
Referring to Page 34, IC16A and IC16B form a free-running multivibrator for the 152kHz "clock" fre- quency. TP2 may be monitored with a counter, and the frequency adjusted with R101.

With each positive transition of the clock, Q10 is momentarily turned off by a pulse through C38. This saturates Q11 and quickly charges C39 to the +15V supply rail.

C39 has a "compound" R/C discharge time constant. As soon as Q11 turns back off, C39 discharges through R113, R108 and R109. When the discharge reaches the bias voltage level at the cathode of CR15, R108 is biased out of the circuit and the discharge assumes a slower rate. Similarly, when the ramp reaches the CR16 bias point, the only remaining path is through R113 and R114 to ground, and the discharge slows even more. The result is a "compounded" log ramp which closely follows the curve shown in Figure 10, but is repetitive at the 152kHz rate.

Clock pulses at TP2 are also differentiated by C37 to produce a 200-nanosecond "holdoff" pulse coincident with the charging of C39. This pulse may be observed at TP3; its purpose is explained later.

The ramp waveform is buffered by Q12 and Q13. It is shown in Figure 11 and may be monitored with an oscilloscope at TP1. Accuracy of the feedforward transfer function depends directly on the integrity of this waveform, and both voltage levels and timing information are noted. Other "TP" monitor points are identified in the table next to Figure 11.



TEST POINT		DESCRIPTION
TP1	-	"RAMP" WAVEFORM
TP2	-	152kHz "CLOCK"
TP3	-	200ns "HOLDOFF"
TP4	-	PK LIMIT PWM
TP5	-	PREEMPHASIS PWM

Figure 11 - "RAMP" WAVEFORM (TP1)

Signal Input Circuitry

IC1A (Page 33) is an active "balancing" stage for the program LINE INPUT. When a section of the buildout resistance in each leg of the input is jumpered, gain increases to accommodate lower signal levels.

IC1B combines a variable-gain amplifier with a third-order, 30kHz lowpass filter. R11 adjusts Processor INPUT GAIN over a 15dB range, and the filter removes any high frequency program or noise components which might be "aliased" by the 152kHz PWM switching frequency.

Peak Limiter

From IC1B, the input signal is split into two routes; the primary signal path to the Peak Limiter gain-control circuit, and through the PEAK LIMITER "ON/OFF" switch to the Limiter control circuitry.

IC3D is the CMOS analog switch section which linearly controls program signal broadband gain. The switch is driven by square-wave PWM. As the duty cycle of the switching waveform varies, so does the equivalent resistance of the switch. IC2B is a current-summing stage with a second-order lowpass characteristic. It converts the PWM-modulated program signal current back to a voltage, the filter action removing high frequency switching components.

The input program signal sample from the PEAK LIMITER "ON/OFF" switch is fed to the rectifier and control circuitry shown on Page 34.

IC12 is a full-wave "precision" rectifier. CR5 and CR6 in the feedback path of IC12A compensate for the forward drop in the actual rectifier diodes, CR7 and CR8. When the front-panel POS. PEAKS control is advanced to allow asymmetrical modulation, the bipolar DC reference fed through R75 and R76 is imbalanced. This causes an offset in the output of IC12B, and positive-going program material initiates less Limiter gain reduction.

The value of rectified peaks is "held" by C32. Occasional fast peaks quickly "release" as C32 discharges through R82 to the DC level across C33. Under dynamic program signal conditions, however, C33 assumes a charge as it integrates the average value of program peak content. This creates the dual-time-constant, "platform" Limiter release characteristic, providing a delayed release for repetitive program peaks.

IC14A buffers the DC control voltage which feeds both the PWM-modulation comparator and the Limiter G/R indicator.

PWM-Generation Comparators

Q4, Q5 and Q6 form the discrete-component, high gain comparator circuit which generates the actual PWM switching signal for Peak Limiter gain reduction. An identical comparator, comprising Q7, Q8 and Q9, serves the variable preemphasis function.

A DC control voltage derived from the input program signal is presented to the base of Q4. The "ramp" waveform is fed to the base of Q5, and each time the negaive-going ramp crosses the control voltage level, the collector of Q6 toggles from +15V to -6V. This is translated to a +/-6V level at pin 2 of IC15A, in keeping with the ground-referenced bipolar 6V operating range of all CMOS logic and signal-control circuits.

With these comparators, a lower DC control voltage will result in a longer PWM duty-cycle ON time. When the voltage drops to zero, as is the case when no signal or preemphasis reduction is required, the PWM waveform would normally revert to a constant +6V logic level. To preserve the "switching" nature of the PWM waveform, a pair of AND gates (IC15A and IC15B) follow each comparator. These combine "raw" PWM with the 200-nano-second "holdoff" pulse to ensure a finite OFF time.

G/R Indicators

The four G/R indicator LEDs in each of the two strings are driven by a series of op-amp voltage comparators (IC17 and IC18). The "+" inputs of the three comparators for each section are presented with the signal-derived DC control voltages. "-" inputs are biased to DC levels corresponding to 2dB, 6dB and 12dB G/R. As the control voltage reaches each bias point, the output of that comparator toggles from +15V to -15V, turning "off" the LED above, and turning "on" the LED below.

"Adaptive" Preemphasis

The leveled program signal at the output of IC2B (Page 33) is passed with unity gain to summing amplifier IC4B, and through the PREEMPHASIS "ON/OFF" switch to a first-order highpass network. C11 and R17 impart a 6db-per-octave rising characteristic (starting at 0Hz) with a "pole" at 8700Hz as specified in the NRSC preemphasis spec.

The signal from the highpass network is buffered by IC2A and fed through CMOS analog switch IC3C to the summing amplifier, IC4B. When the switch is "ON," the combined "flat" and "highpass" signals create the specified preemphasis curve. As the duty cycle of IC3C is varied from "ON" to "OFF," the turnover frequency, normally 2122Hz, shifts upward. This lowers the amount of overall preemphasis as shown in Figure 4, Page 7.

Preemphasis is controlled by a feedforward technique similar to that used for the Peak Limiter.

Highpassed program audio from IC2A is fed to a full-wave peak rectifier, IC13 (Page 34). This circuit is similar to IC12, but includes a second-order lowpass function to remove the now-preemphasized PWM switching component. As with the Peak Limiter, high frequency limiting utilizes a "platform" release characteristic, but with a much shorter time constant.

PWM generation for the variable preemphasis stage is identical to that for the Peak Limiter. The HIGH FREQ. G/R indicator includes a peak-holding capacitor, C44, to ensure a meaningful display despite the very fast attack and release times.

Filter Overshoot Compensator

Nearly any lowpass filter will exhibit a certain amount of "overshoot" and "ringing." Generally, the sharper the cutoff, the more pronounced the effect. A 9-pole "elliptic" filter, such as that used in the 222, can exhibit output overshoots in the order of 1.5 times the level of an amplitude-controlled input signal.

Unlike other systems of overshoot control which allow the filter to overshoot, then somehow re-introduce the overshoots back into the signal path, the circuitry of the Inovonics 222 so conditions the amplitude-limited program signal that the filter, which is placed after the compensator, has little or no tendency to overshoot.

CR1 and CR2 form a "hard" clipper at the compensator input. These diodes are biased to a point which matches the "ceiling" level of the Peak Limiter, and in actual operation rarely act on the already-limited signal. They do, nevertheless, establish a 100%-modulation reference. DC bias for the positive-peak clipper, CR1, is varied by the POS. PEAKS control to pass asymmetrical material.

IC5A is a phase-lag circuit which time-displaces the fast leading and trailing edges of steep wavefronts. Thus the primary characteristic of the program waveform which would normally excite filter overshoot is instead added to the waveform amplitude.

CR3 and CR4, also biased to the 100%-modulation point, "strip" these displaced-and-added components from the program signal. They are then recovered by IC6B, a differential, unity-gain amplifier which compares the "stripper" input with its output. These componets, containing much of the harmonic content of the program, are recombined with the "stripped" program signal in summing stage IC7A, but in opposite phase. The 180-degree displacement of the higher-order program harmonics has no audible effect, but effectively inhibits filter overshoots.

IC7B is a high gain amplifier connected to the output of the differential "recovery" stage, IC6B. Whenever the compensator circuit is active, the amplified output from IC6B is rectified by Q1 and Q2 to turn on Q3, driver for the O.S. COMP. indicator LED. C16 "stretches" the indicator "on" time so that even very fast filter compensations are adequately displayed.

Lowpass Filter

The 9-pole, elliptic-function lowpass filter is of quite conventional design. It is often referred-to as an "FDNR" configuration, because each of the legs to ground simulates a Frequency-Dependent Negative Resistance. With reference to the classic L/C elliptic design upon which this active circuit is based, the resistors in series with the signal path directly replace series inductors, and each of the active circuits to ground directly replaces an inductor/capacitor series resonant element.

For a further, in-depth discussion of this and other varieties of active filter circuitry, the reader is directed to the "cookbook" which aided this design. It's the Electric Filter Design Handbook by Arthur B. Williams, published by McGraw-Hill. In this particular book, the "FDNR" filter is called a "GIC," or Generalized Impedance Converter.

Output Circuit

IC19 (Page 35) buffers and amplifies the output signal from the lowpass filter. CR19 and CR20 are biased to the +/-100% -modulation points to provide a "safety" clipping function. Because filter overshoots are effectively prevented, these diodes rarely, if ever, act on the program signal.

IC20A is a current-summing stage which can accept a program signal from the output of the lowpass filter, or from the earlier preemphasis combining amplifier, IC4B (Page 33), depending on whether the front-panel LOWPASS FUNCTION switch is "ON" or "OFF." From here, the program signal passes through the OUTPUT LEVEL control to the output driver stage, IC21.

Together, IC20A and IC21B comprise a fourth-order lowpass filter with a 30kHz cutoff frequency and linear phase response to at least 15kHz. This filter further attenuates any residual PWM switching components, or any high-order harmonics possibly generated by the "safety" clipper when the Processor is severly overdriven.

IC21B drives the "+" side of the LINE OUTPUT. This signal is then inverted by IC21A to provide the opposite phase for the "-" side of the output.

Power Supply

The power transformer, T1, has a dual primary winding for operation at 115 or 230VAC. The plug-on jumper strip connects the two windings either in parallel (115V) or in series (230V). This procedure is described on Page 11.

IC23 and IC24 are "3-Terminal-Adjustable" voltage regulators for the bipolar 15-volt supplies. The +/-15V is then dropped through R156 and R157, and stabilized by zener diodes CR24 and CR25, to supply bipolar 6V to the CMOS devices.

VI APPENDIX

(Parts List - Schematics - Warranty)

PARTS LIST - INOVONICS MODEL 222

("NRSC" PROCESSOR)

SCHEMATIC DESIGNATION	INOVONICS PART NO.	COMPONENT DESCRIPTION (MFGR. / MFGR. P/N)
Capacitors		
C1,2,38,49	0810	DM-15 Mica; 100pF, 5%, 600V (open)
C3,4	1078	Electrolytic; 22uF, 25VDC (open, radial)
C5,6,9,10,13, 14,30,31	1081	Polycarbonate; .0022uF, 5%, 100V (WIMA / FKC-2))
C7	0812	DM-15 Mica; 150pF, 5%, 600V (open)
C8,12,29,45	0876	Polycarbonate; 470pF, 5%, 100V (WIMA / FKC-2)
C11	0884	Polycarbonate; .001uF, 5%, 100V (WIMA / FKC-2)
C15,28,46,47	1083	Polycarbonate; .0047uF, 5%, 100V (WIMA / FKC-2)
C16,32,34,40, 41,44	0932	Polyester; .1uF, 5%, 63V (WIMA / MKS-2)
C17-25,27	1086	Polypropylene; .0033uF, 2.5%, 100V (WIMA / FKP-2)
C26	1060	Electrolytic; 4.7uF, 25V (open, radial)
C33	1087	Polyester; .22uF, 5%, 63V (WIMA / MKS-2)
C35	0930	Polystyrene; .01uF, 5%, 63V (WIMA / MKS-2)
C36	0836	DM-15 Mica; 200pF, 5%, 600V (open)
C37	0806	DM-15 Mica; 47pF, 5%, 600V (open)
C39	0818	DM-19 Mica; 470pF, 5%, 600V (open)
C42,43,51, 52,54,55	1053	Tantalum; 2.2uF, 25V (open, radial)
C48	1084	Polycarbonate; .0027uF, 5%, 100V (WIMA / FKC-2)
C50,53	0910	Electrolytic; 470uF, 35V (open, axial)
C56,57	1064	Disc Ceramic; .005uF, 1KV (open)
Diodes		
CR1-18	1100	Silicon Signal; 1N4151 (open)
CR19,20	1127	Silicon Schottky; 1N5711 (H.P., TRW)
CR21,22,23, 25,26,27	1125	Silicon Rectifier; 1N4005 (open)
CR24,28	1104	Silicon Zener, 6.2V; 1N4735 (open)

PARTS LIST (continued)

SCHEMATIC DESIGNATION	INOVONICS PART NO.	COMPONENT DESCRIPTION (MFGR. / MFGR. P/N)

Indicators

I1,2,6	2021	LED, Clear/Green, T1 (STANLEY / SBG 3901)
I3,4,5,7,8,9	2022	LED, Clear/Red, T1 (STANLEY / SBR 3901)
I10	2019	LED, Red/Red, T1-3/4 (STANLEY / SPR 5731)

Integrated Circuits

IC1,2,4-11, 19,20	1375	FET-input Dual Op-Amp; LF353N (open)
IC3	1335	CMOS Quad Analog Switch; CD4066BE (open)
IC12,13,14,22	1313	Dual Op-Amp; RC4558NB (RAYTHEON, T.I.)
IC15	1342	CMOS Quad AND; CD4081BE (open)
IC16	1336	CMOS Hex Inverter; CD4069BE (open)
IC17,18	1320	Quad Op-Amp; RC4136N (RAYTHEON, T.I.)
IC21	1314	Dual Op-Amp; NE5535N (SIGNETICS)
IC23	1373	Pos. Volt. Reg.; LM317T (open)
IC24	1374	Neg. Volt. Reg.; LM337T (open)

Transistors

Q1,2,4,5,7,8	1210	NPN, High Beta; 2N5088 (open)
Q3,6,9,10, 11,12	1205	PNP, Gen. Purp.; 2N3906 (open)
Q13	1204	NPN, Gen. Purp.; 2N3904 (open)

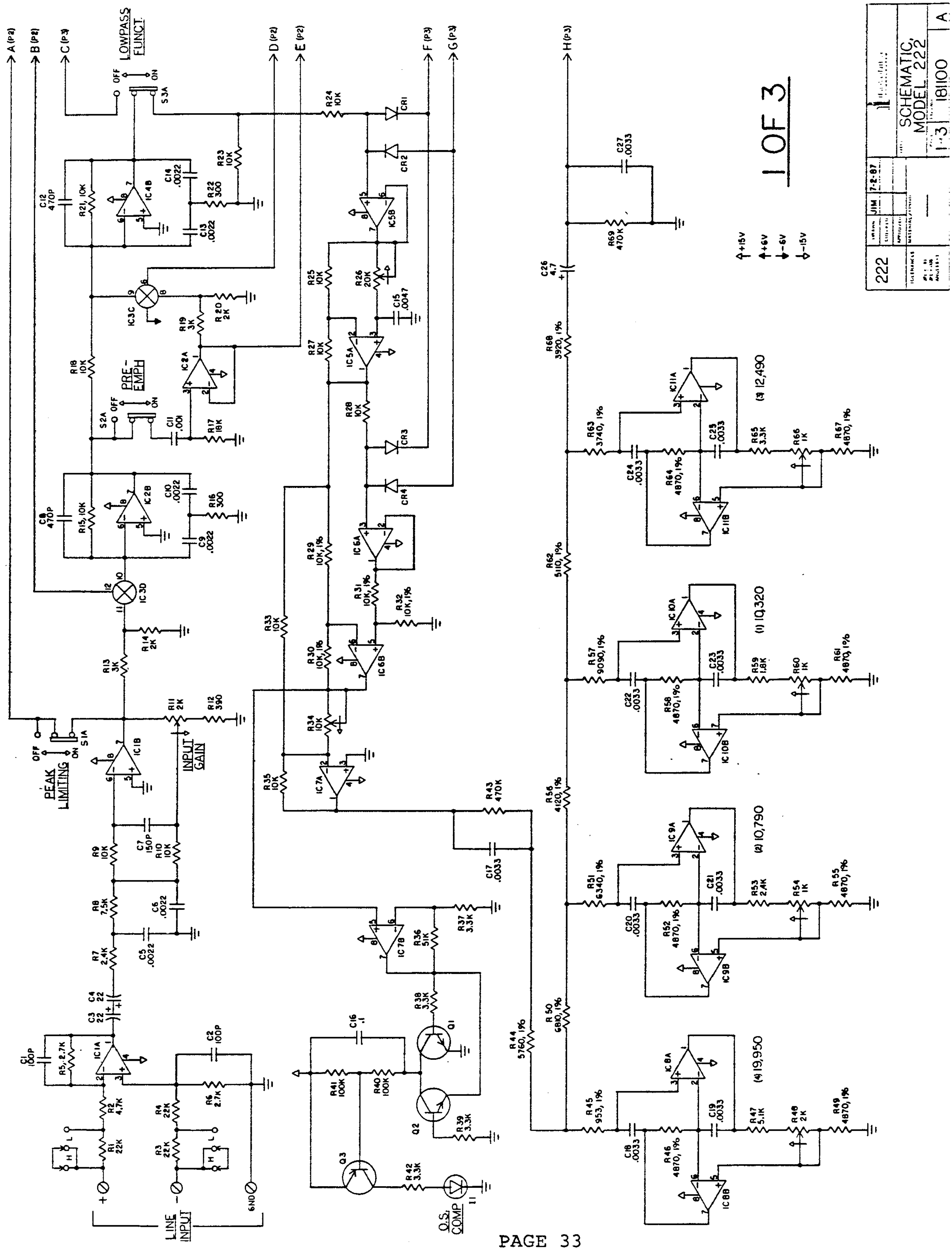
Resistors

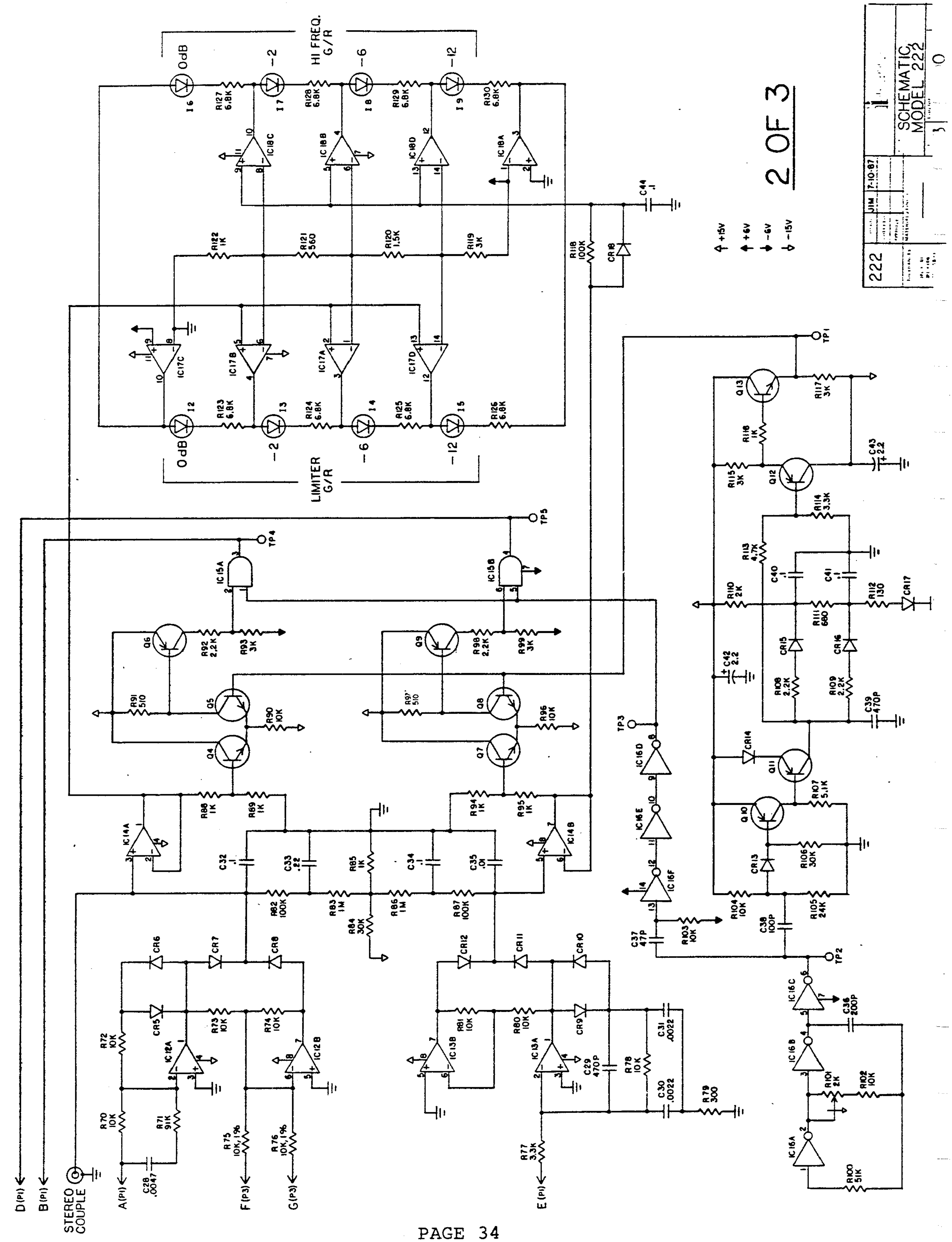
UNLESS NOTED BELOW, fixed resistor values are per schematic notation, in ohms (K = X1000, M = X1Meg). With no tolerance specified, resistor is 5%, 1/4-watt, carbon film; 1% resistors are 1/4-watt, metal film.

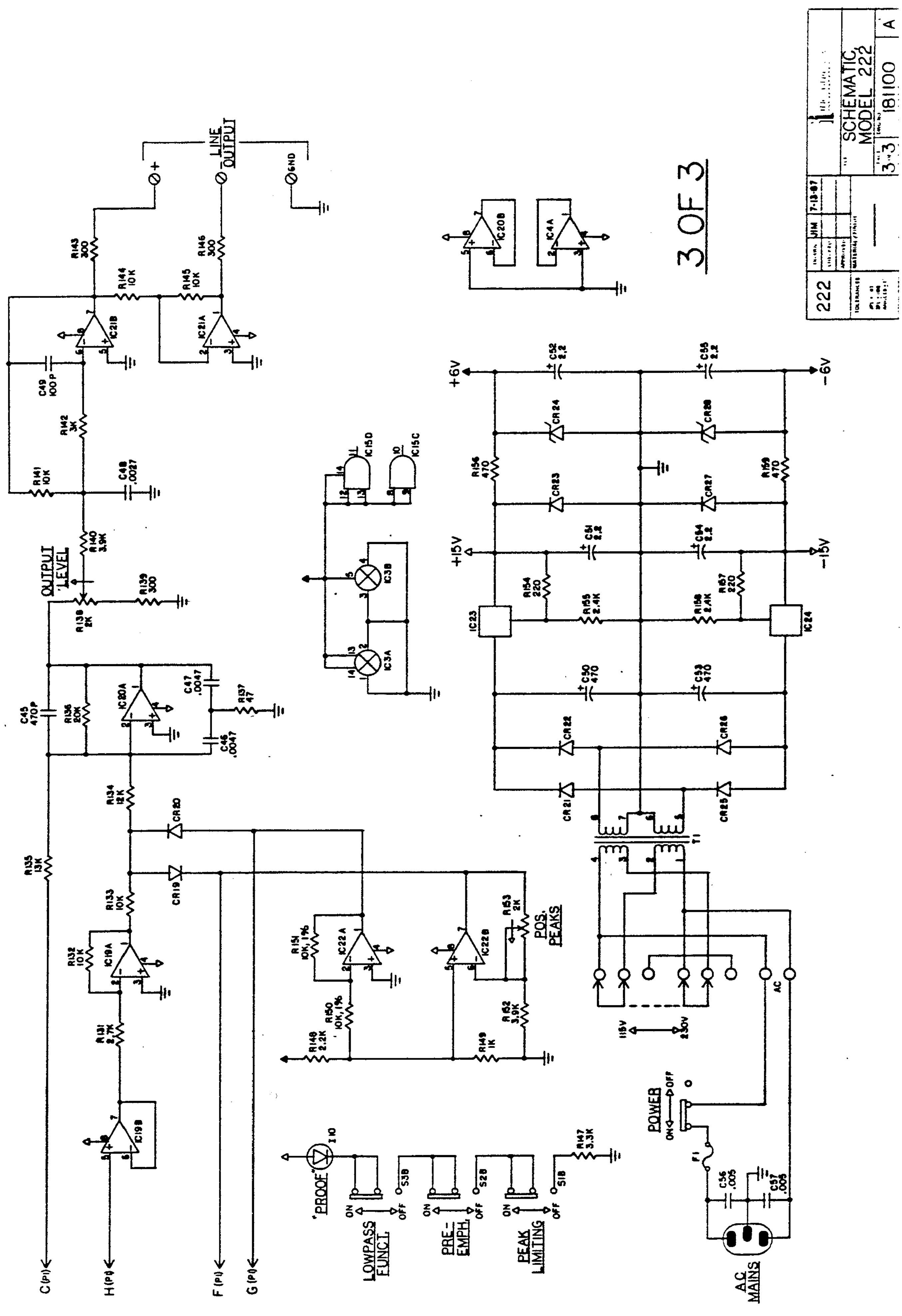
R11,138,153	0508	Multiturn Trimmer; 2K (BECKMAN 89PR2K)
R26	0560	Sgl. Turn Trimmer; 20K (BECKMAN 91AR20K)
R34	0559	Sgl. Turn Trimmer; 10K (BECKMAN 91AR10K)
R48,101	0557	Sgl. Turn Trimmer; 2K (BECKMAN 91AR2K)
R54,60,66	0556	Sgl. Turn Trimmer; 1K (BECKMAN 91AR1K)

PARTS LIST (continued)

SCHEMATIC DESIGNATION	INOVONICS PART NO.	COMPONENT DESCRIPTION (MFGR. / MFGR. P/N)
Switches		
S1,2,3	1857	DPDT Miniature Slide, Side-Actuated (CW INDUS. / GI-152 PC)
S4	1816	SPDT Slide (CW INDUS. / GF-324)
Power Transformer		
T1	1523	Dual Primary, PC-mounting (TRIAD FP34-340, SIGNAL LP-34-340)
Miscellaneous		
J1	1731	Stereo Interconnect "Phono" jack (KEYSTONE)
- -	1737	0.1-inch-spacing "Shunt" (Jumper to set Input Gain Range)
- -	1723	8-position Female "shell" for Mains Voltage Selection Jumper
- -	1674	Female "pins" to fit "shell," above; 4 required.
- -	2605	Silicone Rubber Mounting Washer for TO-220 Voltage Regulators
- -	2604	Fiber Shoulder Washer for mounting TO-220 Voltage Regulators


SCHEMATIC, MODEL 222
181100
222
1 OF 3
LINE INPUT
PEAK LIMITING
INPUT GAIN
PRE-EMPH
LOWPASS FUNCT
O.S. COMP


SCHEMATIC MODEL 222
2 OF 3
222
7-10-87
HI FREQ. G/R
LIMITER G/R
STEREO COUPLE
D (P1)
B (P1)
A (P1)
F (P3)
G (P3)
E (P1)
TP1
TP2
TP3
TP4
TP5
+15V
+6V
-6V
-15V


SCHEMATIC MODEL 222
181100
A
222
3 OF 3
LINE OUTPUT
GND
OUTPUT LEVEL
POS. PEAKS
LOWPASS FUNCT.
PRE-EMPH.
PEAK LIMITING
"PROOF"
POWER
AC MAINS
+6V
-6V
+15V
-15V
115V
230V
C(P1)
H(P1)
F(P1)
G(P1)

INOVONICS WARRANTY

Inovonics, Inc. products are warranted to be free from defects in material and workmanship. Any discrepancies noted within 90 days of the date of purchase will be repaired free of charge. Additionally, parts for repairs required between 90 days and one year from the date of purchase will be supplied free of charge, with installation billed at normal rates. It will be the responsibility of the purchaser to return equipment for warranty service to the dealer from whom it was originally purchased unless prior arrangement is made with the dealer to inspect or repair at the user's location.

This warranty is subject to the following conditions:

1. Warranty card supplied with the equipment must be completed and returned to the factory within 10 days of purchase.

2. Warranty is void if unauthorized attempts at repair or modification have been made, or if serial identification has been defaced, removed, or altered.

3. Warranty does not apply to damage caused by misuse, abuse, or accident.

4. Warranty valid only to original purchaser.

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