SECTION 15

LIMITER (CLIPPER) CIRCUITS

PART A. ELECTRON-TUBE CIRCUITS

DIODE LIMITER.

APPLICATION.

The diode limiter is used to eliminate, or square off, either extremity of the applied signal. The limiter is also known as a clipper, because the output waveform presents a "clipped" appearance on the wave peaks.

CHARACTERISTICS.

Input may be a positive signal, a negative signal, or a combined signal having either the same or different waveforms on the positive and negative peaks, depending on the design application.

Output may be a positive signal with negative portion completely clipped, or a negative signal with positive portion completely clipped; or it may contain only a portion of the positive peaks with the remainder of the positive and all of the negative signal clipped, or contain only a portion of the negative peaks with the remainder of the negative and all of the positive signal clipped. Finally, the output may contain both positive and negative signals, with both positive and negative peaks clipped.

Output amplitude is always lower than input amplitude; may be preset at any value between input amplitude and zero amplitude in the design of the circuit constants.

Output signal is in phase with input signal.

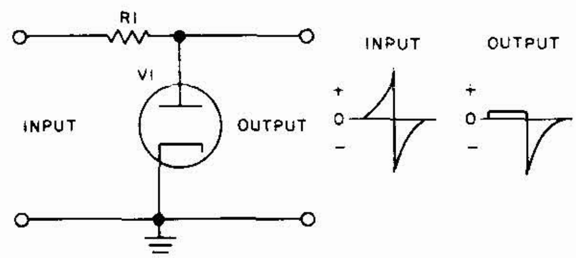
CIRCUIT ANALYSIS.

General. Limiters are used in wave-shaping circuits where it is necessary to "square off" the peaks of the input signal. A sine wave may be applied to the input of a limiter, to obtain a nearly square wave output. A peaked wave may be applied to a limiter, to eliminate either the positive or negative peaks, or parts thereof. Limiters also find use in applications where it is necessary to restrict the amplitude of a signal to a constant value, such as the signal applied to the detector circuit of a frequency modulation receiver. They are also used in a protection type of circuit, where the input or output voltage must be prevented from exceeding a predetermined level.

Circuit Operation. Diode limiters may be divided into two general classifications: series diode limiters and parallel diode limiters. Each of these divisions may be further subdivided into two groups: positive lobe limiters and negative lobe limiters. The specific characteristics and circuit operation of each group are contained in the five circuits to follow in this section. A brief discussion covering diode limiters in general is given in the following paragraphs.

A vacuum-tube diode conducts only when its plate is at a positive potential with respect to its cathode; in other words, when the cathode is negative (less positive) with respect to the plate. If the cathode is fixed at ground potential, the diode will conduct whenever its plate becomes positive with respect to ground. If a positive potential is placed on the cathode, the diode will not conduct until the potential applied to the plate exceeds an equally positive value. In like manner, the cathode may be fixed at a negative potential, and the diode will conduct while the plate is positive, and will continue to conduct while the plate is negative with respect to ground but is less negative than the cathode. When the plate potential is made more positive with respect to the cathode, the conduction of current through the diode increases rapidly, while the plate-to-cathode resistance decreases rapidly from an open-circuit (infinite resistance) value to an average value of approximately 500 ohms.

The action of a diode limiter is shown in the following illustration, which shows a simple typical diode limiter



Typical Diode Limiter Circuit and Input-Output Waveforms

circuit and typical input-output waveforms. When the input voltage rises in the positive direction, the diode (V1) conducts, and continues conducting until the voltage falls to zero. As a result of the current flow most of the voltage drop is across resistor R1; the amount of voltage drop across the diode due to its plate-to-cathode, or forward, resistance is shown in the output waveform as a slight positive value above zero. When the input falls to zero and rises in a negative direction, the diode will not conduct, and its reverse resistance is practically infinite. Since no current flows through the diode and resistor R1, there is no voltage drop across R1 (assuming that the load connected to the output terminals has a high impedance), and the output voltage waveform is therefore a duplicate of the input waveform, during the negative half cycle.

FAILURE ANALYSIS.

No Output. A diode limiter circuit is ordinarily rather simple, and the analysis of failure is also simple. The cause of no output may be resolved to either of three conditions: no input, a defective resistor R1, or a defective diode. Assuming that the proper input signal is being applied, either resistor R1 or the diode must be at fault. The resistor may be open-circuited, or the diode may be shorted. Either condition would result in no output.

Reduced or Unstable Output. In the circuit illustrated previously, a diode which is defective to the extent of poor cathode emission would be responsible for insufficient limiting. As the internal resistance of the diode increases, the voltage drop across it also increases. This will allow an increased value of voltage to remain on the limited half cycle which would have been eliminated in normal operation from the output signal. A radical change in the value of resistance of R1 would also reduce the output signal.

SERIES, POSITIVE LOBE DIODE LIMITER.

APPLICATION.

The series, positive lobe diode limiter is used when it is necessary to square off part, or all, of the positive portion of an input signal waveform and allow the negative portion to pass without modification of waveform.

CHARACTERISTICS.

Input signal waveform contains both positive and negative signals.

Output waveform contains only negative signals.

Output amplitude is lower than input amplitude; no amplification is realized in the circuit.

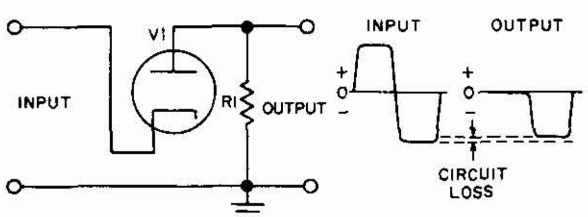
Output signal is taken across a load resistor.

Output signal is in phase with input signal.

CIRCUIT ANALYSIS.

General. The series, positive lobe diode limiter consists essentially of a diode connected in the signal line, in series with the signal source and the load, and polarized so that the negative portions of the signal will pass through the diode without being affected. A load resistor is connected on the load side of the diode, and the output signal is taken across this resistor.

Circuit Operation. A simplified series, positive lobe diode limiter is shown in the following illustration. In this circuit, the diode conducts during the negative portion of the input signal. Conduction is accomplished by driving the cathode negative with respect to the plate, which has the same effect from the viewpoint of the tube electrodes as driving the plate positive with respect to the cathode.



Simplified Series, Positive Lobe Diode Limiter and Input-Output Waveforms

When the input signal goes negative, the diode conducts, and it presents a low value of resistance to the signal. The total resistance in the circuit, connected across the input terminals, then consists of diode V1, which has a low resistance, in series with load resistor R1, which has a comparatively high resistance. Since the voltage drop across each individual resistance in a series circuit is in direct proportion to its resistance divided by the sum of the resistances, according to Kirchhoff's laws, most of the input signal voltage will appear across load resistor R1, while a small amount will drop across diode V1 and be lost insofar as the circuit output is concerned. For this reason the value of the load resistor, R1 should be many times greater than the forward resistance of the diode, V1. When the input signal goes positive, the diode cuts off and thus limits the flow of current in the series circuit. The voltage across load resistor R1 then falls suddenly to zero, and remains at zero until the input signal goes negative on the following half cycle.

The value of load resistor R1 affects the output of the circuit in several ways. First, for the best frequency response characteristic, R1 should be as low as practicable. But in order for the circuit to function to the best advantage as a limiter, the load resistor must be several times the value of the forward, or conduction, resistance of the diode. The effect of various values of load resistance on the output voltage, for three characteristic tube types at V1 in the previous circuit, are shown in the following table. The three tube types are all twin-diodes, and have different values of forward resistance. The forward resistance, or resistance during the period of conduction, of a single section of each of the tubes is as follows: 6AL5, 250 ohms; 6X5, 500 ohms; 6H6, 750 ohms. The values of output voltage are listed, assuming an input voltage of 10 volts to the circuit, with the polarity of the voltage such that the diode V1 conducts to the maximum value (10 volts) on the negative half cycles.

Value of R1	Tube Type 6AL5 (250 ohms fwd res)	Tube Type 6X5 (500 ohms fwd res)	Tube Type 6H6 (750 ohms fwd res)
1K	8.0	6.66	5.71
5K	9.52	9.09	8.69
10K	9.75	9.52	9.30
50K	9.95	9.90	9.85
100K	9.97	9.95	9.92

Output Voltage of Diode Limiter Using Various Tubes and Load Resistances, at 10 Volts Input

It can be seen, from the table above, that with a load resistance of 100K, which is 400 times the value of the forward resistance of a type 6AL5 tube, practically the entire input voltage is available at the output of the limiter, with only 0.3 volt circuit loss occurring within the tube.

FAILURE ANALYSIS.

No Output. Because of the relative simplicity of the series, positive lobe diode limiter, the analysis of failure is likewise simple. The failure of either component will cause trouble, but only the failure of the diode would be responsible for a no-output condition. Obviously, the failure of the applied signal at the input to the limiter should be suspected if no output is obtained from the limiter.

Reduced or Unstable Output. In a series, positive lobe diode limiter, a reduced value of output would most likely be due to a diode which has poor cathode emission, and therefore has a high internal, or forward, resistance. It is also possible, although less likely, that the load resistor may have decreased in ohmic value because of age or overload. If, however, the cathode emission of the diode falls off, its internal resistance will increase, and the end result will be a decrease in the output voltage. This can be seen from the previous table, which shows the dependance of the output voltage upon both the load resistance and the diode used. Consulting the table, suppose that the circuit comprised one section of a type 6AL5 diode and a 1K load resistor. With a 10-volt input, the output may be expected to be on the order of 8 volts, since the 6AL5 has approximately 250 ohms forward resistance. If, however, the cathode emission decreased to the extent that the forward resistance increased to 500 ohms (comparable to that of the type 6X5 diode), the output will also have decreased to approximately 6.66 volts, comparable to the output of the 6X5 under its normal operating conditions.

SERIES, NEGATIVE LOBE DIODE LIMITER.

APPLICATION.

The series, negative lobe diode limiter is used when it is necessary to limit, or square off, part or all of the negative portion of an input signal waveform, and at the same time allow the positive portion of the input signal to pass without modification of waveform.

CHARACTERISTICS.

Input signal waveform contains both positive and negative signals.

Output waveform contains only positive signals.

Output amplitude is lower than input amplitude; no amplification is realized in the circuit.

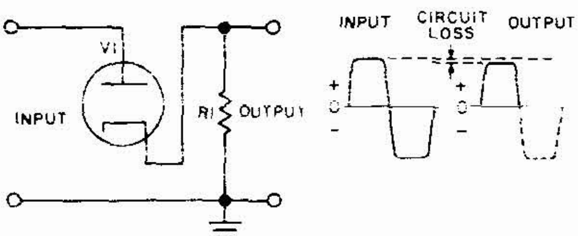
Output is taken across a load resistor.

Output signal is in phase with input signal.

CIRCUIT ANALYSIS.

General. The series, negative lobe diode limiter consists essentially of a diode connected in the signal line, in series with the signal source and the load, and polarized so that the positive portions of the signal will pass through the diode without being affected. The output is taken across a load resistor which is connected in series with the diode.

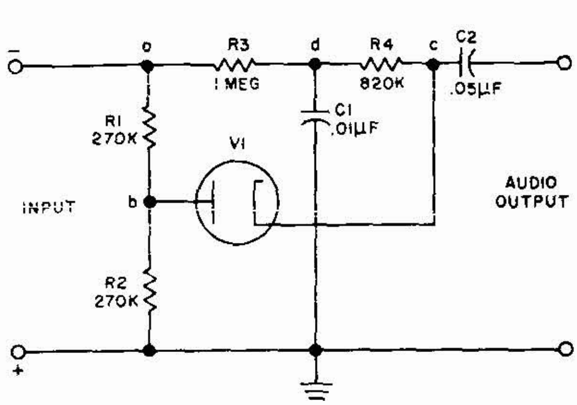
Circuit Operation. A simplified series, negative lobe diode limiter is shown in the following illustration. In this



Simplified Series, Negative Lobe Diode Limiter and Input-Output Waveforms

circuit, the diode conducts during the positive portion of the input signal. When the input signal goes positive, the diode presents a low value of resistance (called the forward resistance) to the signal, and passes the signal through the circuit to the output. The total resistance in the circuit then consists of diode V1 connected in series with the load resistor, R1, and this combination is connected across the input terminals. As explained in the previous circuit covering the series, positive lobe diode limiter, the value of the load resistor should be many times greater than the forward resistance of the diode. When this condition prevails, most of the input signal voltage will appear across load resistor R1 and thereby be furnished to the output terminals, while only a small amount of the input voltage will drop across diode V1 and be lost insofar as the circuit output is concerned. When the input signal goes negative, the diode cuts off and thus limits the flow of current in the series circuit. The voltage across load resistor R1 then falls to zero, and remains at zero until the input signal goes positive on the following half cycle.

One application of the series, negative lobe diode limiter is given in the following illustration, which shows a series-connected peak noise limiter for use in an AM receiver. This circuit operates as follows: Assume that an input



Series, Negative Lobe Diode Limiter Used in a Noise Limiter Circuit

audio level (rectified dc from a diode rectifier applied between point **a** and ground of −10 volts is applied to the input terminals of the circuit. The cathode of diode V1 is connected to point **c** and assumes a potential through resistors R3 and R4 of −10 volts with respect to ground. (Since no appreciable current flows through R3 and R4 there is no appreciable voltage drop across them.) The plate of diode V1 is connected to point **b** and, with no current flowing, assumes a potential —5 volts with respect to ground, through the voltage-divider effect of resistors R1 and R2. The plate of the diode (point **b**) is thereby momentarily 5 volts positive with respect to its cathode (point **c**); under these conditions the diode conducts, and its resistance becomes approximately 2000 ohms. Capacitor C1 is connected to point **d** and charges through resistor R3 to a potential of approximately −7 volts with respect to ground when the diode resistance is 2000 ohms. Any considerable change in this potential would require approximately 0.1 second, because of the time constant of R3 and C1.

If a noise voltage of −100 volts suddenly appears at the input to the circuit (point **a**) across R1 and R2, the plate of the diode (point **b**) will assume a potential of −50 volts instantaneously, while its cathode (point **c**) remains at −7 volts due to the time delay of the R-C circuit R3C1. This makes the plate of the diode 43 volts more negative than its cathode, and the resistance of the diode becomes almost infinite. This effectively disconnects point **c** and audio output capacitor C2 from point **b**, and the circuit momentarily has no output except that small value which passes through R3 and R4, shunted to ground at their junction point by C1, and also shunted by the capacitance of the diode. By the time the momentary noise pulse has decayed, the cathode of the diode will have assumed a potential considerably more negative than its plate (due to its connection to point **a**, through R4 and R3), and will again conduct the audio input signal from point **b** to point **c** and the output capacitor, C2.

The time period during which the circuit limits a noise pulse depends upon the R-C time constant of R3 and C1, while the percentage of the audio input voltage which is available at the output of the circuit depends upon the relationship of R1 and R2. The actual values of these components that may be encountered in a particular circuit depend upon the intended use and application of the circuit.

FAILURE ANALYSIS.

No Output. In a series, negative lobe diode limiter circuit similar to that shown in the first illustration, the analysis of failure is simple. Either the failure of the diode or the failure of the applied signal are the only possibilities which could be the cause of a no-output condition.

When the series, negative lobe diode limiter is used in a more complicated circuit, such as the noise limiter shown in the second illustration, a few additional components could be responsible for no output. If R1 became open-circuited or if output coupling capacitor C2 became open-circuited no output would be realized from the circuit. (If R1 became open-circuited, there is a possibility that some small value of the input signal, without limiting, would be obtained through R3 and R4, depending upon the particular input waveform.) If capacitor C1 became shorted, the cathode of the diode would be at ground potential and, since the plate of the diode is at a negative potential, the diode would be cut off; thus, no output would be obtained from the circuit. In any case, an analysis of the particular circuit would be necessary in order to isolate the faulty component.

Reduced or Unstable Output. A weak tube, due to poor cathode emission, would likely be responsible for a reduced value of output. In the application of the series, negative lobe diode limiter shown in the second illustration, a leaky capacitor C1 could cause both a reduced and a distorted output, while a substantial change in the value of either R3 or R4 could be the cause of distorted output, as could also a shorted coupling capacitor C2. Since the output voltage is dependent upon the comparative values of R1 and R2, a change in the value of either R1 or R2 will affect the circuit output. If R1 should increase in value, the output voltage will decrease, while if R2 should increase in value, output voltage will increase. An open capacitor C1 will prevent the circuit from limiting and, as a result, noise pulses will be present in the output; furthermore, some slight increase in output may be noticed.

PARALLEL, POSITIVE LOBE DIODE LIMITER.

APPLICATION.

The parallel, positive lobe diode limiter is used when it is necessary to limit any part of the positive portion, or the positive-going part of the negative portion, of an input signal waveform, and allow the remainder of the input signal to pass without modification of waveform.

CHARACTERISTICS.

Input signal may contain both positive and negative signals. In special cases it may contain only positive signals, in which case only those of higher amplitude will be limited, or clipped.

Output waveform contains only negative signals, or signals which are less positive than a predetermined limiting level.

Output amplitude is lower than input amplitude; no amplification is realized in the circuit.

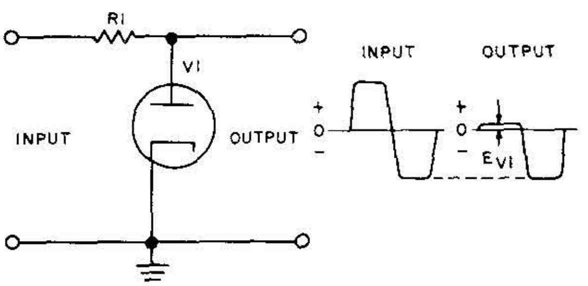
Output is taken across a diode tube.

Output signal is limited when the diode conducts.

CIRCUIT ANALYSIS.

General. The parallel, positive lobe diode limiter circuit consists of a diode and a resistor connected in series with each other across the input signal. The diode is polarized so that it will conduct during the positive portions of the input signal. The output signal is taken across the diode tube and is produced during the period that the diode does not conduct.

Circuit Operation. A simplified parallel, positive lobe diode limiter is shown in the following illustration. In this circuit, the diode, V1, conducts only during the positive portion of the input signal. When the input signal goes positive, the diode conducts, and its internal (or conduction) resistance drops from an infinite resistance, when non-conducting, to a value of approximately 500 ohms. Since the resistance value of resistor R1 is very large compared to the conduction resistance of the diode, practically the



Simplified Parallel, Positive Lobe Diode Limiter and Input-Output Waveforms

entire value of the input voltage drops across load resistor R1, while only a very small voltage drops across diode V1. This voltage may become negligible when the ratio of the load resistance R1 to the diode resistance is very high. Some value of voltage, however small, will still exist across diode V1, because any diode has some measurable amount of resistance. This value of voltage is shown in the output waveform as E_{V1}, on the positive side of the zero-voltage baseline, and represents a loss in the circuit because the output contains *this unwanted amount of positive* signal. When the input signal goes negative, the diode does not conduct, and the current flow through R1 is interrupted (except for that infinitesimal current which flows through R1 because of the high resistance of the load connected to the output terminals). With no (or almost no) current flowing through R1 there is no voltage drop across R1; hence, the output voltage is equal to the input voltage. It should now be obvious that the load impedance connected to the output terminals should be as high as possible in order to obtain the highest possible voltage at the output terminals. The *actual value of the output voltage* in the previously illustrated circuit during the negative half cycle of the input signal (neglecting the source impedance of the input signal, and assuming that the resistance of the diode *when non*-conducting is infinite) may be calculated by applying Ohm's law according to the proportion:

$$E_o : E_1 = R_o : R_o + R1$$

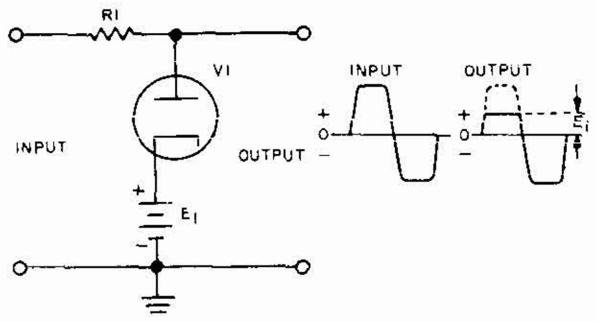
where: E_o = output voltage of circuit
E_1 = input voltage to circuit
R_o = output load resistance (impedance)
R1 = limiter load resistor

The proportion above can be restated and solved for E_o, as follows:

$$E_o = \frac{E_1 R_o}{R_o + R_1}$$

It can be seen from the above formula that the output voltage (E_o) will be approximately equal to the input voltage (E_1) when the output load resistance (R_o) is very large compared to the resistance of the limiter load resistor, (R1).

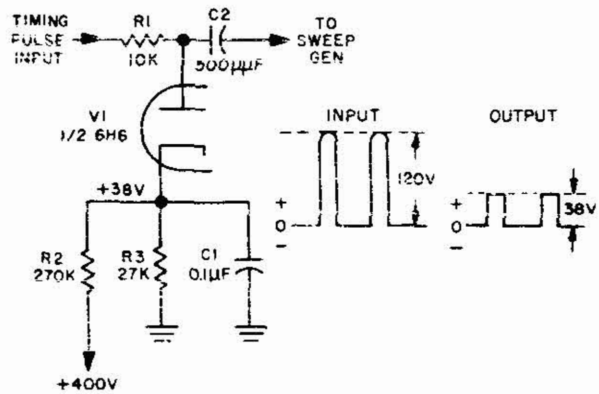
A parallel, positive lobe diode limiter may be used to limit only the peaks of the positive waveform, while allowing a given value of the positive signal to pass through the circuit to the output. This may be accomplished by applying a biasing voltage, having a value equal to the value of the positive signal to be passed by the circuit, to the cathode of the diode, *as shown in the accompanying illustration*. The biasing, or limiting, voltage may be obtained from a battery, as shown in the illustration, or from a tap on a bleeder resistor connected in the output *circuit of a d-c* power supply. When connected as shown in the illustration, with the cathode of V1 connected to the positive terminal of the d-c source, the cathode of the diode is held more positive than the plate by the value of E_1 in the absence of an input signal. As long as the positive cycles of the input voltage remain less positive than E_1, the bias voltage of the battery, the diode remains nonconducting, and the output voltage is approximately equal to the input voltage. Since all of the negative cycles of the input voltage are less posi-



Parallel, Positive Lobe Diode Limiter Used as a Positive Peak Limiter

tive than E_1, these too cause the diode to remain nonconducting, with the result that the output voltage is approximately equal to the input voltage. When the input signal increases to a value which exceeds the voltage of E_1, the diode conducts during that portion of the positive cycle when the input voltage is greater than E_1. During this period of conduction, *the output voltage of the circuit is equal to the value* of E_1 (on the positive cycle), while the peak of the positive input cycle which exceeds the value of E_1 is clipped, or limited, appearing as a voltage drop across the diode load resistor R1.

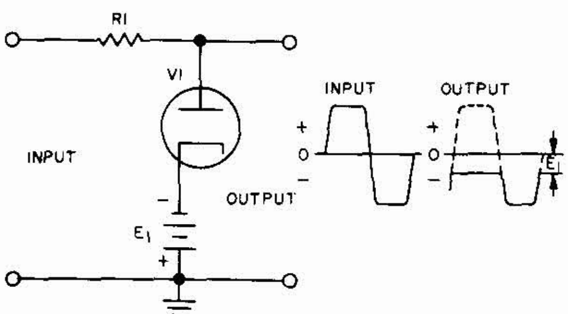
An application of the positive peak limiter is shown in the following illustration. In this circuit an input timing



Typical Application of Parallel, Positive Lobe Diode Limiter in a Radar Indicator Circuit

pulse having a pulse duration of approximately 5 microseconds and an amplitude of +120 volts, from a radar transmitter, is applied through a diode limiter to a sweep generator circuit, to produce the sweep presentation on an indicator scope. The diode limiter, which is a parallel, positive lobe diode limiter, is used to provide a fixed pulse amplitude of +38 volts output to the sweep generator circuit. This is accomplished by applying a fixed bias potential of +38 volts to the cathode of diode V1, from a voltage divider composed of R2 and R3 connected to a +400-volt power supply. When the input signal rises to a potential more positive than +38 volts, V1 conducts, and its resistance (conduction resistance) drops to a very low value. Since the cathode is held at a potential of +38 volts and the resistance of V1 is negligible, the potential at the plate of V1 is also +38 volts, while the remainder of the +120-volt input pulse appears as a voltage drop across the plate load resistor, R1. The +38-volt pulse, which comprises the output of the limiter stage, is coupled through capacitor C2 to the following (sweep generator) stage. The output potential is thus held, or limited, to a maximum of +38 volts, regardless of how large the value of the pulse is at the input to the limiter circuit. If, however, the input pulse decreased to a value less than +38 volts, the entire pulse would be passed through the circuit to the output, and no limiting would occur. In this event the voltage at the plate of the diode would be less positive than the voltage at the cathode, and the diode would not conduct.

A parallel, positive lobe diode limiter may also be used where it is desired to limit not only the entire positive peaks of the input signal, but also a predetermined level of the negative peaks, in order to furnish an output only when the negative peaks exceed this predetermined level. This may be accomplished by applying a biasing voltage to the cathode of the diode, equal to the value of the predetermined level, but of opposite polarity to that of the preceding circuit, as shown in the following illustration. In this circuit



Parallel, Positive Lobe Diode Limiter Used to Pass Negative Peaks

a negative potential E_1 is applied to the cathode of diode V1, from a battery or power supply. With the cathode negative with respect to the plate, the diode is maintained in a conducting state in the absence of an input signal, and the output voltage is held at a steady (negative) d-c level equal to E_1. With an input signal applied to the circuit, the output voltage will continue to be held at this steady d-c level, with the input signal appearing across the diode load resistor, R1, until the input signal becomes more negative than E_1. When this point is reached, the diode will no longer conduct; its resistance will then have increased to an infinite value. As a result, the input signal, which previously appeared across R1 because R1 was much greater in resistance than diode V1, now will appear across V1 and the output terminals of the circuit, since V1 is now much greater in resistance than R1. The output signal, therefore, contains only the negative peaks of the input signal which are more negative than the biasing voltage, E_1.

FAILURE ANALYSIS.

No Output. In a parallel, positive lobe diode limiter circuit similar to those shown in the first two illustrations, the analysis of failure is as simple as the circuit itself. Either the failure of the diode by shorting, or the failure of diode load resistor R1 or coupling capacitor C2 by open-circuiting, or the failure of the applied signal are the only possible causes of a no-output condition.

When the parallel, positive lobe diode limiter is used in a more extensive circuit, such as in the radar indicator circuit shown in third illustration, some of the additional components could be responsible for no output. In this particular circuit, which is intended to limit positive pulses to a level of +38 volts and not to completely limit positive pulses to zero potential, a shorted cathode bypass capacitor C1 would cause complete limiting to zero (ground) potential. Since the input contained only positive pulses, complete limiting would produce no output.

Reduced or Unstable Output. In a parallel, positive lobe diode limiter, a reduced value of output may be due to either an increased value of the diode load resistor R1, or the result of a change in the parallel portion of the circuit, which consists of the diode itself and its cathode biasing components when applicable. In the first two illustrations, an increased value of R1 due to overheating or aging or an improper value of biasing voltage E_1 could be the cause of reduced output. In the circuit shown in the third illustration, the failure of the applied voltage to the cathode circuit or an open-circuited resistor R2 would allow the diode to almost completely limit the input pulses (assuming they are positive pulses, as shown in the illustration), and would thus cause a substantially reduced output. If, however, the low end of the cathode voltage divider, resistor R3, became open-circuited or resistor R2 become shorted, the full value of the bias voltage from the power supply (+400 volts) would be applied to the cathode of V1. With a +400-volt potential on the cathode, the diode would be completely cut off, and no limiting would be realized. In this case, the output signal would be the same as the input signal.

PARALLEL, NEGATIVE LOBE DIODE LIMITER.

APPLICATION.

The parallel, negative lobe diode limiter is used when it is necessary to limit any part of the negative portion, or the negative-going part of the positive portion, of an input signal waveform, and allow the remainder of the input signal to pass without modification of waveform.

CHARACTERISTICS.

Input signal may contain both positive and negative signals. In special cases it may contain only negative signals, in which case only those signals of higher amplitude will be limited, or clipped, to a predetermined level.

Output waveform contains only positive signals, or signals which are less negative than a predetermined limiting level.

Output amplitude is lower than input amplitude; no amplification is afforded by the circuit.

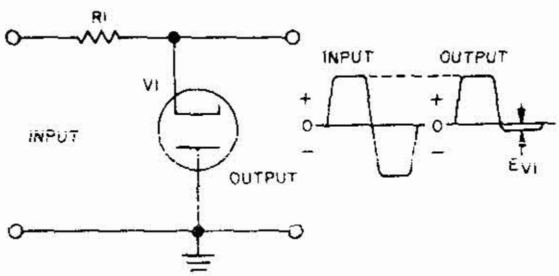
Output is taken across a diode tube.

Output signal is limited to a preset value, determined by initial circuit design, when the diode conducts.

CIRCUIT ANALYSIS.

General. The parallel, negative lobe diode limiter circuit consists of a diode and a resistor connected in series with each other across the input signal. The diode is polarized so that it will conduct during the negative portions of the input signal. The output signal is taken across the diode tube, and the output signal is produced during the period that the diode does not conduct.

Circuit Operation. The circuit of a simplified parallel, negative lobe diode limiter is shown in the following illustration. In this circuit, the diode, V1, conducts only during

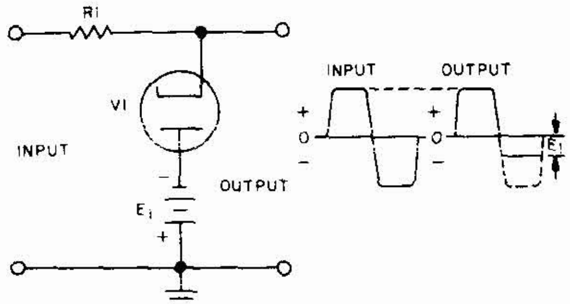


Simplified Parallel, Negative Lobe Diode Limiter and Input-Output Waveforms

the negative portion of the input signal. As long as the input signal remains positive, the diode remains in a nonconducting state, and the input signal is conducted through R1 to the output terminals. Since under ordinary conditions the load connected to the output terminals has a very high resistance, and therefore the amount of current flow is infinitesimal, there is practically no voltage drop across the diode load resistor, R1. As a result, the output voltage is practically equal to the input voltage. This is shown in the positive portion of the output waveform diagram above. When the input signal goes negative, the diode conducts, and its resistance drops from an infinite value (when in a nonconducting state) to an average value of 500 ohms. Since the diode load resistor, R1, is very large compared to the resistance of V1 when conducting (500 ohms), nearly all of the signal input voltage drops across R1, and only a very small part of the signal input voltage (shown in the output waveform as E_{V1}) drops across diode V1. This value of voltage, which becomes negligible when the ratio R1/V1 is very large, is present in the output of the circuit, however, and represents a loss because it subtracts from the overall effective value of the output signal, since it is a voltage of opposite polarity.

A parallel, negative lobe diode limiter may be used in several different applications, each of which requires a slight modification of the circuit and associated components. By the application of a fixed value of biasing voltage to the diode, through the use of a battery or biasing resistor, the voltage at which the diode will start to conduct, and thereby limit, may be preset to any desired value. In addition to the basic limiter circuit, in which the entire negative lobe is cut off, or limited, two other applications are commonly used. In these applications, either the peaks of the negative portion of the input waveform may be limited, or the peaks of the positive portion of an input waveform may be retained, while the remainder of the positive portion and all of the negative portion of the waveform are limited. These circuit applications are described in the following paragraphs.

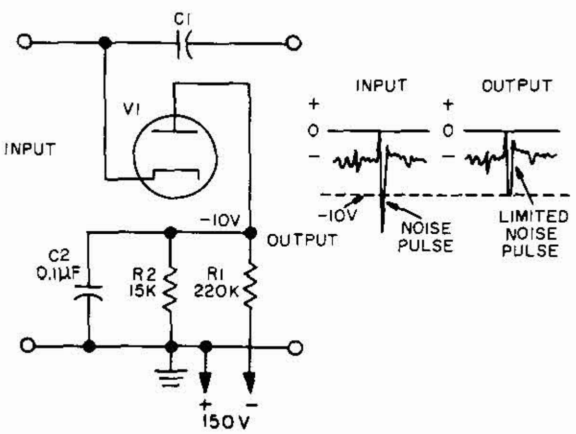
When it is desired to limit only the negative peaks of the input signal and allow the remainder of the negative portion and all of the positive portion (if any is included) of the input signal to pass, unmodified, to the output of the limiter, the circuit shown in the following illustration may be used. In this circuit, a negative biasing voltage, equal



Parallel, Negative Lobe Diode Limiter Used as a Negative Peak Limiter

in value to the negative signal which the circuit is to pass, is applied from a battery or power supply bleeder resistor to the plate of diode V1, while the positive terminal of the bias voltage is returned to ground. By this means the plate of the diode is held negative with respect to the cathode by the value of E_1, under conditions of no input signal. When an input signal is applied to the circuit, any positive voltage, or any value of negative voltage which is less negative than the voltage E_1 applied to the plate will not alter the static conditions of V1, and V1 will remain nonconducting. The input signal will thereby pass through the diode load resistor, R1, to the output terminals, incurring very little—if any—voltage drop through R1 because of the very high impedance of the load under normal conditions, and the extremely minute value of current flowing in the load circuit. The output signal will therefore be approximately equal to the input voltage, while the diode is nonconducting. When the input signal becomes more negative than the biasing voltage, E_1, diode V1 conducts, and its resistance drops to approximately 500 ohms, which is very low compared to the normally high value of load resistor R1. This low resistance is now in parallel with the output load, effectively short-circuiting the output. The resulting current which flows through V1 and its load resistor R1 produces voltage drops across R1 and V1 in direct proportion to their resistances. Since R1 is very high compared to the forward, or conduction, resistance of V1, practically all of the negative portion of the input signal which is more negative than E_1 appears as a voltage drop across R1, and is thereby clipped from the output signal. Thus the value of the applied biasing voltage, E_1, establishes the point at which the circuit will limit, or clip, the input signal.

An application of the negative peak limiter is shown in the following illustration. This circuit is used as a noise limiter following the diode detector stage in an AM receiver. The output of the detector is a negative audio signal having a maximum value of 0.2 volt rms, and this signal is applied to the input of the peak noise limiter. The resistors, R1 and R2, are connected as a bleeder to a negative 150-volt power source. The -10 volts obtained at the junction of R1 and R2 due to the voltage divider action is applied as a fixed bias to the plate of the parallel diode limiter, V1. Under normal conditions the input signal is passed through coupling capacitor C1 to the output terminals, unaffected by V1 and its associated circuit. When a noise pulse having a peak amplitude exceeding -10 volts (the value of the fixed bias applied to V1) appears at the input terminals, diode V1 conducts, placing an effective short circuit across the output terminals for the duration of the noise pulse. The noise pulse is conducted to ground through the low resistance of V1 (when in a conducting state) and the low reactance offered by C2 to a sharp noise pulse. Since the noise pulse is shorted to ground, the pulse is prevented from activating the agc circuit, which would in turn block the i-f amplifiers and interrupt the output signal for a much longer time interval than the actual time duration of the noise pulse.



Parallel, Negative Lobe Diode Limiter Used as a Peak Noise Limiter

FAILURE ANALYSIS.

No Output. The analysis of failure which results in no outout from a parallel, negative lobe limiter should be relatively simple, because of the small number of components comprising the circuit. In the first two illustrations, for example, only three conditions could be the cause of no output. Either the diode load resistor R1 may be open-circuited, the diode V1 may be shorted, or the input signal may have failed. One other condition could contribute to no output in the second circuit illustrated, but the possibility that this condition will occur is remote. If the input signal to this circuit contained only negative pulses, the peaks of which were to be limited, and the biasing voltage E_1 was removed (because of battery or power supply failure) or the polarity of the voltage was inadvertently reversed, then the entire negative input signal would be conducted to ground through diode V1, and no output from the circuit would be obtained. In a more complicated circuit, such as that shown in the third illustration, additional causes of no output may be an open coupling capacitor C1, a shorted bypass capacitor C2, or failure of the biasing voltage due to either power supply failure or an open resistor R1 in the voltage divider circuit.

Reduced or Unstable Output. A reduced or an unstable output from a parallel, negative lobe diode limiter may be due to a substantially increased value of the diode load resistor, R1, resulting from overheating or aging; an intermittently shorting diode, V1; or an erratic output from the biasing voltage supply, E_1, when used. In a more extensive circuit, such as that shown in the third illustration, a leaky coupling capacitor, C1, would contribute to an unstable or erratic output. In addition, if the resistor at the low end of of the bleeder supplying the biasing voltage became open-circuited (R2 in the circuit illustrated), the output of the circuit would be distorted from the normal output, in that the output would contain negative signals up to a possible negative 150-volt value, and no limiting would be obtained. If, on the other hand, bypass capacitor C2 became open-circuited, a sharp negative increment of a noise pulse applied to the input to the circuit would encounter a much greater impedance to ground through R2 than would normally be offered by C2. As a result, the decay time of the noise pulse would be increased because of R2, resulting in distortion of the output waveform.

TWO-DIODE, POSITIVE AND NEGATIVE LOBE DIODE LIMITER.

APPLICATION.

The two-diode, positive and negative lobe diode limiter is used where it is required to limit both the positive and negative peaks of an input signal waveform, in order to prevent the output signal from exceeding predetermined maximum values for both the positive and negative peaks. With the elimination of both peaks, the remaining signal is generally of square-wave shape; therefore, this circuit is often used as a square wave generator.

CHARACTERISTICS.

Input signal contains both positive and negative signals.

Output waveform contains both positive and negative signals, both of which do not exceed values which are preset limits in the initial design of the circuit.

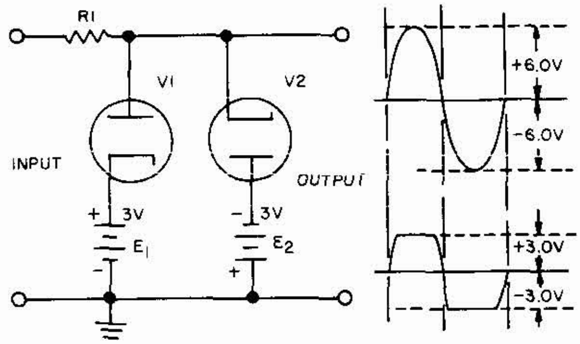
Output amplitude is lower than the input amplitude; no amplification is afforded by the circuit.

Output is taken across two reverse-connected diode tubes.

CIRCUIT ANALYSIS.

General. The two-diode, positive and negative lobe diode limiter consists of two diodes, a source of both positive and negative voltage, and a load resistor. The load resistor is connected on the input side of the two diodes, and the diodes with their source of (bias) voltage are connected in parallel with each other and in parallel with the output terminals of the circuit. The output signal is produced as a repetition of the input signal during the interval that either diode does not conduct, and is limited at the point where either diode conducts.

Circuit Operation. The circuit of a simplified two-diode, positive and negative lobe diode limiter is shown in the following illustration. In this circuit the two diodes, V1 and V2, each have a d-c voltage connected in series with them. The cathode of diode V1 has a positive potential applied which, for the purpose of illustration, has a value of +3.0 volts, as indicated in the associated waveform. The plate of V2 has a negative potential applied, which for illustration has a value of -3.0 volts. A load resistor, R1, is connected between the input terminals and the two diodes. Under conditions of no input signal, both diodes are in a nonconducting state, since the voltages that are applied to them are of such polarity as to oppose the flow of current through the diodes. These voltages are often termed bias voltages, since they establish the level of potential at which the diode will switch from a nonconducting to a conducting state. Now assume that an input signal, having a sine waveform with positive and negative peaks of +6.0 and -6.0 volts, respectively, is applied to



Simplified Two-Diode, Positive and Negative Lobe Diode Limiter and Waveforms

the input to the circuit, as shown by the input waveform in in the illustration. When the voltage on the positive cycle of the input signal reaches +3 volts, this same value of voltage appears at the plate of V1, since, with no current flow, there is no voltage drop across the load resistor R1. At this point the plate voltage is equal to the voltage applied to the cathode from the bias battery, E_1. As soon as the positive cycle of input signal exceeds +3 volts, diode V1 conducts, and a current flows through V1 and load resistor R1. If the voltage drop across V1 is assumed to be negligible, any value of input voltage which exceeds +3 volts will appear as a voltage drop across R1, resulting from the current flow due to the conduction of V1. This is in accordance with Kirchhoff's laws, in that the algebraic sum of the voltage drops and the applied voltage around any closed circuit equals zero. (At this moment–during the positive input cycle–the parallel path consisting of diode V2 and battery E_2 is effectively out of the circuit, since it is in a nonconducting state.) The signal at the output terminals, during the positive half of the cycle, will then rise in sine-wave fashion to a value of +3 volts, at which point the voltage will be limited, or held, until the input signal passes through its peak of +6 volts and falls to +3 volts again, when it will follow the sine waveform during the decay of the positive cycle down to zero volts. Thus the positive half cycle of the output waveform will have a flat top at +3 volts. When the input signal passes through zero volts and increases in a negative direction, the output signal retains the sine waveform until the input signal reaches a value of −3 volts. At this point the cathode voltage of V2 is equal to the negative voltage (−3 volts) applied to the plate of V2 from bias battery E_2. As soon as the negative cycle of the input signal exceeds (negatively) the −3 volts bias, diode V2 conducts, causing a current to flow through V2 and load resistor R1. In a similar manner to that described for diode V1 and the positive cycle, any value of input voltage which is more negative than −3 volts will appear as a voltage drop across R1, as a result of the current flow when V2 conducts. The output signal, during the negative half cycle, will then follow the sine waveform of the input signal to a point at −3 volts, when the voltage will be limited until the input signal passes through its negative peak of −6 volts and returns to the value of −3 volts again. Then V2 will stop conducting, and the output signal will again follow the sine waveform of the input signal as the negative half of the cycle is completed.

The point at which the positive portion of the input signal will be limited, or clipped, may be preset by applying a positive bias voltage of equal value to the cathode of diode V1, which is the positive peak limiter diode. In like manner, the point of negative limiting may be preset by applying a negative bias voltage to the plate of the negative peak limiter diode, V2. In this way the output signal may be held within any desired positive and negative limits. Such a circuit is sometimes referred to as a gate clipper, since it acts as a gate which allows the center portion of an input signal to pass through to the output. More infrequently it is known as a slicer.

When the applied bias voltages are equally positive and negative and of a low value, while the input signal is a sine wave of a relatively high value, most of the curved portions of the sine wave at its peaks will be clipped, and the remaining positive-going and negative-going portions of the waveform will have steep sides which approach the vertical. Thus a fairly accurate square wave output may be obtained, and such a circuit is often used as a square wave generator.

FAILURE ANALYSIS.

No Output. In a two-diode, positive and negative lobe diode limiter such as that previously illustrated, several conditions could be responsible for no output. Failure of diode load resistor R1, due to an "open" resistor, or failure of the applied input signal would result in no output. Another possibility which should be investigated is the failure of both bias voltages. If individual batteries are used for both the negative and positive biases, the simultaneous failure of both is very unlikely, and thus some measure of output signal would be obtained. If, however, the bias voltages are obtained from a d-c power supply operated from a power line, and the power supply failed, the diodes could then conduct through the circuit completed by the bleeder resistor in the output circuit of the power supply. Under these conditions the positive portion of the input signal would be clipped, or limited, by diode V1, and the negative portion would be limited by diode V2; thus no signal - or extremely little - would be present at the output terminals.

Reduced or Unstable Output. In a two-diode, positive and negative lobe diode limiter, a reduced or unstable output may be due to a defective load resistor, R1, which may have suffered a considerable increase in resistance value. In addition, poor emission of the cathode in diode V1 or V2 may cause unstable output, as may also insufficient bias voltage E_1 or E_2 due to aging batteries or a defective power supply. Finally, the possibility of a reduced value of input signal, due to some defect in the preceding circuit, should not be overlooked.

TRIODE LIMITERS.

APPLICATION.

The triode limiter is used to limit, or square off, a portion of the input waveform. It is often referred to as a clipper, or clipper amplifier, because of the "clipped" appearance of the wave peaks in the output waveform.

CHARACTERISTICS.

Input may be a positive signal, a negative signal, or a combination of both in which the waveforms on the positive and negative portions may be either the same or different, depending upon the design application.

Output may be a positive signal with the negative portion completely clipped, or a negative signal with the positive portion completely clipped, or either a positive or a negative signal with the opposite portion partially clipped.

Output amplitude (peak value) may be higher than input amplitude on the peak which is not limited; that is, amplification is afforded by the circuit. However, the overall amplitude (peak to peak) of the output signal may be higher or lower than the input amplitude, depending upon the circuit application design.

Output signal is out of phase with input signal.

CIRCUIT ANALYSIS.

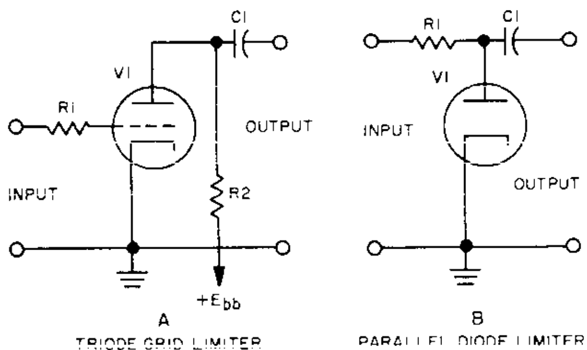
General. Triode limiters are extensively used in radar circuitry, where very narrow pulses often are required to trigger oscillators into action, or to force grid potentials above cutoff values so that a tube may conduct for a short period, or to modulate radio-frequency power into brief pulses. Alternate positive and negative pulses, obtained from various types of pulse-generating circuits, may be passed through a limiting circuit to obtain pulses which are either positive or negative with respect to a predetermined reference level. This reference level may be at zero voltage or any desired value of positive or negative potential. By alternate stages of amplification and limiting, the pulse may be narrowed to any width desired.

Circuit Operation. Triode limiters may be divided into four classifications: Grid Limiters, Saturation Limiters, Cutoff Limiters, and Overdriven Amplifier Limiters. The specific characteristics and circuit operation of each of these classifications are contained in the four circuits to follow in this section. A brief discussion of triode limiters in general is given in the following paragraphs.

A grid limiter utilizes the grid-to-cathode circuit of a triode in the same manner that the plate-to-cathode circuit is utilized in a parallel, positive-lobe diode limiter. The similarity between these two circuits is shown in the following illustration.

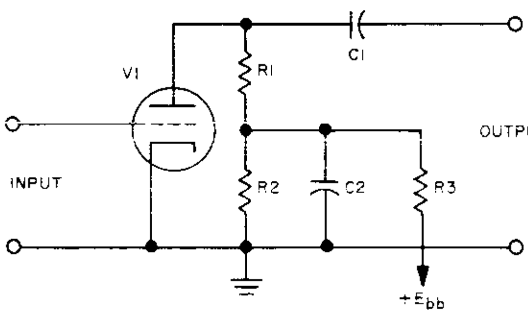
In part A of the accompanying illustration, the grid of the triode, when driven positive with respect to the cathode by the positive portion of the input signal, conducts current and acts the same as the plate of the parallel diode shown in part B of the illustration. Limiting of the input waveform occurs only when the triode grid draws current.

A saturation limiter utilizes the cathode-to-plate circuit of a triode, with an input signal applied to the grid which is of sufficient amplitude to cause plate current saturation on the positive portion of the cycle, but which



Typical Limiter Circuits

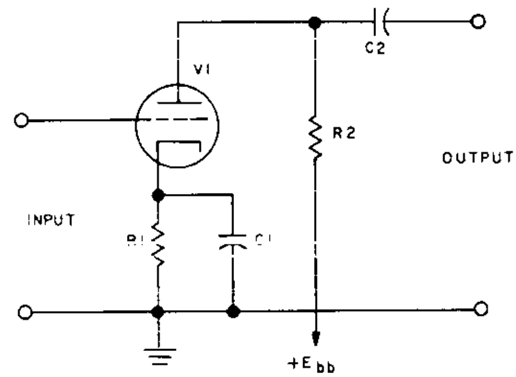
is not of sufficient amplitude to drive the plate current to cutoff on the negative portion of the cycle. A typical saturation limiter circuit is shown in the following illustration.



Typical Triode Saturation Limiter

In this circuit, a relatively low plate voltage is used, and is obtained from the regular plate supply by means of a voltage divider composed of R2 and R3, with the low-voltage tap filtered by means of C2. The plate load resistor, R1, is of a high value of resistance. The combination of a low plate voltage and high load resistance allows an input signal of reasonably low amplitude to cause maximum plate current (plate current saturation) to flow, during the positive portion of the input signal waveform. As a result, any further increase in amplitude during the positive portion of the input signal will be cut off, or limited, since the plate current is already at its maximum limit. The output waveform has its negative portion clipped, similar to the output of the grid limiter, because of phase inversion within the triode.

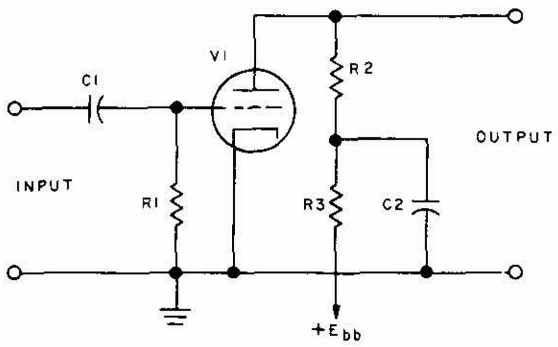
A cutoff limiter utilizes the zero plate current portion of the E_g-I_p curve of a triode, with an input signal which is of sufficient amplitude to cause plate current cutoff on the negative portion of the input signal, but which is not of sufficient amplitude to drive the plate current to saturation on the positive portion of the input signal. The circuit of a typical cutoff limiter is shown in the following illustration.



Typical Triode Cutoff Limiter

In this circuit, self-bias is obtained by means of cathode resistor R1, bypassed by C1 to maintain the d-c bias value relatively constant. The value of R1, in combination with the voltage at the plate of V1, determines the no-signal grid bias. If cathode resistor R1 is sufficiently high in value, the bias will set the operating point nearly to cutoff. It should be noted that, in this circuit, with no input signal the value of self-bias can never drive the tube to, or beyond, cutoff, because the cathode bias is obtained only as a result of cathode (plate) current, and if the triode could be at cutoff there would be no plate current, hence no cathode bias. If, however, the operating point is set nearly to cutoff, limiting will occur on the negative portions of an input signal. The output of the circuit will have the positive portion of the waveform clipped, because of the phase inversion within the triode.

An overdriven amplifier limiter utilizes the combined characteristics of the saturation limiter and the cutoff limiter. The input signal is of very high amplitude—often ten times the value required to drive the grid to cutoff and to saturation. The circuit of a typical overdriven amplifier limiter is shown in the following illustration. In this circuit, the cathode is operated at ground potential, and the input signal to the grid is an approximate square wave which is produced from a sine wave by a preceding limiter. The purpose of passing this signal waveform through the overdriven amplifier limiter is to make the sides of the square wave steeper. The input signal has a high amplitude of approximately 150 volts peak to peak. When the circuit condition s have assumed a stable operating condition (after the completion of several input cycles), an average grid-leak bias potential will be established, as a result of the input waveform applied to the R-C circuit composed of R1 and C1. When the input signal, on its positive cycle, drives the grid above cutoff, the tube conducts, and the plate voltage of V1 drops sharply. As the input signal continues to increase on the positive cycle,



Typical Overdriven Amplifier Limiter

the grid is driven above ground potential, and at this point grid current flows, limiting the signal. The plate voltage, now at its lowest value, remains at this point until the input signal passes through its positive peak and falls again to ground potential, when grid current ceases to flow. Limiting of the positive peak is thus completed. When the input signal, on the negative cycle, falls to the cutoff potential of the grid, conduction ceases, and the signal is limited on the negative peak. The plate voltage, now at its highest value, remains at this point until the input signal passes through its negative peak and again returns, on its positive cycle, to cutoff, when the operating cycle is repeated. In this manner, the overdriven amplifier may be utilized to clip both the positive and negative peaks of an input signal, and at the same time decrease the rise and fall times of the center portion of the input waveform by steepening the sides of the output square wave.

FAILURE ANALYSIS.

No Output. The circuits of triode limiters present various configurations, depending upon their type and particular application. In general, a no-output condition is usually caused by a defective tube or a failure of the input signal. If a tube becomes defective as a result of internally shorted elements, an excessive current may momentarily flow and cause the burnout of a cathode or plate load resistor, and possibly a plate supply voltage divider resistor if used. Therefore, if a shorted tube is found, the possibility of these additional defects should not be overlooked. An open output coupling capacitor could be the cause of no output, as could also failure of the plate voltage supply. One additional possible cause of no output, although rare in occurrence, is failure of cathode emission in the tube due to trouble in the heater supply circuit. Therefore, although it may appear to be superfluous to mention, the triode should be checked to see that the heater/cathode is glowing and that the tube envelope is warm.

Reduced or Unstable Output. Reduced output or unstability in a triode limiter could result from several conditions. A tube having poor cathode emission, due to age or sustained overload during its operating life, may be responsible for a reduced value of output. A change in value of a grid resistor, if used, may affect the waveform of the input signal abnormally, and thereby reduce or distort the output waveform. If the circuit contains an input capacitor, and the capacitor is leaky or shorted, an improper value of bias may be applied to the grid from a preceding stage, thereby changing the operating point of the grid with reference to the input signal. If an output capacitor, where used, becomes leaky or shorted, the plate voltage may be decreased because of the additional load path and the increased current through the plate load resistor, resulting in reduced output and possible distortion. A shorted cathode bypass capacitor, if used, would cause the cathode to operate at zero bias, increasing the plate current and possibly causing grid current to flow, resulting in distortion of the output waveform. A reduced value of voltage applied to the plate of the triode, as a result of a defective power supply, may change operating conditions, in addition to being the cause of a reduced value of output signal.

TRIODE GRID LIMITER.

APPLICATION.

The triode grid limiter is used to limit, or clip, the entire positive half cycle, or a portion thereof, of the input waveform.

CHARACTERISTICS.

Input may be either a positive signal or a signal containing both positive and negative portions.

Output may be a negative signal with peaks clipped, or a signal having positive and negative portions in which all or a portion of the negative peaks are clipped.

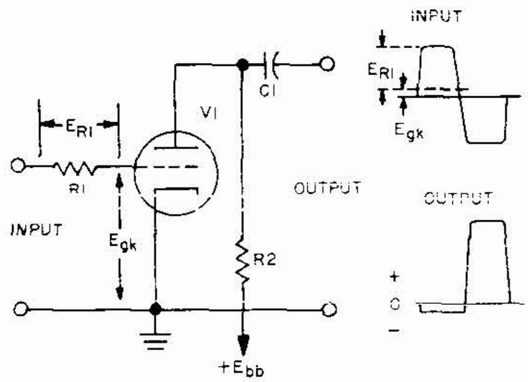
Output signal is out of phase with input signal; therefore, the clipped positive half cycle of the input becomes a clipped negative half cycle of the output signal.

Output signal will contain a positive signal which is the amplified negative input signal. It may contain a negative portion, which is the result of a partially clipped positive input signal that has been amplified. The over-all output peak amplitude may be higher or lower than the input, depending upon the circuit application design.

CIRCUIT ANALYSIS.

General. The triode grid limiter is similar in its limiting action to that of the parallel, positive lobe diode limiter. An advantage of the triode grid limiter over the diode limiter, however, is that amplification of the negative portion (that part of the input signal which is not limited) is accomplished, in addition to the clipping action. In the triode grid limiter, the clipping is obtained as a result of the action of the cathode and control grid, in the same manner as the action of the cathode and plate of a diode limiter. Limiting action is obtained when conduction occurs i.e., when the grid is positive with respect to the cathode. When conduction of the "diode" (cathode to grid) does not occur, i.e., when the grid is negative with respect to the cathode, amplification and phase inversion of the input signal take place, in the manner which is characteristic of a regular triode amplifier.

Circuit Operation. A typical unbiased grid limiter circuit is shown in the following illustration. In this circuit the input signal is applied to the grid of triode V1 through

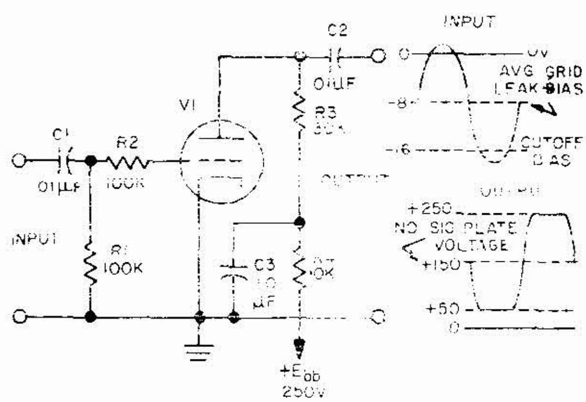


Typical Unbiased Triode Grid Limiter and Input-Output Waveform

grid resistor R1. In the circuit illustrated the no-signal plate current will be relatively high because the tube is unbiased; therefore, the plate voltage will be correspondingly low. For this reason, a positive input signal may have little effect upon the plate current. However, when the input signal goes positive, this positive voltage appears at the grid of V1, and grid current begins to flow. Since the cathode of V1 is grounded, the only resistance to the flow of grid current in addition to R1 is that offered by the grid-to-cathode resistance of V1. If grid resistor R1 has a very high resistance in comparison to the grid-to-cathode resistance of V1 when grid current flows, practically the entire positive portion of the input signal will be clipped, or limited, to the voltage of the cathode (which in this particular circuit is zero voltage, or ground potential). In the same manner that the reverse resistance of a diode (the plate-to-cathode resistance when in a nonconducting state) is infinite, while the forward (or conduction) resistance is only 500 (approximately) ohms, so also is the grid-to-cathode resistance of a triode of an infinite value when in a nonconducting state (when the grid is negative with respect to the cathode); however, this resistance drops to a value of 500 to 1000 ohms when the grid becomes positive with respect to the cathode. Therefore, practically the entire value of the positive portion of the input voltage will drop across the very high resistance of R_1 and is shown on the input waveform as E_{R1}. Only a very small part of the input voltage will drop across the grid-to-cathode (conduction) resistance of V_1 which is a relatively low resistance; this voltage drop, although small, is shown on the input waveform as the value E_{gk}. As a result of the small positive bias on the grid of V1, a maximum value of plate current flows in the plate circuit. The high plate current, flowing through plate load resistor R2, causes a maximum voltage drop across R2, resulting in a minimum (nearly zero) voltage at the plate of V1. Because of the phase inversion within the triode, the effective grid voltage, which is the minimum positive voltage drop across the grid-to-cathode resistance of V1, becomes an inverted (negative) and amplified voltage, although still minimum, at the plate of V1.

When the positive half cycle of the input signal is completed and the input voltage falls to zero (the potential of the cathode), the grid current ceases to flow. As a result there is no longer a voltage drop across R1. Then, as the grid goes more negative during the negative half cycle, with no voltage drop across R1, the entire value of input voltage appears at the grid of V1, since it is applied across the (infinite) resistance between the grid and the cathode. Assuming that the negative input signal does not drive the grid to cutoff, the negative half cycle is amplified by the triode and inverted, and this positive waveform appears at the output terminals of the circuit. In this manner, the positive portion of the input signal waveform is cut off, or limited, practically to zero, while the negative portion of the input signal is amplified without distortion and inverted, and passed through coupling capacitor C1 to the output terminals.

Another type of grid limiter circuit, which develops grid-leak bias to limit both the positive and negative peaks of the input signal, is the grid-leak biased grid limiter illustrated below. In this circuit, a sine wave from a master oscillator is applied to the input terminals, to produce a square wave which will be eventually used to produce trigger and timing pulses in a radar circuit application. The triode, V1, operates without fixed bias, but develops grid-leak bias as a result of grid current flow. As the input voltage rises, during the positive portion of the input signal, the input coupling capacitor, C1, charges because of the current which flows through grid return resistor R1 and through grid resistor R2 in series with the grid-to-cathode resistance of V1. When the positive portion of the input cycle is completed and the input goes negative, the charge in capacitor C1 leaks off through resistor R1. During the



Typical Grid-Leak Biased Grid Limiter and Input-Output Waveforms

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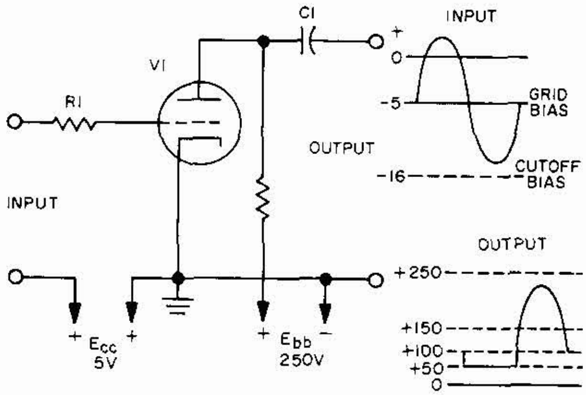
charging cycle of C1, the resistance in series with C1 consisted of R1 in parallel with R2 and V1. During discharge, V1 will not conduct when the grid is more negative than the cathode, and therefore the resistance in series with C1 is that of R1 alone. The resistance in series with C1 is thereby greater during discharge than it is during the charge cycle; as a result, a charge accumulates in capacitor C1 and becomes a negative bias, applied to the grid of V1 (between grid and cathode).

The negative bias on the grid, produced by the flow of grid current during the charging cycle of C1, acts in opposition to the effect of the input signal in driving the grid positive. The bias therefore establishes the average value, or baseline, about which the input sine wave varies. In the previous illustration, this bias is shown as having a value of −8 volts. Now, when the input signal during the positive portion of the cycle swings from −8 volts to zero volts, or cathode potential, the flow of grid current through the high value of the grid resistance of R1 limits the signal at approximately zero volts at the grid of V1. The increased flow of plate current through the plate load resistors, R3 and R4, produces an increased voltage drop across them and a minimum voltage at the plate of V1. This is shown in the output waveform as the output signal falls from +150 volts to +50 volts, and is clipped at the level of +50 volts until the positive portion of the input signal, at the input terminals, passes through the crest of the waveform and falls back to zero volts. As the input signal falls below zero volts, the plate current begins to fall, the voltage drop in R3 and R4 decreases, and the voltage at the plate of V1 —which is the output voltage of the circuit — begins to rise. When the negative-going input signal falls toward the cutoff bias value, the plate current decreases toward zero, reaching zero when the combination of input signal and bias reaches cutoff. The plate voltage of V1, and therefore the output signal voltage, increases toward the B+ voltage, reaching this value of +250 volts at cutoff. Thus the top of the output waveform is limited, or clipped, at the level of +250 volts, as shown in the illustration.

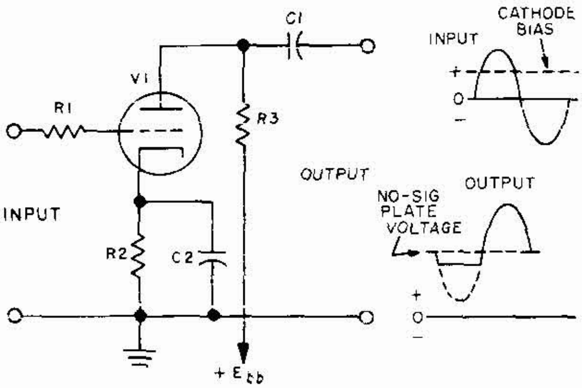
A third type of grid limiter circuit is that in which a fixed negative bias is applied to the grid, from a battery or d-c power supply. A typical circuit of this type of grid limiter is shown in the following illustration. In this circuit, a fixed bias of −5 volts, dc, is applied to the grid from a bias supply, along with the input signal. As the signal increases from the negative 5-volt bias value in a positive direction, the plate current increases in accordance with the signal input, with a consequent decrease in plate voltage, until the input signal reaches the cathode potential of zero volts. When this point is reached, any further rise in grid voltage drives the grid positive with respect to the cathode, and the resulting flow of grid current through grid resistor R1 limits the voltage at the grid to approximately zero volts (disregarding the voltage drop across the grid-to-cathode resistance of V1). The plate voltage, now at its lowest value, is clipped, or limited, at a level determined by the circuit application, which for illustration is shown as +50 volts in the output waveform. As the input signal passes through its positive crest and falls, grid current ceases to flow when the input signal falls to zero volts. During the remainder of the positive half



Typical Fixed Bias Grid Limiter and Input-Output Waveforms

cycle of the input signal, and through the complete negative half cycle, the flow of plate current follows in accordance with the grid voltage, without distortion, and the amplified and inverted waveform of voltage is furnished to the output terminals of the circuit. (The amplitude of the negative portion of the input signal is not sufficient to drive the tube to cutoff.)

A fourth type of grid limiter circuit is the self-biased grid limiter, in which the bias is automatically developed by the flow of plate current through a bypassed cathode resistor. A typical circuit of this type of grid limiter is shown in the following illustration. In this circuit, the grid of V1 is normally held at ground potential, and the grid bias is produced by the flow of plate current through cathode resistor R2. In order to maintain the bias at a relatively constant level, so that it does not vary with the input signal waveform, R2 is bypassed with capacitor C2, which has a large value of capacitance. The flow of plate current through R2 established the cathode of V1 at a positive voltage above ground potential, thus furnishing the bias to the grid, which is at ground potential and therefore negative with respect to the cathode. When the input signal rises at the start of the positive half cycle, the plate current in V1 increases with the signal, and the waveform is not limited until the grid voltage reaches a value equally positive to that of the cathode. When this point is reached, a further rise of the input voltage produces grid current, which results in the limiting of the voltage at the grid. This is indicated by the input waveform in the illustration, at the point of cathode bias. Grid current ceases to flow, and thereby limiting is completed, when the input signal has fallen back to the point where the voltage is equal to that of the cathode. During the remainder of the positive half cycle, and throughout the negative half cycle, the circuit operates as a Class-A amplifier, furnishing an output waveform which is an amplified and inverted reproduction of the input signal, without



Typical Cathode-Biased Grid Limiter and Input-Output Waveforms

distortion. (The amplitude of the negative portion of the input signal is not sufficient to drive the tube to cutoff.)

FAILURE ANALYSIS.

No Output. The analysis of failure which results in no output from a triode grid limiter is somewhat similar to that of the parallel, positive lobe diode limiter. In the triode grid limiter, failure of triode V1, or an open-circuited grid resistor or plate load resistor, or failure of the plate supply voltage could each be responsible for a no-output condition. If the circuit utilizes cathode bias, an open cathode resistor would also be a cause of no output. If the circuit contains input and/or output coupling capacitors, an open-circuited capacitor in either position would result in no output. Finally, failure of the applied signal, or an input signal of incorrect waveform or voltage level, could also be responsible for a no-output condition.

Reduced or Unstable Output. Assuming that an input signal of correct waveform and voltage level is being furnished to the input terminals of a grid limiter circuit, a reduced value of output is probably the result of either insufficient signal at the grid terminal of the triode, insufficient voltage at the plate terminal of the triode, or a leaky coupling capacitor in the grid or plate circuit, when used. Insufficient signal at the grid may be due to a defective grid resistor which has increased in value or become open-circuited. Insufficient plate voltage may be due to a defective plate load resistor or insufficient plate supply voltage brought about by a defect in the power supply. A shorted plate output coupling capacitor may also be responsible for low plate voltage, with the following stage loading the plate circuit. A cathode resistor, if used, may be too low in value and cause excessive plate current, resulting in a low plate voltage. Leaky coupling capacitors, if used, may cause distortion of the waveform, in addition to placing an additional load on the circuit. Finally, a shorted or leaky decoupling capacitor in the plate supply decoupling circuit, when used, would be responsible for low, or absence of, plate voltage.

TRIODE SATURATION LIMITER.

APPLICATION.

The triode saturation limiter is used to limit, or clip, the positive peaks of an input waveform. This limiter is useful when low amplitude input signals are used, at rather low plate supply voltages.

CHARACTERISTICS.

Input may be a positive signal or a combination of positive and negative signals.

Output may be a negative signal with the negative peak clipped, or a combination of negative and positive signals with the negative peaks, or the entire negative portions, of the signal clipped.

Output amplitude (peak value) may be higher than input amplitude on the positive peak of the output signal. Amplification of the unclipped portions of the input signal is provided. The total (peak-to-peak) output amplitude may be higher or lower than the input amplitude, depending upon the relative values of the positive and negative peaks of the input signal waveform.

Output signal is out of phase with input signal.

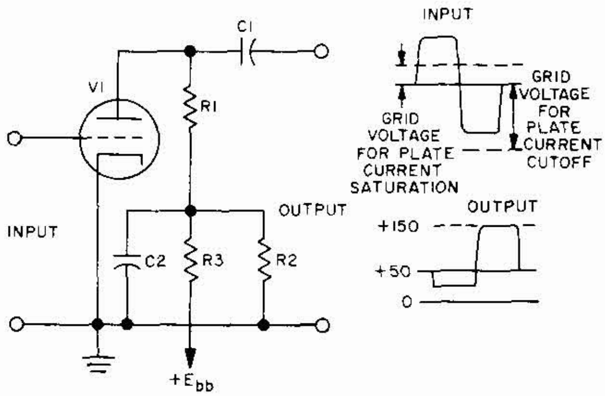
CIRCUIT ANALYSIS.

General. The triode saturation limiter differs from the triode grid limiter in its limiting action, in that the actual limiting is accomplished in the plate circuit, while in the grid limiter it is accomplished in the input, or grid circuit. In the saturation limiter the entire input signal is applied to the grid of the triode. Amplification of the entire signal is provided by the triode, up to its maximum capability insofar as its maximum plate current is concerned. When the input signal to the grid is such that maximum plate current flows, any additional value of input signal has no further effect on the plate current; this additional value is thereby limited, or clipped, at the level of maximum current flow in the plate circuit.

The action of the triode saturation limiter is similar to that of the triode grid limiter in its end result; that is, in both cases the positive portion of the input waveform is the portion which is limited, or clipped. In the saturation limiter, however, the output is generally of a higher amplitude, because the plate current is driven to its maximum value. On the other hand, since it is necessary to drive the plate circuit to its maximum conduction to produce limiting, this becomes a disadvantage because a higher input signal is required to drive the grid.

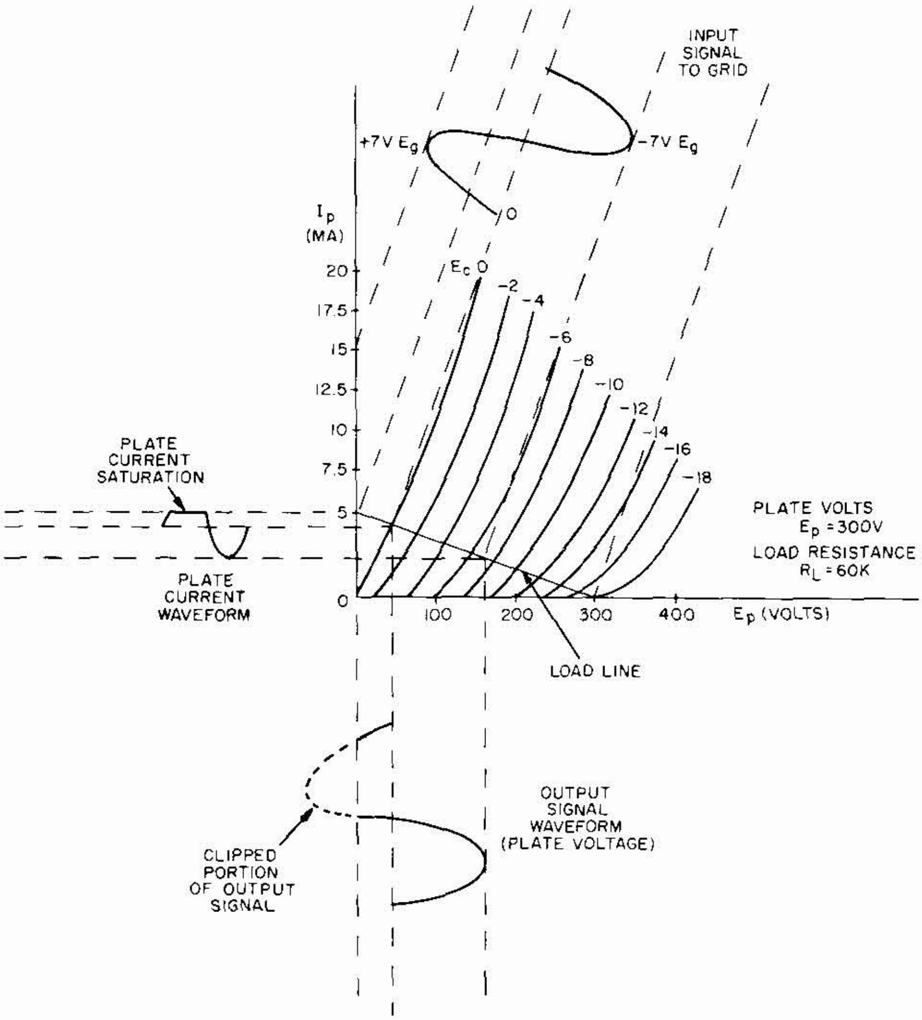
Circuit Operation. The circuit of a typical triode saturation limiter is shown in the accompanying illustration.

In this circuit the input signal, which is obtained from a low-impedance source that is capable of a relatively high power output, is applied directly to the grid of triode V1, and no grid resistor is used. The cathode is connected



Typical Triode Saturation Limiter and Input-Output Waveforms

directly to ground, and the triode is thereby operated at zero grid bias. A voltage divider, consisting of R3 and R2, is connected in the plate supply circuit, to obtain a lower value of voltage. Capacitor C2 acts as an additional filter for the plate voltage supply, while resistor R1 is the plate load resistor. If the resistance value of R1 is relatively high, and the relative resistance value of R3 and R2 are such that the voltage at their junction is relatively low, then a fairly low value of positive input signal will drive the grid to the point of plate current saturation, and limiting will occur. The reason for this is as follows: The following illustration shows the dynamic characteristics of a typical triode amplifier tube—a single section of a type 12AU7. Assume that this tube is used in the circuit previously illustrated, with a plate voltage (at the junction of R3 and R2) of +300 volts, and a load resistance R1 of 60K. The triode is operated at zero bias, since the cathode is grounded, and the input signal to the grid is a sine wave of 14 volts peak-to-peak. From the illustration, it may be seen that the plate current flowing in the circuit, with no



Operating Characteristics of a Typical Triode Saturation Limiter

signal input, is approximately 4 ma. It is also evident that the maximum plate current that can flow, with the fixed values of plate voltage and load resistance given, is 5 milliamperes. When the input signal rises from zero toward +7.0 volts on its positive half cycle, plate current increases from 4 ma to 5 ma, reaching 5 ma when the input signal reaches approximately +2.5 volts. At this point the plate current is maximum, and limiting occurs. The output voltage at this point has decreased nearly to zero (there is always some value of voltage drop within the triode, because of its plate resistance). The output voltage waveform is thereby clipped on its negative half cycle, until the input signal has passed through its positive peak of +7.0 volts and fallen back to +2.5 volts. At this point limiting ceases, and the plate current begins to decrease in accordance with the input signal.

It becomes evident, from the illustration, that the point at which saturation is reached, and thereby the positive limit at which clipping of the input signal occurs, may be adjusted by adjusting the slope of the load line, which in turn may be adjusted by varying the load resistance and/or the plate voltage. On the other hand, the percentage of the positive portion of the input waveform which is clipped may be adjusted by varying the peak voltage of the input signal. Referring again to the previous illustration, it can be seen that clipping of the positive portion of the input signal occurs at approximately +2.5 volts. This is approximately 30 percent of the positive peak input waveform. If the input signal is now increased to 25 volts peak-to-peak, clipping of the 12.5-volt positive peak still occurs at +2.5 volts. The positive portion of the input signal is now clipped at 20 percent of the peak input value.

FAILURE ANALYSIS.

No Output. The cause of a no-output condition in a triode saturation limiter may be one of four possibilities. Either the input signal may have failed, the triode tube may be defective, the plate supply voltage may have failed, or the output coupling capacitor may be open-circuited. Failure of the plate supply voltage may be due not only to a defective power supply, but also to an "open" resistor R1 or R3 or a shorted bypass capacitor C2, in the plate circuit.

Reduced or Unstable Output. A reduced or unstable output from a triode saturation limiter could result from almost any component of the circuit which has become defective. A weak or leaky (partially shorted) triode V1 or a reduced value of plate voltage may be the cause of either condition, depending upon the extent of the defect. A reduced value of plate voltage may be due to a defective power supply, or it may be due to an increase in the value of resistor R1 or R3 or a decrease in the value of R2. A leaky coupling capacitor C1 may allow some of the d-c plate voltage at V1 to appear at the input to the following stage, resulting in an improper bias to that stage and probable distortion therein. Finally, in the analysis of failure of a circuit it is often assumed that the proper input signal is being supplied. This fact will bear checking, however, because an input signal of incorrect value or waveform could well be responsible for a distorted or reduced value of output signal.

TRIODE CUTOFF LIMITER.

APPLICATION.

The triode cutoff limiter is used to limit, or clip, the entire negative half-cycle, or the negative peaks, of the input waveform.

CHARACTERISTICS.

Input may be either a negative signal or a signal containing both positive and negative portions.

Output may be positive signal with peaks which exceed a preset value clipped, or a signal having both positive and negative portions in which all or a portion of the positive peaks are clipped.

Output signal is out of phase with input signal; therefore, the clipped negative half-cycle of the input signal becomes a clipped positive half-cycle of the output signal.

Output signal will contain a negative signal which is the amplified positive portion of the input signal, if such is included in the input. It may contain a positive portion, which is the result of a partially clipped negative input signal that has been amplified. The peak amplitude of the output signal, including both positive and negative portions when applicable, may be higher or lower than the input peak amplitude, depending upon the circuit application design.

CIRCUIT ANALYSIS.

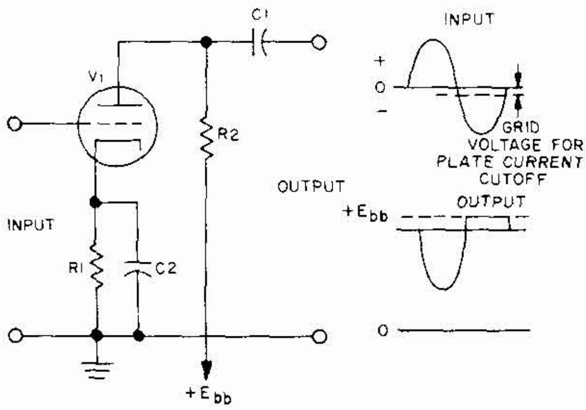
General. The triode cutoff limiter depends, for its limiting action, upon the fact that an electron current within a vacuum tube can flow only from the cathode to the plate, and not in the reverse direction. When the signal at the grid of the triode drives the grid to cutoff, the plate current is decreased to zero, and it remains at zero during the time that the grid is held at or below cutoff by the input signal. At cutoff the plate current is zero, and, regardless of how much farther the grid is driven negative, the plate current remains at zero, since the plate current cannot become a negative value. When the grid is at (or below) cutoff, since no current flows in the plate circuit, there is no voltage drop across the plate load resistor. The voltage at the plate, therefore, increases to, and is maintained at, its maximum value, which is the voltage of the plate power supply, E_{bb}. The limiting thus attained affects the positive peak of the output waveform, whereby the positive peak is cut off, or flattened, at the voltage level E_{bb}, as a result of driving the grid in the negative direction to cutoff.

Cutoff voltage is that value of negative voltage, with respect to the cathode, which must be applied to the grid to reduce the plate current to zero. This value of voltage is dependent upon the value of the plate supply voltage, E_{bb}. In a triode the cutoff voltage, E_{co}, is approximately equal to the plate supply voltage, E_{bb}, divided by the amplification factor, μ, of the triode; thus:

$$(-)\,E_{co} = \frac{E_{bb}}{\mu}$$

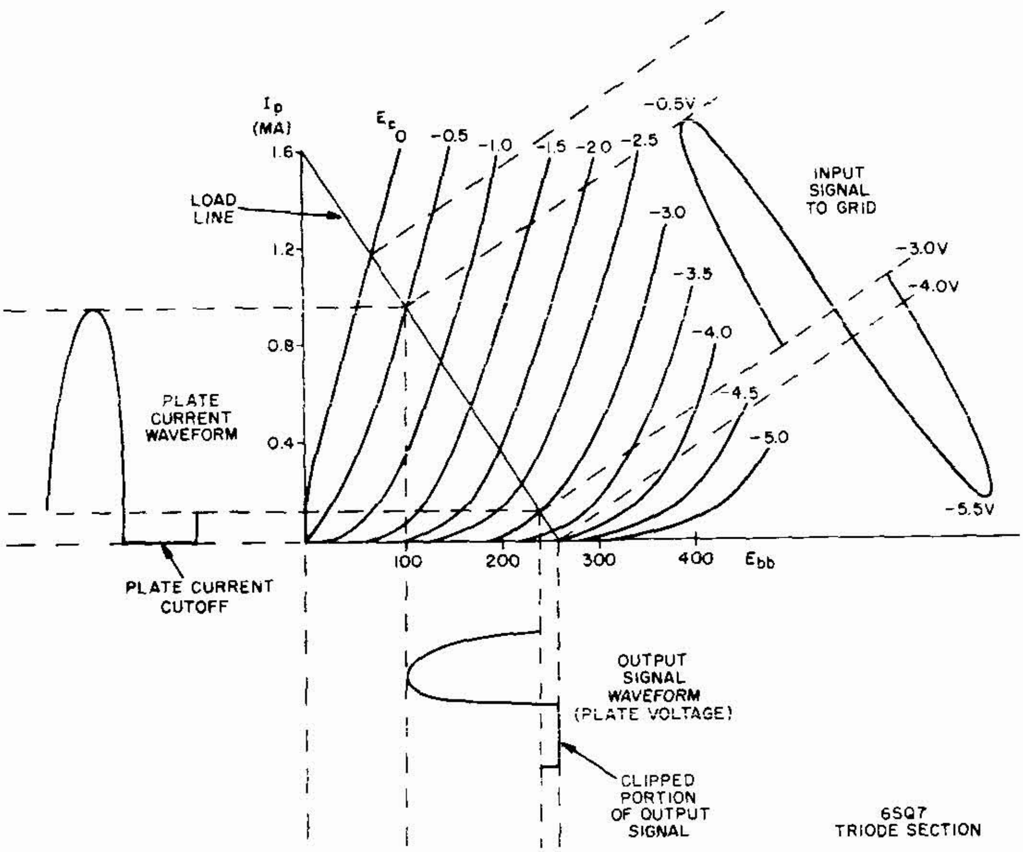
The relationship expressed above is valid **only** for a triode; it does not apply to tetrodes or pentodes.

Circuit Operation. The circuit of a typical triode cutoff limiter is shown in the following illustration. In this circuit the input signal is applied directly to the grid of triode V1, and no grid resistor is used. Cathode bias is supplied by resistor R1, bypassed by C2 to hold the bias value constant with the average value of the plate current. If the value of the cathode resistor, R1, is sufficiently large the bias developed will set the operating point of the tube near cutoff. When the input signal rises on the



Typical Triode Cutoff Limiter and Input-Output Waveforms

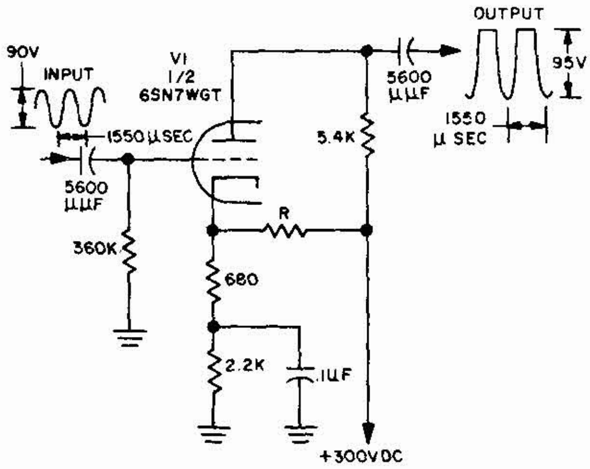
positive half cycle, the plate current will increase and thus produce the resultant plate voltage waveform shown in the illustration. When t input signal begins to fall, this causes a correspon positive excursion of plate voltage, and this action conti until cutoff is reached on the negative half cycle of the ut signal. At this time the plate current is zero, thus limiting (clipping) the positive portion of the plate-voltage waveform. For the purpose of illustration, assume that the resistance value of R1 is such that the no-signal d-c bias is −3.0 volts at the grid. The plate supply voltage, E_{bb}, for this illustration is +250 volts, and the maximum amplitude of the input signal is 2.5 volts. The grid voltage, with input signal, therefore swings from −0.5 volt to −5.5 volts. The dynamic conditions existing in this example are shown in the following illustration, based on utilizing the triode section of a type 6SQ7 tube. From the illustration, it may be seen that the no-signal plate current is approximately 0.125 ma. When the input signal rises on its positive half-cycle, the plate current increases from 0.125 to 0.95 ma, reaching this maximum value when the input signal reaches its most positive (or least negative) value of −0.5 volt. The input signal then begins to fall, completing the positive half-cycle when the voltage at the grid is −3.0 volts. As the input signal begins its negative half-cycle, the voltage at the grid continues in its negative direction until it reaches −4.0 volts. At this point cutoff occurs, and the plate current has fallen to zero. The output voltage at this point, with no plate current flowing and therefore no voltage drop through plate load resistor R2, has increased to +250 volts, the value of E_{bb}. With the plate current cut off, the output voltage remains at this value until the input signal has fallen through its negative peak of −5.5 volts and increased to the cutoff point of −4.0 volts. As the input signal continues to rise, the plate current begins to flow and the plate voltage (output signal) begins to fall; at the end of the negative half-cycle of input signal the output voltage has fallen to its no-signal value of approximately +235 volts, and the plate current has increased to 0.125 ma again.



Operating Characteristics of a Typical Cutoff Limiter

From the preceding illustration it becomes evident that the point at which cutoff is reached, and thereby the negative limit at which clipping of the input signal occurs, may be changed by adjusting the slope of the load line and/or the no-signal grid bias. The slope of load line may be adjusted by changing the plate supply voltage, E_{bb}, and/or the load resistance; this adjustment, however, will affect the no-signal grid bias when cathode biasing is utilized. The grid bias may be further adjusted by changing the value of the cathode resistor. It should be noted that, with cathode bias, cutoff cannot be maintained with a steady d-c signal, because the bias is obtained by means of the plate current flowing through the cathode resistor. At cutoff, no plate current flows, and therefore no bias will be obtained. But with ac, and especially with pulsed signals and the use of a *large capacitor* bypassing the cathode resistor, the bias may be adjusted over a considerable range by changing the value of the cathode resistor, thereby adjusting the point at which cutoff is reached. When complete clipping of the negative portion of the input signal is not required, the percentage of the negative portion which is clipped may be adjusted by varying the peak voltage of the input signal. However, the maximum limit of the input signal must in no case be great enough to drive the grid into the positive region, where grid limiting would act to clip the positive peak of the input signal and thereby introduce distortion to that portion of the waveform. Refer to the previous illustration; the positive peak of the input signal is shown driving the grid to −0.5 volt, and the negative peak to −5.5 volts. Clipping occurs at −4.0 volts, and the no-signal bias is −3.0 volts. With the negative swing from −3.0 to −5.5 volts, or a total swing of 2.5 volts (of which the portion between −4.0 and −5.5 volts, or a total of 1.5 volts, is clipped), the percentage of the negative portion clipped is therefore 1.5/2.5, or 60 percent. Under the same circuit conditions, the percentage of the negative portion which is clipped may be increased, by increasing the input signal amplitude, only by the additional amount of 1.0 volt peak to peak. This increased input would drive the grid to −6.0 volts on the negative peak, and to zero volts on the positive peak, which is the absolute maximum limit without incurring grid limiting. With the additional drive on the negative swing, the percentage of the negative portion clipped would thereby be increased to 2.0/3.0, or 66 per cent.

The circuit of a triode cutoff limiter used in a specific application is shown in the following illustration. This cutoff limiter is used in the modulator circuit of Radar Set AN/SPS-10D, and in this application begins the shaping of a sine wave at a frequency of 650 cps, obtained from a repetition rate oscillator, to a square wave. In the absence



Triode Cutoff Limiter Used in Modulator of Radar Set AN/SPS-10D

of an input signal, V1 is cut off by the positive voltage present at the cathode, obtained from the voltage divider composed of the two cathode resistors and resistor R returned to +300 volts, dc. Resistor R in this circuit represents the conduction through another triode tube. The 0.1-μf capacitor across the 2.2K resistor in the cathode circuit acts to maintain the cathode bias at a constant average value. The input to the grid of V1 is a sine wave of approximately 90 volts peak to peak. As the input voltage increases on the positive portion of the input signal, the grid voltage overcomes the positive bias voltage at the cathode from the voltage divider, and the triode conducts. The output signal, which had maintained a flat top at +300 volts, dc during the cutoff interval, now begins to fall in accordance with the rising sine wave input signal, because of phase inversion within V1. The output signal maintains the 1550-μsec pulse width of the input signal, but has a waveform which is approximately a square wave, with the positive peaks cut off sharply, and a peak voltage of 95 volts, as shown in the illustration.

FAILURE ANALYSIS.

No Output. Assuming that an input signal of correct polarity and sufficient voltage is being furnished to the triode cutoff limiter, the cause of a no-output condition could be one of several possibilities. The triode tube itself should be first suspected. If the tube is found to be capable of operation, the input signal may not be present at the grid of the tube, because of an open coupling capacitor. The absence of voltage at the plate, due to an open plate load resistor, an inoperative power supply, or a shorted bypass capacitor across a plate load decoupling circuit, if such a circuit is used, may be responsible for no output, as may also an open cathode resistor. Finally, an open output coupling capacitor, if used, would prevent the output from the limiter from being furnished to the following stage.

Reduced or Unstable Output. Several conditions could contribute to a reduced or unstable output from the triode cutoff limiter. A reduced value of plate voltage, due to a defective power supply, or an aging triode tube due to low cathode emission, may be responsible for a reduced output. An open cathode bypass capacitor would be the cause of degeneration, and reduce the output signal. If a fixed cathode bias is obtained from a voltage divider in the plate voltage supply line, such as shown in the second circuit illustrated herein, and if the resistor on the high side should become open-circuited, the operation of the circuit would be changed from fixed bias to self (cathode) bias, thereby changing the point of limiting, with the possibility of a distorted, or even excessive, output. An open grid resistor, if used, may cause grid "blocking" and severe distortion. In addition, the possibility of an input signal of incorrect waveform, or of insufficient amplitude, should not be overlooked in cases of reduced or otherwise faulty output.

TRIODE OVERDRIVEN AMPLIFIER LIMITER.

APPLICATION.

The triode overdriven amplifier limiter is used to limit, or clip, both the positive and the negative peaks of an input signal waveform. It is also used to steepen the sides of an input signal having a waveform which is approximately a square wave.

CHARACTERISTICS.

Input is generally a sine wave, or a partially squared wave produced from a sine wave by a preceding limiter.

Output is usually a square wave having relatively steep sides.

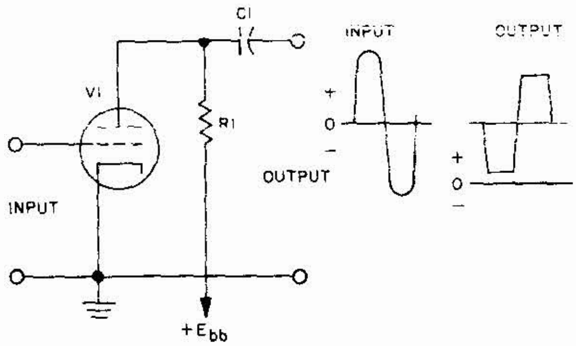
Output signal is out of phase with input signal.

Amplitude of output signal may be higher or lower than input amplitude, depending upon the points at which the positive and negative peaks are clipped. Amplification is afforded by the circuit to the input signal, before the peaks are clipped.

CIRCUIT ANALYSIS.

General. The triode overdriven amplifier limiter accomplishes its limiting action by combining cutoff limiting with saturation limiting (or with grid limiting). The principal use of this type of limiter is to produce a square wave, having steep sides which are very close to true vertical, from an input signal whose waveform is only a rough approximation of a square wave, having sides which deviate at considerable angles from the vertical. The preceding circuit which furnishes the input signal should have an output impedance which is relatively low, and therefore be capable of delivering power, because a current of some degree is drawn by the grid of the triode when it is driven positive. The preceding circuit should also be capable of furnishing an input signal of considerable amplitude, so that the slope of the sides of the waveform may be as nearly vertical as possible before amplification and limiting.

Circuit Operation. The circuit of a typical triode overdriven amplifier limiter is shown in the following illustration. In this circuit the input signal is applied directly



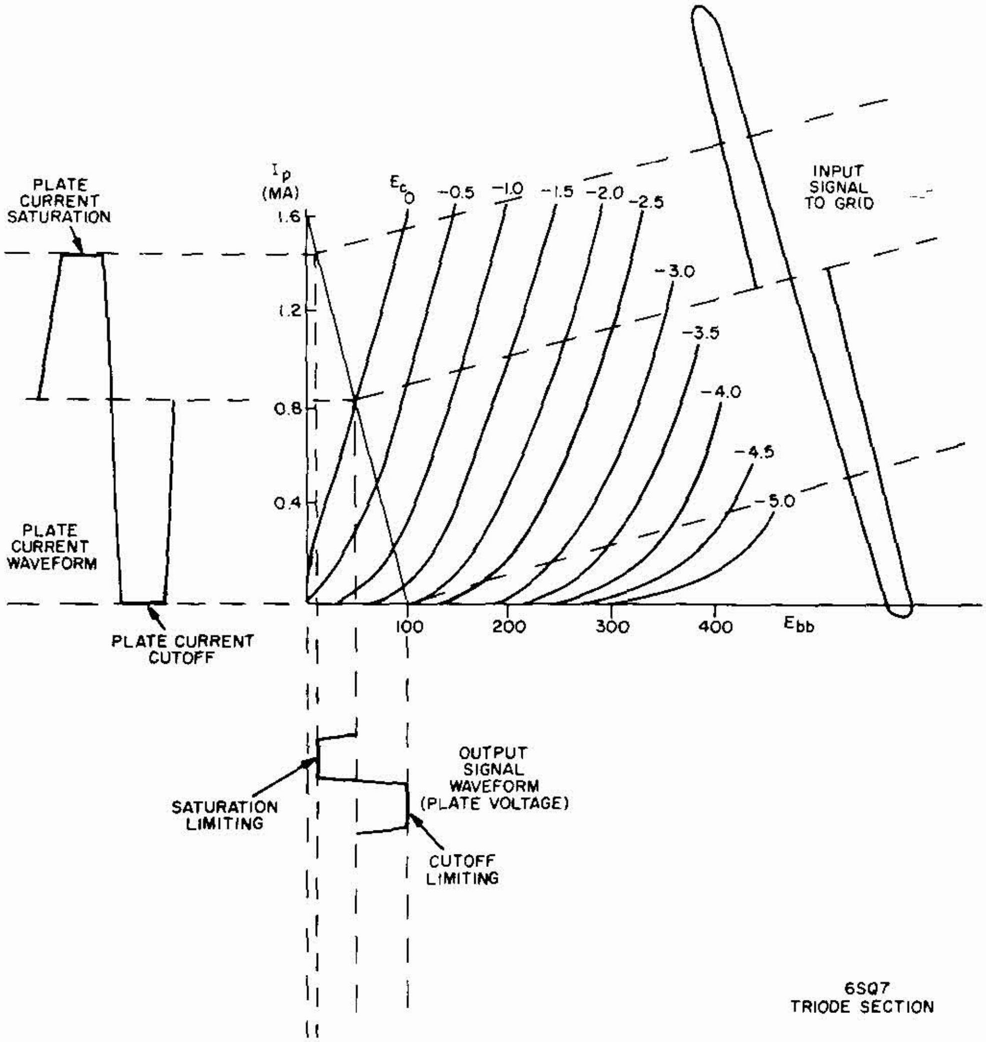
Typical Overdriven Amplifier Limiter and Input-Output Waveforms

to the grid of the triode, V1, and no grid resistor is used. Since the source of the signal has a low impedance and thereby can furnish current to the grid of V1, no limiting is performed in the grid circuit. No cathode resistor is used; hence the grid is operated at zero bias. The input is a very large amplitude signal, often ten times the value required to drive the tube to cutoff and to saturation. When the input signal rises, the plate current also rises until the point of plate current saturation is reached. The input signal continues to rise to its peak; however, the plate current cannot increase further because it is already at maximum. During this time, the plate voltage is limited to its minimum value. As the input signal passes through its positive peak and begins to fall, it drops below the saturation point, and at this time the plate current again follows the input signal. As the input signal continues to fall, the plate current decreases accordingly to cause the plate voltage to rise until the plate current is cut off by the input signal. The plate voltage is thus limited to its maximum positive value. When the input signal passes through its negative extreme and begins to rise, it rises above the cutoff point and, once again, plate current begins to flow.

The action of the triode overdriven amplifier with an input sine-wave signal of sufficient amplitude is shown in the following illustration. This illustration shows the dynamic conditions existing in the circuit, based on utilizing the triode section of a type 6SQ7 tube, with an input signal having an amplitude sufficient to drive the grid into plate current saturation on the positive swing, and beyond cutoff on the negative swing. It may be seen that the plate current flowing, in the absence of an input signal, is 0.8 ma. When the input signal rises on the positive portion of its cycle, the plate current increases from 0.8 ma to approximately 1.4 ma, at which point plate current saturation is reached. As the input signal continues to rise to its peak, the plate current cannot increase in accordance with the input signal, because it is already at its maximum value. The plate voltage at this time is at its lowest value, with nearly all of the plate supply voltage, E_{bb}, existing as a voltage drop across the plate load. (A small portion of the total voltage drop exists across the plate-to-cathode resistance of the triode itself.) The plate current is thereby limited at the saturation value, and the output voltage is limited at its lowest value, until the input signal passes through its positive peak and falls again below the saturation point. At that time the plate current begins to fall in accordance with the input signal, and, consequently, the output signal begins to rise. The input signal continues to fall as the positive portion of the input cycle is completed and the negative portion begins.

As the input signal continues to fall, the plate current continues to decrease until the grid voltage reaches -2.0 volts. At this point cutoff occurs, and the plate current has decreased to zero. The output voltage at this point, with no plate current flowing and therefore no voltage drop through the plate load resistor, has increased to maximum (the value of E_{bb}). The plate current is thereby limited at zero, and the output voltage is limited at its maximum value, until the input signal passes through its negative peak and rises again to the cutoff point. At that time plate current again begins to flow, and the output voltage begins to fall, until the plate current increases to 0.8 ma when the negative portion of the input cycle is completed.

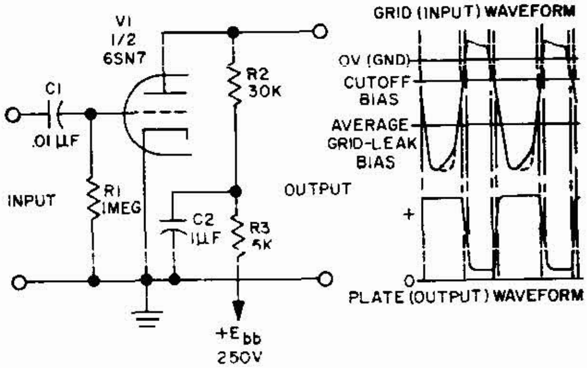
It becomes evident, from the preceding illustration, that the point at which the positive portion of the input signal is clipped (plate current saturation), and the point at which the negative portion of the input signal is clipped



Operating Characteristics of a Typical Overdriven Amplifier Limiter

(cutoff), may be adjusted by changing the slope of the load line and the plate load resistance. The slope of the load line may be increased by increasing the plate supply voltage, E_{bb}, and at the same time increasing the plate load resistance. This will produce a larger positive output signal, because it increases the value of the negative input signal required to reach cutoff.

A practical application of a triode overdriven amplifier limiter is its use in the timer circuitry of a radar transmitter. In this application the overdriven amplifier functions as one of the stages in a chain of circuits, which generate a sine wave in a master oscillator, and from it produce sync and timing pulses for the operation of the complete system. The overdriven amplifier follows after the master oscillator and a triode limiter in the chain, and it receives an input signal whose waveform is that of a sine wave which has been approximately squared by a triode limiter. The function of the overdriven amplifier is to steepen the sides of the square wave from the limiter, to produce a square wave having sides as nearly vertical as possible, which may be used in a following stage to produce a sharp trigger pulse. The circuit of the overdriven amplifier used in this application is shown in the following illustration. In this circuit, which utilizes cutoff limiting with grid limiting (instead of saturation limiting), the input signal waveform is somewhat like a square wave, and of large amplitude. As the input signal begins to rise toward its positive peak, the plate current remains at zero, since the grid voltage is



Overdriven Amplifier Used in Radar Timing Circuitry, and Waveforms

below cutoff, until the grid voltage rises (becomes less negative) to the cutoff potential. The triode then conducts, as the grid voltage rises to zero (ground) potential. When the signal drives the grid to zero bias, grid current begins to flow, limiting any further rise of the grid voltage at this point. The grid current charges coupling capacitor C1, through the relatively low grid-to-cathode resistance of triode V1, to an average voltage which serves as a highly negative bias for the grid of triode V1. During this time the plate (output) voltage has fallen abruptly, decreasing nearly to zero, and it remains at that value until the grid signal falls, from its positive peak, back to zero. At zero bias, the plate current begins to fall rapidly as the grid voltage becomes more negative, until cutoff is reached, when the plate current has fallen to zero. During this time the plate (output) voltage has risen sharply to its maximum value of Ebb. From the waveforms shown, it should be noted that the negative portion of the output waveform is narrower than the positive portion; this is due to the fact that the tube conducts only during a portion of the positive half-cycle of the input signal, while it remains nonconductive during the entire negative half-cycle.

FAILURE ANALYSIS.

No Output. The cause of a no-output condition in the triode overdriven amplifier limiter may be defective triode tube, failure of the plate supply voltage, an open input or output coupling capacitor (if either is used), or failure of the input signal. Assuming that the tube has been determined to be capable of operation, and that an input signal of proper amplitude and polarity is present at the input to the circuit, an open plate load resistor (or plate decoupling resistor if a decoupling circuit is used) would render the circuit inoperative, and no output would be available. A shorted decoupling bypass capacitor (C2 in the second circuit illustrated), if a decoupling circuit is used, may also be the cause of a no-output condition. An open coupling capacitor in the input grid circuit, if one is used, would likewise prevent any output from being produced.

Reduced or Unstable Output. When the output of the triode overdriven amplifier becomes unstable or is of reduced value, a low value of plate voltage, due to a defective power supply, or an increased value of plate load resistance, due to a defective or "aging" resistor, may be the cause of this condition. Either a leaky input or output coupling capacitor or an open grid resistor could be responsible for unstable operation. The triode tube itself may have low cathode emission; this would produce a reduced output. Finally, the input signal itself should be checked to ascertain whether it is of correct waveform and has sufficient amplitude, since any deficiency in the input signal would be evident in the output from the overdriven amplifier.

PENTODE LIMITER.

A limiter is a circuit used to reduce, or for all practical purposes, remove the effect of unwanted amplitude variations, which occur because of inherently different levels, atmospheric disturbances, or because of unequal response of tuned circuits within a receiver, or in a combination of circuits. It restricts to a specific voltage level either the positive, the negative, or both portions of the waveform.

Two major uses for limiters are found in video circuitry and radio frequency circuitry. In video circuitry the limiter follows the video detector stage and precedes the low level, cathode-follower output stage. In this position it performs the function of both amplifying and limiting low level video signals. In the case of r-f circuitry the limiter is located after the last i-f amplifier stage and prior to the discriminator (detector) stage in an fm receiver. Here again it serves to amplify the i-f signal as well as limit it. The limiter is important in both video and r-f circuitry, since in both cases the circuitry following the limiter stage is sensitive to amplitude variations.

Limiting is accomplished by utilizing the cutoff, saturation, and grid current characteristics of an electron tube. Careful examination of the two types of vacuum tubes (triode and pentode) which are most feasible for use in limiter circuits reveals the advantages of the pentode over a triode. An important advantage is the sharp cutoff characteristic which is especially apparent in the pentode and not apparent in the triode. This characteristic permits the tube to attain cutoff with a less negative-going (smaller) signal. At the same time, the pentode has the advantage of greater electrode voltage swing. This is made available by the large range of voltages which may be applied to not only the plate of the tube (as in the case of the triode) but also the screen grid. The greater the screen voltage, the larger is the range of plate current and applied voltage. These characteristics make available a greater range over which saturation, cutoff, and grid conduction may occur.

When both plate and screen grid voltages are lowered, a smaller input signal is required to drive the plate current into saturation. At the same time, smaller negative voltage values are also required to drive the tube to cutoff; therefore, better limiting is provided for weaker input signals when lower electrode potentials are used, rather than the full rated operating potentials.

On the other hand, by increasing electrode potentials and utilizing grid leak bias good limiting can also be obtained and, at the same time, a higher overall gain is made available.

In addition to the previous advantages, the pentode also has a higher transconductance (gain) which produces a higher signal to noise ratio. It also has a higher amplification factor and better isolation between input and output impedances, which is an advantage in almost any circuit. Thus, it is seen why a pentode is to be preferred over a triode for limiter circuitry. Typical pentode limiters of the video and r-f type are discussed in detail in the following paragraphs in this section of the Handbook.

VIDEO LIMITER.

APPLICATION.

The video limiter is used to amplify and limit to a specific amplitude low level video input signal voltages in radar and television equipment.

CHARACTERISTICS.

Constant output is obtained once the limiting level is reached. Linear amplification occurs up to limiting level.

Screen grid and plate voltages determine limiting level for a specific bias.

Best performance is obtained with sharp cutoff pentode–has rapid rise time –has little droop.

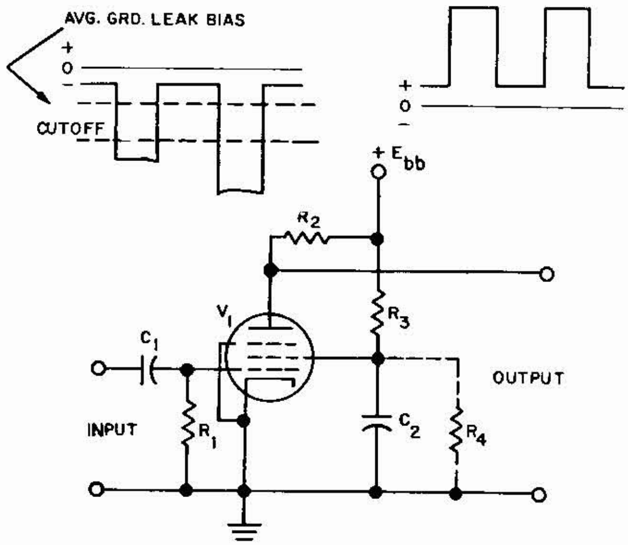
CIRCUIT ANALYSIS.

General. The pentode video limiter is located between the video detector and the low level cathode follower output stage in radar and TV receivers. Cutoff type limiting, rather than grid current or plate saturation limiting, is preferred in video limiter operation. Cutoff limiting occurs when the limiting level is determined solely by the cutoff bias level. Grid current limiting occurs when sufficient grid current is drawn to produce the desired limiting bias. Plate saturation limiting occurs when the grid bias is low or at zero and the signal drives the plate current into the saturation (no current change) level at which limiting occurs.

The limiter is supplied with a negative signal from the video detector. The signal is restricted in its negative amplitude direction by biasing the limiter tube so that cutoff occurs at the point where the desired negative voltage amplitude is attained. As the negative voltage is applied to the grid of the pentode it is inverted and amplified at the plate and coupled to the cathode follower following the limiter stage.

A pentode tube is preferred in limiter applications for several reasons. The primary reason is that the pentode inherently has sharp cutoff capabilities. This allows the tube to reach cutoff bias with a less negative-going (smaller) signal than normally would be required, and thus performs better for smaller input signals.

Circuit Operation. The schematic of a typical video limiter circuit using a pentode type of electron tube is shown in the accompanying illustration.



Pentode Video Limiter

The input signal is capacitively coupled through coupling capacitor C_1 to the grid of V_1. The combination of capacitor C_1 and grid leak resistor R_1 establish the bias potential. Plate load resistor R_2 is used to develop the plate output voltage. The screen grid dropping resistor R3 drops the screen grid voltage to the proper value and bypass capacitor C_2 places the screen at ground potential for video.

Without a signal applied, only contact bias is developed and the tube operates near zero bias. At this point the plate and screen grid voltages largely control the amount of plate current flowing.

With the application of the negative input signal (obtained from the video detector) to C_1, grid leak bias is established by the combination of C_1 and R_1. This is somewhat different than the grid leak bias explained in paragraph 2.2.2 in section 2 of this Handbook since in this application only negative pulses are used.

When the input signal used is first applied, the current through C_1 is maximum and the total input voltage is dropped across R_1, with electron flow through R_1, placing the control grid at a negative potential with respect to the cathode. C_1 charges through R_1 for the duration of the pulse. The capacitor then discharges through R_1 for the period between pulses. Before completely discharging, however, C_1 begins to charge again with the application of a new pulse. After a few cycles of operation, an average negative voltage (bias) is established at the control grid of the tube because of the relation of the time constant of $C_1 R_1$ to the duty cycle of the input signal. This negative voltage (bias) establishes the cutoff point for limiting, which is determined from the plate current versus grid voltage characteristic curve of the particular pentode used for V_1. This average negative bias voltage determines where the input signal causes cutoff to occur, and thus, which portion of the input signal will be reproduced.

With the application of the input pulse, plate current flows for that portion of the pulse above cutoff. Once the tube reaches cutoff the current is at zero and remains at this point for all portions of the negative signal beyond cutoff regardless of whether or not the input signal increases. At cutoff, the plate voltage is at its maximum and, likewise, will remain at this limited amplitude for all portions of the input signal beyond cutoff. The plate voltage then decreases to a minimum value when the plate current is brought back to its maximum value by the trailing edge of the negative input pulse. Note that during the entire time the signal is less than the cutoff bias value, no limiting occurs. Thus, in the region from zero bias to cutoff, normal tube amplification action occurs. Hence, limiting occurs only for those input signals which are larger in amplitude than the value of cutoff bias. The larger the input signal, the more effective the cutoff action.

The limited voltage output level is also controlled slightly by the plate and screen grid voltages of the tube since these voltages in addition to the biasing level affect the tube characteristics and control the total amount of plate current flowing. The approximate magnitude of the limited output can be obtained from the product of load resistor R_2 and the plate current (in milliamperes) with no signal applied.

Circuit Variations. If the plate current changes between pulses because of a duty cycle change, the effective limiter output voltage is altered accordingly. This plate current change occurs if the duty ratio of the input signal is increased.

$$(\text{duty ratio} = \frac{\text{AVE. POWER}}{\text{PEAK POWER}} = \frac{\text{PULSE WIDTH}}{\text{PULSE TIME PERIOD}} = \text{duty cycle}$$

This increase in duty ratio decreases the amount of screen grid current flowing, thereby increasing the screen grid voltage. This results in greater plate current flow during the intervals between signals because of the increased voltage on the plate. An additional screen resistor R_4 placed in parallel with C_2 (as illustrated in the dotted lines in the schematic) reduces the effect of any change in plate current by voltage divider action. There will be little shift of screen voltage with increased duty ratio when the current taken by R_3 and R_4 is relatively large compared to the screen current, since the voltage division is fixed at that developed across R_4.

FAILURE ANALYSIS.

No Output. In a pentode video limiter, a no-output condition may be caused by any of the following (provided the input signal is the proper value and polarity): an open coupling capacitor C_1, an open bias resistor R_1 or plate resistor R_2, or by absence of plate or screen voltage, or by a defective tube V_1. To determine the component at fault, first check the supply voltage and then the plate and screen voltages with a high resistance voltmeter. If the supply voltage is low or zero the trouble is in the power supply or primary fuse. If the supply voltage is normal but the plate voltage is low or zerok plate load resistor R_2 may have increased in value or is open. Likewise, if the screen voltage is low or zero, screen resistor R_3 may have increased in value or is open. Check R_2 and R_3 for value with an ohmmeter. Note that zero screen voltage will also occur if screen capacitor C_2 is shorted. Meanwhile the excessive current drain through R_3 will cause it to heat, smoke, and eventually burn out. Check for a shorted C_2 by measuring the resistance to ground from the screen terminal. If both plate and screen circuits are satisfactory, check for a signal on the grid of V_1 using a vacuum tube voltmeter or an oscilloscope. If the signal appears on the grid but no output is obtained, check R_1 for proper value and continuity, since an open grid resistance will cause grid-blocking. The blocked grid will be indicated by no output and a large negative grid bias which reduces as the meter is connected from grid to ground substituting for the grid resistor. As the meter is left across the circuit unblocking will occur, and when the meter is removed the grid will again block. This indicates R_1 is either open or so large in value as to be useless. If coupling capacitor C_1 is shorted the plate voltage from the preceding stage will drive V_1 into plate current saturation. Such a condition will be indicated by obtaining identical voltage readings to ground from either side of C_1 , or by checking for a short with an in-circuit capacitance checker. If all tests are normal and the trouble persists the tube is most probably at fault.

Reduced or Distorted Output. This condition may exist because: capacitor C_1 is shorted, resistor R_1 is open, screen grid bypass capacitor C_2 is shorted, plate and/or screen voltage is reduced, or tube V_1 is defective.

With C_1 shorted DC plate voltage from the previous stage will drive the grid of V_1 positive into saturation and cause a reduced output. An open R_1 will result in grid blocking and may cause audio oscillations at a slow rate. A shorted C_2 will result in reduced screen and output voltage and may also result in the burning out of resistor R_3 because of excessive screen current. A reduced plate or screen grid voltage caused by an increase in the resistance of R_2 or R_3 will also cause reduced output voltage.

To determine the component at fault, first check the supply voltage and then plate and screen voltages with a high resistance voltmeter. If the supply voltage is low the trouble is in the power supply. If the supply voltage is normal but the plate voltage is low, plate load resistor R_2 may have increased in value. Likewise, if the screen voltage is low screen resistor R_3 may have increased in value. Check R_2 and R_3 for value with an ohmmeter. If zero screen voltage exists screen capacitor, C_2 may be shorted. Check C_2 for shorted condition by measuring the resistance to ground from the screen terminal. If the signal appears on the grid of the tube but the output is not limited to the proper value and the electrode potentials have been checked, check R_1 for proper value with an ohmmeter. If R_1 is not within tolerance this condition will exist. If C_1 is shorted the DC plate voltage from the preceding stage will drive V_1 into plate saturation. This condition is indicated by identical voltage readings to ground from either side of C_1, or by checking for a short with an in-circuit capacitance checker. If all tests are normal and the trouble persists, the tube is most likely at fault.

R-F PENTODE LIMITER.

APPLICATION.

The r-f pentode limiter is used in f-m receivers to remove amplitude variations from the i-f signal prior to being applied to an f-m detector circuit.

CHARACTERISTICS.

Constant output is obtained once limiting level is reached. Linear amplification occurs up to limiting level.

Screen grid and plate voltage determine limiting level for specific bias.

Grid limiting and plate current saturation limiting are used in conjunction with cutoff limiting.

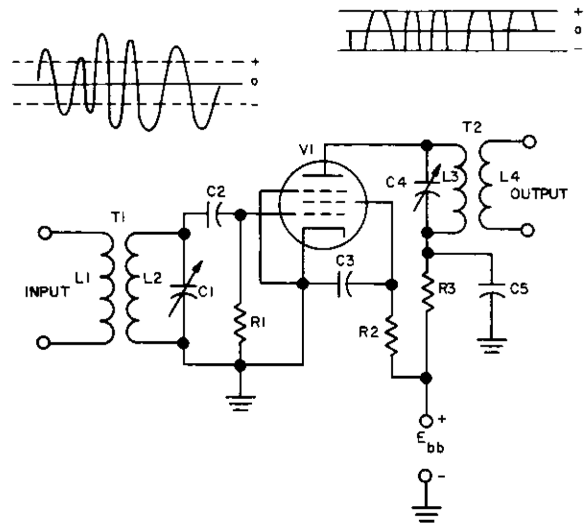
Best performance is obtained with sharp cutoff pentode-has rapid rise time-has little droop.

CIRCUIT ANALYSIS.

General. The pentode r-f limiter is located between the last i-f amplifier stage and f-m detector stage. Grid current or the plate current saturation type of limiter operation is usually used for r-f limiters. Cutoff limiting is also used with one of the aforementioned methods, but it is not used by itself, since this method can only limit the negative halves of the alternating input waveform.

The pentode, besides offering sharp cutoff characteristics, makes available a greater range of screen grid and plate voltage. Operating the plate at a low voltage produces plate current saturation, as well as plate current cutoff, more readily. In order to do this, the plate load resistor must be large enough to produce a load line below the knee of the pentode tube characteristic. Since the magnitude of the plate load resistor can not be made too large in wideband limiter design, grid current limiting must be used where a wideband limiter is required. The effective signal voltage values that may produce current change, are those between the cutoff of the tube and the point at which grid current flow occurs or plate saturation occurs. These points, then are the limiting levels of the circuit.

Circuit Operation. A schematic of a typical r-f limiter circuit using a pentode type of electron tube is shown in the accompanying illustration.



Pentode R-F Limiter

The input signal is inductively coupled from the preceding i-f stages through primary L1 (of T1) to secondary L2, with C1 and L2 providing the proper tuning and selectivity for i-f output transformer T1. The i-f signal is then capacitively coupled to the grid of V1 through coupling capacitor C2. The combination of capacitor C2 and grid leak resistor R1 establishes the bias potential by grid current flow when a signal is applied. Plate load resistor R3 is used to drop the plate supply to the desired value of plate voltage. Screen grid dropping resistor R2 drops the supply voltage to the proper screen voltage value and bypass capacitor C3 places the screen grid at ground potential for i-f. C4 and L3 (of T2) form another tuned i-f circuit which enables the proper band of output frequencies to be inductively coupled by L4 to the f-m detector. C5 in conjunction with plate load resistor R3 forms a decoupling circuit.

When a positive-going input signal is applied to the grid of limiter V1 grid current flows, charging capacitor C2. The plate of C2 closest to the grid of V1 becomes negative and the opposite plate positive. When the signal swings negative, capacitor C2 discharges through resistor R1. The capacitor discharge current develops a voltage across R1 which makes the grid negative with respect to the cathode. When the input signal again goes positive, C2 has not had sufficient time to discharge completely. No further grid current is drawn until the input signal becomes sufficiently positive to overcome the residual negative charge remaining on capacitor C2. Each additional cycle adds a little to the charge that remains from the last cycle. After several cycles of operation an average bias is established, and the voltage across R1 remains relatively constant. This constant voltage across R1 establishes the average bias value around which the input voltage fluctuates. This bias point is dependent on several factors, which include the vacuum tube electrode potentials, the time constant of C2 and R1 (TC=R1XC2) and **the amplitude of the input signal.** The last factor determines the amount of limiting performed by the grid leak bias method.

Limiting is accomplished by the instantaneous bias on the vacuum tube varying at the same rate that the peak amplitude of the input signal varies. If, on the positive portion of the signal, the peak signal amplitude increases to the point of zero bias level, or about where grid current flows, the charge on the plate of capacitor C2 closest to the grid becomes more negative with respect to the other plate. The grid bias is then increased instantaneously by the same amount to a new level and grid current no longer flows because the input level is not large enough to drive the bias to zero or above. This point is the point where limiting occurs, because in effect it is the highest positive voltage that the grid may attain. It is, thereby the value at which constant peak plate current flow occurs and the value for which minimum plate voltage is obtained.

This stable or constant (limited) plate output voltage can also be obtained by lowering the screen grid and plate voltage values to where plate current saturation, rather than grid current flow occurs, when the positive portion of the input signal reaches or exceeds the desired positive peak voltage. At this point plate current is maximum and will no longer increase with an increase in signal amplitude. Since plate current is maximum, then the plate output voltage is minimum, and remains at this limited minimum for any increase in input signal amplitude.

Although this method facilitates reaching cutoff with a less negative-going signal because of the lower electrode potentials, it is somewhat restricted by the magnitude of the plate load resistor. In order for plate saturation to occur before grid current flow, the plate load resistor value must be increased to decrease effective d-c potential at the plate. By increasing the size of the plate load resistor, however, the usable bandwidth of the limiter is lowered. Grid current limiting is therefore preferred for wide-band applications even though in order for cutoff to occur a greater negative half cycle of voltage must be present.

When the input signal is operating over the negative half-cycle, the bias is also established by the grid RC time constant, the electrode potentials, and the amplitude of the negative half cycle. If the magnitude of the negative half cycle is sufficient cutoff bias occurs. Plate current no longer flows at this cutoff point and plate voltage is at its maximum value. Thus, when the negative half cycle reaches or exceeds the cutoff bias level, plate output voltage remains at a constant limited value.

Limiting will only occur when the signal amplitude exceeds the voltage extremes necessary for grid current to flow on the positive half cycle, or (on the negative half cycle) for cutoff to occur. Any signal strength less than those amplitude extremes will result in plate current changes and plate voltage variations in accordance with this signal strength and no limiting. In order to have a constant limited output, then, the input (drive) signal strength must exceed the points where grid current flow and cutoff occurs.

FAILURE ANALYSIS.

No Output. In a pentode r-f limiter a no-output condition may be caused by any of the following (provided the signal from the previous stage is the proper value): a shorted input tank circuit capacitor C1 or output tank circuit capacitor C4, a shorted screen bypass capacitor C3, an open or shorted transformer T1 or T2, an open coupling capacitor C2, an open bias resistor R1, or by lack of plate voltage caused by an open plate resistor, R3, or a shorted plate bypass capacitor, C5, or by a defective tube V1.

To determine the components at fault, first check the supply voltage, then the plate and screen voltages with a high resistance voltmeter. If the supply voltage is normal but the plate voltage is low or zero, plate load resistor R3 may have increased in value or opened. Check R3 for value with an ohmmeter. To check if capacitors C1, C3, C4, or C5 are shorted, use an in-circuit capacitance checker. If the capacitor C2 is open or if T1 is defective, no signal would be present at the grid of V1. This may be checked by an oscilloscope. If the plate circuit is satisfactory and a signal appears at the grid of V1, but there still is no output, check resistor R1 for proper value and continuity, since an open grid resistance will cause grid blocking. The blocked grid will be indicated by no output and a large negative grid bias which reduces as the voltmeter is connected from grid to ground substituting for the grid resistor. As the meter is left across the circuit the blocking action will subside. When the meter is removed the grid will again become blocked. This indicates that R1 is either open or so large in value that it is useless.

If T1 is open or shorted no input signal will be applied to the grid of V1. Likewise, if T2 is open or shorted no output will be obtained. Check the resistance value of the corresponding transformer primaries and secondaries with an ohmmeter (be certain to turn off the plate power before measuring). If the resistance value obtained is zero, the winding is shorted. If the value obtained is infinite, the winding is open. If all tests are normal and the trouble persists, the tube is most likely at fault.

Low or Distorted Output. This condition may exist because of capacitor C2 being shorted, capacitor C1 being open, resistor R1 being open, L1 being defective because of a partial short, or tube V1 being defective.

If C2 is shorted, the plate voltage from the previous stage will drive the grid of V1 positive, and into saturation, causing a reduced output. If C1 were open, i-f transformer T1 will not resonate at the proper i-f and loss of gain will result. Thus, there will be little or no output. An open resistor R1 will result in grid blocking and may cause audio oscillations at a slow rate. If screen bypass capacitor C3 is shorted, the screen and output voltages will both be reduced and eventually will result in resistor R2 burning out because of excessive screen current. If screen bypass capacitor C3 is open, resistor R2 will have dropped across it the r-f voltage occuring at the screen grid, which will produce degeneration and result in altered screen and plate currents, and plate voltage. Reduced screen or plate voltage, caused by increased resistance of R2 or R3, will also cause a reduced output voltage. If capacitor C4 is open, the tuned circuit of L2 and C4 will not be resonant to the proper i-f frequency band. If C5 is open, the r-f voltage appearing at the plate will be fed back into the power supply through R3 and cause feedback with possible oscillation.

To determine the component at fault, first check the supply voltage and then the plate and screen voltages with a high resistance voltmeter. If the supply voltage is low the trouble is in the power supply. If the supply voltage is normal but the plate is low, plate load resistor R3 may have increased in value. Likewise, if the screen voltage is low, screen resistor R2 may have increased in value. Check R2 and R3 for proper value with an ohmmeter.

A reduced plate or screen voltage may also be caused by open capacitors C3 or C5. Check C3 and C5 with an in-circuit capacitor checker if prior checks have failed to find the fault. This same check (in-circuit capacitor checker) may be used if symptoms seem to indicate open capacitors C1 or C4. If V1 is at a constant saturation level, check C1 for a short by measuring the voltage from each plate of C1 to ground with a high resistance voltmeter, or by checking for a short with an in-circuit capacitor checker. If symptoms indicate trouble in either input or output tank circuits and capacitors C1 and C4 are not defective, remove one lead of the suspected winding and check the d-c resistance value of the winding. If all tests are normal and the trouble persists the tube is most likely at fault.

PART B. SEMICONDUCTOR CIRCUITS

DIODE LIMITERS.

The semiconductor diode limiter is comparable with the electron tube diode limiter; therefore, the general considerations on limiter circuits discussed in Part A – Electron Tube Circuits, of this section are generally applicable.

In addition to its small size and lack of filament power requirements, the semiconductor diode is more economical from a cost standpoint than the electron tube diode. Although the semiconductor diode may be operated at somewhat lower power and voltage levels than the electron tube, the difference in operating levels is slight. Usually there is no problem in obtaining a semiconductor diode with peak current and peak inverse voltage ratings equal to those of a given electron tube diode. In fact, in most instances the semiconductor diode has a current rating higher than that of the comparable electron tube. The forward and reverse resistances of the semiconductor diode are different from those of the electron tube. Generally speaking, the lower forward resistance of the semiconductor makes it more efficient than a tube in a clipper circuit, because the loss across the diode is less. On the other hand, this advantage is somewhat offset by the fact that the semiconductor diode has a finite reverse resistance, rather than the almost infinite reverse resistance possessed by the electron tube diode. In communications work, the clipper is used to clip off the peaks of modulation and allow a higher average percentage of modulation to be employed. In this application, both the positive and the negative peaks are usually clipped, requiring the use of both **positive- and negative-lobe** clipping cricuits. As far as types of limiter circuits are concerned, both the semiconductor and the tube diode are identical, each providing two general classes – the series-diode limiter, and the shunt-diode limiter. As a result five diode circuit variations are available: the series-circuit positive-lobe clipper, the series-circuit negative-lobe clipper, the shunt-circuit positive-lobe clipper, the shunt-circuit negative-lobe clipper, and the two (double) diode positive-and negative-lobe clipper. Each of these circuits will be discussed in this section.

SERIES LIMITER, POSITIVE-LOBE.

APPLICATION.

The series limiter is used in communications equipment as a speech clipper, in electronic equipment where amplitude limiting is desired (such as FM receivers or transmitters) and in waveshaping circuits where all or a portion of the positive half-cycle of a waveform is to be clipped off. This circuit is particularly suited for squaring off a peaked waveform. It is used universally in display circuits for modifying waveforms and determining the levels at which they are clipped or limited.

CHARACTERISTICS.

No amplification is realized in the circuit; because of circuit losses the output amplitude is slightly less than the input amplitude.

Negative waveform is passed unchanged, but positive waveform is either partially or completely clipped.

Phase of waveform is unchanged (output phase is same as input phase).

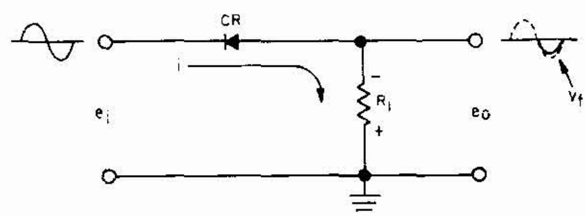
Presents a low (forward) resistance to a negative signal, and a high (reverse) resistance to a positive signal.

Isolates output circuit from input circuit in nonconducting condition.

CIRCUIT ANALYSIS.

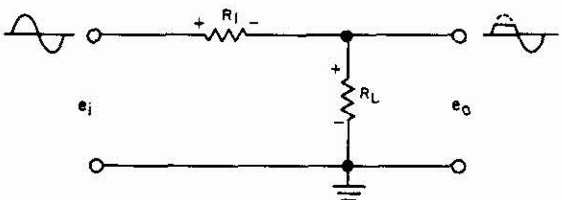
General. A limiter circuit is used to accomplish any of the following functions: to square off the peaks of an applied signal, to obtain a rectangular waveform from a sine-wave signal, to eliminate the positive (or negative) portion of a waveform, or to keep the input amplitude to an FM detector at a constant value. The positive-lobe limiter is designed to effectively eliminate or reduce the positive portion of the input signal.

Circuit Operation. A schematic diagram of a typical series-diode positive-lobe limiter is shown in the accompanying figure.



Series-Diode Positive-Lobe Limiter

As can be seen, diode CR is connected in series between the input and output, with R1 serving as the load resistor. When a positive input is applied between the cathode and ground, the cathode is made more positive than the anode, and the diode does not conduct. Thus, for this condition only the reverse resistance of the diode (which will be discussed later) will allow any signal to pass to the load. When the input signal is negatively polarized, the cathode is more negative than the anode and the diode conducts. When the diode conducts, electrons flow opposite the direction of the arrow through R1 to ground, and the polarity of the voltage developed across R1 is negative with respect to ground, as shown in the illustration. The amount of current flow and the resistance value determine the output voltage produced. Since the forward resistance of the diode is in series with R1 to ground, together they form a voltage divider and the output voltage taken across R1 is always less than the input voltage. (The loss (voltage drop) produced by the forward resistance is shown in dotted lines on the negative portion of the waveform and identified by the symbol v_f in the illustration.) Also since the load resistor is not frequency-selective, the waveform of that portion of the signal produced by forward current flow through the resistor is the same as the waveform of the original signal (except where clipped) and of the same phase. The polarity, of course, is always negative. In forward conduction, the diode can be considered as a switch which connects the output to the input. Since the diode is a semi conductor, it introduces a slight amount of resistance, usually not more than 10 ohms, in series with the circuit. When the diode is nonconducting, its reverse resistance is relatively high (50K to 1 megohm, or greater), but finite (unlike the electron-tube reverse resistance which is usually infinite). In most applications, the reverse-resistance value is high enough to have little effect on circuit operation, but in a series limiter its effect may be important. The following figure shows the equivalent circuit for a diode limiter with a back resistance of 50K, plus a load resistance of 50K. As is clearly evident from the figure, the diode resistance, R1, and the load resistor, R_L, form a voltage divider across the input. Even though the diode is not conducting, in the forward direction, the small leakage current which flows through the diode reverse resistance causes it to act as a voltage divider with R1. As a result, half the applied input voltage appears in the output circuit. This illustrates the serious disadvantage of semiconductor limiters. As shown in the figure, the positive portion of the waveform is only partially clipped, whereas in a vacuum-tube circuit the entire positive waveform would have been eliminated. One of the practical results of this reverse-resistance effect is that diodes of one type cannot be replaced with those of another type (even though voltage and current ratings may be adequate) unless their reverse re-

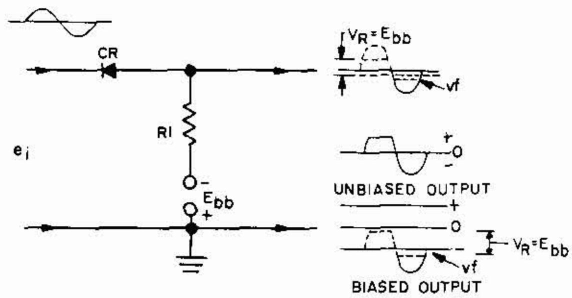


Reverse-Resistance Equivalent Circuit

sistances are similar. Otherwise, the amount of limiting or clipping will be different from the amount selected by the designer, and improper functioning of following circuits can occur.

Consideration of the equivalent circuit, in the figure above, during forward-resistance conditions reveals why the output waveform can never have the same value as the input signal. If the forward diode resistance is assumed to be 5 ohms and the load resistance 50K, then the input signal will be diminished by an amount equal to the ratio of the resistance of the diode and the load resistor, or one ten-thousandth. It is clear from this example that the forward resistance of the semiconductor diode is low enough to produce even less loss than that of the electron tube diode, which is never less than 100 ohms and is usually more. (Practically speaking, 250 ohms is the average low value with the high value being on the order of 500 to 700 ohms.)

The amount of clipping of the input waveform can be selected by using a diode which has the proper value of reverse resistance, or by placing a negative potential (E_{bb}) in series with R1, as shown in the following figure. In the latter case, the diode will not conduct until the



Bias Control of Clipping

input signal is more negative than the applied bias (V_R). Thus the reverse resistance loading of the diode on the input circuit is effectively nullified (the reverse resistance voltage divider action with R1 is eliminated). The complete positive lobe, in this case, is eliminated. Note, however, that the voltage divider action produced by the forward resistance and R1 still remains, as indicated by v_f in the figure. The total negative signal amplitude is reduced by the amount of forward voltage drop and the effective negative bias.

FAILURE ANALYSIS.

No Output. A no-output condition can be the result of either an open-circuit condition (a defective diode, or open connection) or a short-circuit condition (R1 shorted). A resistance check of the diode and load resistor will quickly reveal the defective component.

Low Output. Lack of sufficient input signal, as well as a defective diode, can cause low output. A change in value of the load resistor with age, although not very likely to occur, can also cause a reduction of output. If the diode is biased, a change of bias voltage can cause improper output. In either case, a resistance check will determine whether the components are defective, and a voltage check will determine whether the bias is correct. Be certain to observe the proper polarity when checking the diode with an ohmmeter; otherwise misleading results will be obtained.

Distortion. Except for the clipping effect, a diode limiter produces no inherent distortion. If a distorted waveform is obtained, check the input with an oscilloscope to determine whether the input signal is distorted. The negative portion of the output waveform should be identical to the negative portion of the input signal; if it is not, the diode is defective. Another possibility is that the circuit following the limiter introduces distortion by feeding back an out-of-phase signal. In some cases, it may be necessary to disconnect the limiter output to determine whether such feedback exists.

SERIES LIMITER, NEGATIVE-LOBE.

APPLICATION.

The series limiter is used in communications equipment as a speech clipper, in electronic equipment where amplitude limiting is desired (such as FM receivers or transmitters) and in waveshaping circuits where all or a portion of the negative half-cycle of a waveform is to be clipped off. This circuit is particularly suited for squaring off a peaked waveform. It is used universally in display circuits for modifying waveforms and determining the levels at which they are clipped or limited.

CHARACTERISTICS.

No amplification is realized in the circuit; because of circuit losses the output amplitude is slightly less than the input amplitude.

Positive waveform is passed unchanged, but negative waveform is either partially or completely clipped.

Phase of waveform is unchanged (output phase is same as input phase).

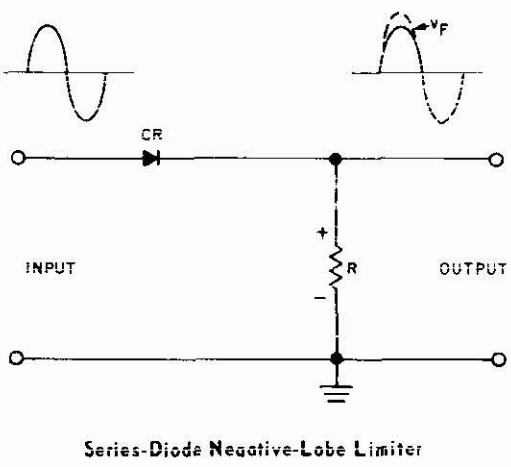
Presents a low (forward) resistance to the positive signal, and a high (reverse) resistance to a negative signal.

Isolates output circuit from input circuit in nonconducting condition.

CIRCUIT ANALYSIS.

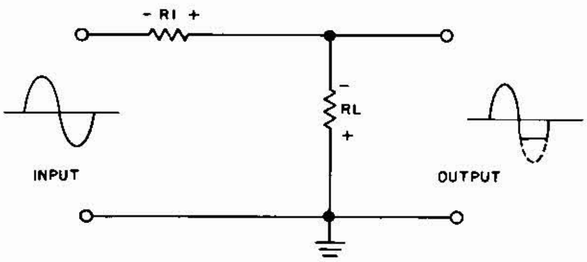
General. A limiter circuit is used to accomplish any of the following functions: to square off the peaks of an applied signal, to obtain a rectangular waveform from a sine-wave signal, to eliminate the positive or negative portion of a waveform, or to keep the input amplitude to an FM detector at a constant value. The negative-lobe limiter is designed to effectively eliminate or reduce the negative portion of the input signal.

Circuit Operation. A schematic diagram of a typical series-diode negative lobe limiter is shown in the accompanying illustration.



Series-Diode Negative-Lobe Limiter

As can be seen, diode CR is connected in series between the input and output, with R serving as the load resistor. When a positive input is applied between the plate and ground, the cathode is made more negative than the anode, and the diode conducts. When the diode conducts, electrons flow opposite the direction of the arrow from ground, and up through R, and the polarity of the voltage developed across R is positive with respect to ground, as shown in the illustration. The amount of current flow and the resistance value determine the output voltage produced. Since the forward resistance of the diode is in series with R to ground, together they form a voltage divider and the output voltage taken across R is always less than the input voltage. (The loss (voltage drop) produced by the forward resistance is shown in dotted lines on the positive portion of the waveform and identified by the symbol ▼F in the illustration). When a negative signal is applied between the cathode and ground, the cathode is made more positive than the anode, and the diode does not conduct. Thus, for this condition only the reverse resistance of the diode will allow any signal to pass to the load. Since the load resistor is not frequency-selective, the waveform of that portion of the signal produced by forward current flow through the resistor is the same as the waveform of the original signal (except where clipped) and of the same phase. The polarity, of course, is always positive. In forward conduction, the diode can be considered as a switch which connects the output to the input. Since the diode is a semiconductor, it introduces a slight amount of resistance, usually not more than 10 ohms, in series with the circuit. When the diode is nonconducting, its reverse resistance is relatively high (50K to 1 megohm, or greater), but finite (unlike the electron-tube reverse resistance which is usually infinite). In most applications, the reverse-resistance value is high enough to have little effect on circuit operation, but in a series limiter its effect may be important. The following figure shows the equivalent circuit for a diode limiter with a back resistance of 50K, plus a load resistance of 50K. As is clearly evident from the figure, the diode resistance, R1 and the load resistor, R_L, form a voltage divider across the input. Even though the diode is not conducting in the forward direction, the small leakage current which flows through the diode reverse resistance causes it to act as a voltage divider with R1. As a result half the applied input voltage appears in the output circuit. This illustrates the serious disadvantage of semiconductor limiters. As shown in the figure, the negative portion of the waveform is only partially clipped, whereas in a vacuum-tube circuit the entire negative waveform would have been eliminated. One of the practical results of this reverse-resistance effect is that diodes of one type cannot be replaced with those of another type (even though voltage and current ratings may be adequate) unless their reverse resistances are similar. Otherwise, the amount of limiting or clipping will be different from the amount selected by the designer, and improper functioning of following circuits can occur.



Reverse Resistance Equivalent Circuit

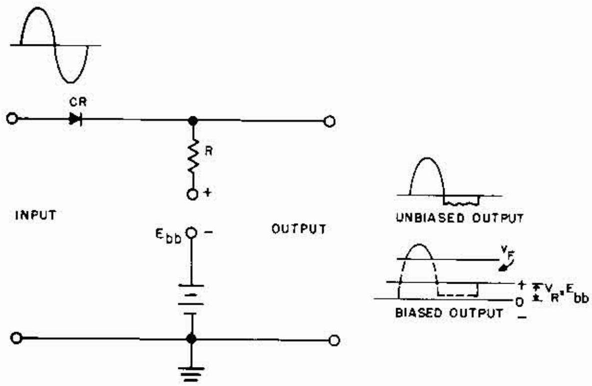
Consideration of the equivalent circuit, in the figure above, during forward resistance conditions, reveals why the output waveform can never have the same value as the input signal. If the forward diode resistance is assumed to be 5 ohms and the load resistance 50K, then the input signal will be diminished by an amount equal to the ratio of the resistance of the diode and the load and the load resistor, or one ten thousandth. It is clear from this example that the forward resistance of the semiconductor diode is low enough to produce even less loss than that of the electron tube diode, which is never less than 100 ohms and is usually more. (Practically speaking, 250 ohms is the average low value with the high value being on the order of 500 to 700 ohms).

The amount of clipping of the input waveform can be selected by using a diode which has the proper value of reverse resistance, or by placing a positive potential (E_{bb}) in series with R, as shown in the following figure. In the latter case, the diode will not conduct until the input signal is more positive than the applied bias (V_R). Thus the reverse resistance loading of the diode on the input circuit is effectively nullified (the reverse resistance voltage divider action with R is eliminated). The complete negative lobe, in this case, is eliminated. Note, however, that the voltage divider action produced by the forward resistance and Rl still remains, as indicated by v_F in the figure. The total positive signal amplitude is reduced by the amount of forward voltage drop and the effective positive bias.

FAILURE ANALYSIS.

No Output. A no-output condition can be the result of either an open-circuit condition (a defective diode, or open connection) or a short-circuit condition (R shorted). A resistance check of diode and load resistor will quickly reveal the defective component.

Low Output. Lack of sufficient input signal, as well as a defective diode, can cause a low output. A change in value of the load resistor with age, although not very likely to occur, can also cause a reduction of the output.



Bias Control of Clipping

If the diode is biased, a change of bias voltage can cause improper output. In either case, a resistance check will determine whether the components are defective, and a voltage check will determine whether the bias is correct. Be certain to observe the proper polarity when checking the diode with an ohmmeter; otherwise misleading results will be obtained.

Distortion. Except for the clipping effect, a diode limiter produces no inherent distortion. If a distorted waveform is obtained, check the input with an oscilloscope to determine whether the input signal is distorted. The positive portion of the output waveform should be identical to the positive portion of the input signal. If it is not, the diode is defective. Another possibility is that the circuit following the limiter introduces distortion by feeding back an out-of-phase signal. In some cases, it may be necessary to disconnect the limiter output to determine whether such feedback exists.

PARALLEL LIMITER, POSITIVE-LOBE.

APPLICATION.

The parallel limiter is used in communications equipment as a speech clipper, in electronic equipment where amplitude limiting is desired (such as FM receivers or transmitters) and in waveshaping circuits where all or a portion of the positive half cycle of a waveform is to be clipped off. This circuit is particularly suited for squaring off a peaked waveform. It is used universally in display circuits for modifying waveforms and determining the levels at which they are clipped or limited.

CHARACTERISTICS.

No amplification is realized in the circuit; because of circuit losses the output amplitude is slightly less than the input amplitude.

Negative waveform is passed unchanged, but positive waveform is either partially or completely clipped.

Phase of waveform is unchanged (output phase is same as input phase).

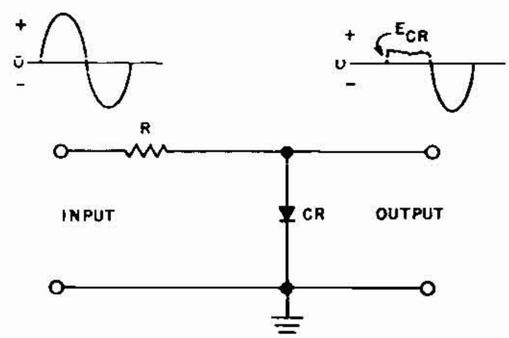
Presents a low (forward) resistance to the positive signal, and a high (reverse) resistance to a negative signal.

Output is taken from across a diode.

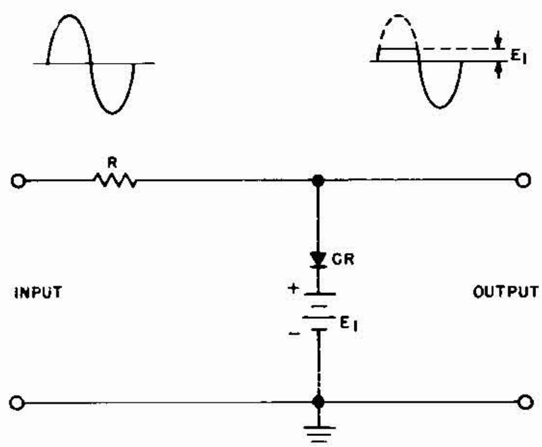
CIRCUIT ANALYSIS.

General. The positive-lobe limiter circuit is used to accomplish any of the following functions: to square off the peaks of an applied signal, to obtain a rectangular waveform from a sine-wave signal, to eliminate the positive portion of a waveform, or to keep the input amplitude to an FM detector at a constant value. The Positive-lobe limiter is designed primarily to eliminate or reduce the positive portion of the input signal.

Circuit Operation. A parallel, positive-lobe diode limiter is shown in the accompanying illustration. In this circuit, diode CR conducts only during the positive portion of the input signal. When the input signal goes positive, the diode conducts, and its resistance drops from a very high reverse resistance to a very low forward resistance. The amount of resistance of the diode in the conducting (or the nonconducting state) is determined by the internal characteristics of the particular diode selected for the circuit. Since the resistance value of R is very large compared to the conducting resistance of the diode, practically the entire value of the input voltage drops across load resistor R, while only a very small voltage drops across diode CR. This voltage may become negligible when the ratio of the load resistance R to the diode resistance is very high. Some value of voltage, however, will still exist across CR, because of its conducting resistance, called the forward resistance and is shown on the illustration as E_{CR}. When the input signal goes negative, the diode does not conduct, and current flow through R almost ceases. A small reverse current still flows through CR, because of the reverse resistance of the diode and thus a small portion of the input voltage is dropped across R. The amount of reverse resistance of the diode depends upon the characteristics of the diode selected. Thus, this is one of the disadvantages of the semiconductor diode over the vacuum tube. The vacuum tube reverse resistance is considered to be infinite, whereas the semiconductor is finite. The voltage dropped across R subtracts from the output, and thus the gain of the limiter is less than unity. On the other hand, the forward resistance of the semiconductor is less than that of the vacuum tube, making the semiconductor better in some applications.

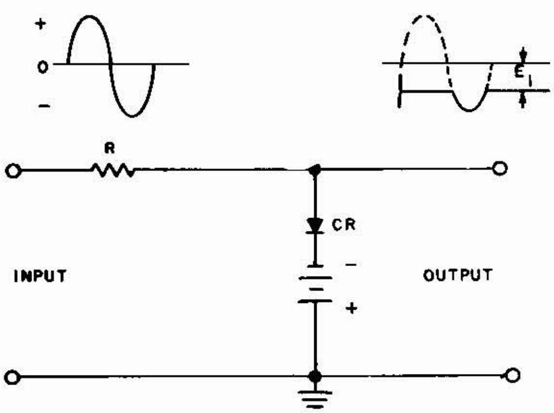


Parallel-Diode Positive-Lobe Limiter



Parallel, Positive Lobe Diode Limiter Used as a Positive Peak Limiter

A parallel, positive lobe limiter may also be used to limit only the peaks of the positive waveform, while allowing a given value of the positive signal to pass through the circuit to the output. This may be accomplished by applying a biasing voltage, having a value equal to the value of the positive signal to be passed by the circuit, to the cathode of the diode, as shown in the accompanying illustration. The biasing, or limiting, voltage may be obtained from a battery, as shown in the illustration, or from a tap on a bleeder resistor connected in the output circuit of a d-c power supply. When connected as shown in the illustration, with the cathode of CR connected to the positive terminal of the d-c source, the cathode of the diode is held more positive than the anode by the value of E_1 in the absence of an input signal. As long as the positive cycles of the input voltage remain less positive than E_1, the battery bias voltage, the diode remains essentially nonconducting, because its cathode is positive with respect to the anode and the output voltage is equal to the input voltage minus the voltage developed by the reverse resistance of the diode. Since all of the negative cycles of the input voltage are less positive than E_1, these too cause the diode to remain essentially nonconducting, with the result that the output voltage is again equal to the input voltage minus the voltage developed by the reverse resistance of the diode. When the input signal increases to a value which exceeds the voltage of E_1, the anode becomes positive with respect to the cathode and the diode conducts, and continues conducting as long as the input remains more positive than E_1. During this period of conduction, the output voltage of the circuit is equal to the value of E_1, and that portion of the input signal which exceeds the bias voltage is clipped, or limited, appearing as a voltage drop across the diode load resistor, R.



Parallel, Positive Lobe Diode Limiter Used to Pass Negative Peaks

By reversing the polarity of E_1, the parallel, positive lobe diode limiter may also be used where it is desired to limit not only the entire positive peaks of the input signal, but also a predetermined level of the negative peaks, in order to furnish an output only when the negative peaks exceed this predetermined level. With the cathode negative with respect to the anode, the diode is maintained in a conducting state in the absence of an input signal, and the output voltage is held at a steady (negative) d-c level equal to E_1. With an input signal applied to the circuit, the output voltage continues to be held at this steady d-c level, with the input signal appearing across the diode load resistor, R, until the input signal becomes more negative than E_1. When this point is reached, the diode no longer conducts; and its forward resistance increases to a very high value. As a result, the input signal, which previously appeared across R because R was much greater in resistance than CR, now appears across CR and the output terminals of the circuit, since CR is now much greater in resistance than R. The output signal, therefore, contains only the negative peaks of the input signal which are more negative than biasing voltage E_1.

FAILURE ANALYSIS.

No Output. A shorted diode or an open load resistor will cause a no-output condition to exist. The only other likely possibility is the absence of the input signal. Check the diode and the resistor with an ohmmeter, making certain to observe the polarities of the diode, since an erroneous indication may be obtained if the proper polarity is not observed. If both components check good, check for the presence of the input signal, making sure that it is of proper amplitude.

For the special case where the diode is not completely shorted, but reads a very low resistance of, say 200-ohms or less, the diode may be considered defective.

In the case of the biased limiter, check the bias for proper voltage with a voltmeter. In the case of a battery bias supply the voltage will be either weak or absent, but in the case of the bias supply being a power supply, it could also be high.

Reduced or Unstable Output. A defective load resistor, R, or a defect in the parallel branch of the circuit, consisting of CR and the bias supply, E_1, can produce a reduced or unstable output. The only other likely possibility is a decrease in the amplitude of the input signal. The trouble can be localized in the same manner as described above for a no-output condition.

PARALLEL LIMITER, NEGATIVE-LOBE.

APPLICATION.

The parallel, negative-lobe diode limiter is used in transistorized equipment when it is necessary to limit any part of the negative portion, or the negative going part of the positive portion of an input single waveform, and allow the remainder of the input signal to pass without modification of the waveform. It is used universally in display circuits for modifying waveforms and determining the levels at which they are clipped or limited.

CHARACTERISTICS.

No amplification is realized in the circuit; because of circuit losses the output amplitude is slightly less than the input amplitude.

Positive waveform is passed unchanged, but negative waveform is either partially or completely clipped.

Phase of waveform is unchanged (output phase is same as input phase).

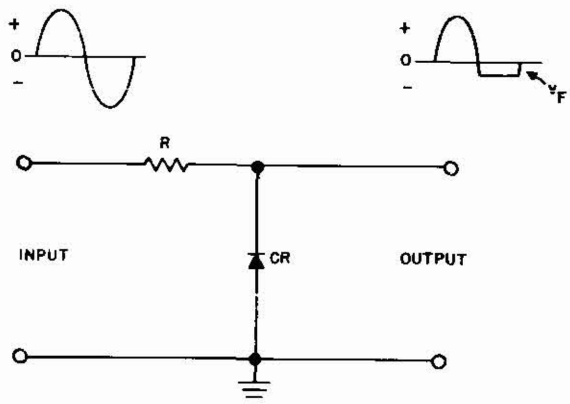
Presents a low (forward) resistance to the negative signal, and a high (reverse) resistance to a positive signal.

Output is taken from across a diode.

CIRCUIT ANALYSIS.

General. The negative-lobe limiter circuit is used to accomplish any of the following functions: To square off the peaks of an applied signal, to obtain a rectangular waveform from a sine-wave signal, to eliminate the negative portion of a waveform, or to keep the input amplitude to an FM detector at a constant value. The Negative-lobe limiter is designed primarily to eliminate or reduce the negative portion of the input signal.

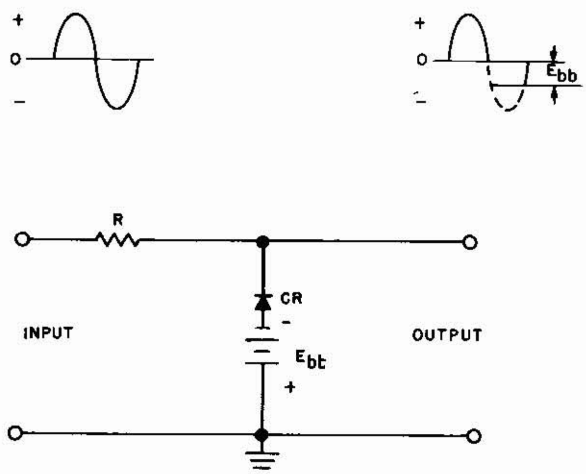
Circuit Operation. The circuit of a parallel, negative-lobe diode limiter is shown in the accompanying illustration. In this circuit, diode CR conducts only during the negative portion of the input signal. As long as the input signal remains positive, the diode remains in a nonconducting state, and current flow through R almost ceases. A small reverse current still flows through R and CR, because of the reverse resistance of the diode, and thus a small portion of the input voltage is dropped across the resistor. The amount of reverse resistance of the diode depends upon the characteristics of the diode selected. Thus, one of the disadvantages of the semiconductor diode over the vacuum tube is encountered. The vacuum tube reverse resistance is considered to be infinite, whereas the semiconductor is finite. The voltage dropped across R subtracts from the output, and thus the gain of the limiter is less than unity. On the other hand, forward resistance of the semiconductor is less than that of the vacuum tube, making the semiconductor better in some applications. When the input signal goes negative, the anode becomes positive with respect to the cathode and the diode conducts. Thus the diode resistance changes from a very high resistance to a very low resistance. The amount of resistance of the diode in the conducting state, as well as the non-conducting state is determined by the internal characteristics of the particular diode selected for the circuit. Since the resistance value of R is very large in comparison to the conduction resistance of the diode, practically the entire value of the input voltage drops across the load resistor R, while only a very small voltage drops across diode CR. This voltage may become negligible when the ratio of the load resistance R to the diode resistance is very high. Some value of voltage, however, still exists across CR, because of its conducting resistance, called the forward resistance. This voltage is shown on the illustration of the basic schematic as VF.



Negative Lobe Diode Limiter and Input-Output Waveforms

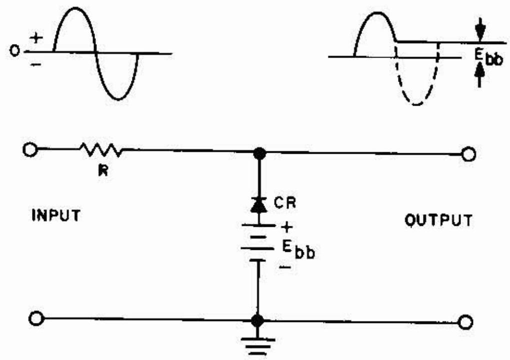
A parallel, negative-lobe diode limiter may be also used to limit only the negative waveform peak, while allowing a given value of negative signal to pass through the circuit to the output. This may be accomplished by applying a negative biasing voltage, having a value equal to the value of the negative signal to be passed by the circuit, to the anode of the diode, as shown in the accompanying illustration. The biasing, or limiting, voltage may be obtained from a battery, as shown in the illustration, or from a tap on a bleeder resistor connected in the output circuit of a d-c power supply. When connected as shown in the illustration, with the anode of CR connected to the negative terminal of the d-c source, the anode of the diode is held more negative than the cathode by the value of Ebb *in the absence of an input signal. As long as the negative* cycles of the input voltage remain less negative than Ebb, the bias voltage of the battery the diode remains essentially nonconducting, and the output voltage is equal to the input voltage minus the voltage dropped by the reverse resistance of the diode. Since all of the positive cycles of the input voltage are more positive than Ebb, these to cause the diode to remain essentially nonconducting, with the result that the output voltage is again equal to the input voltage minus the voltage developed by the reverse resistance of the diode. When the input signal increases to a negative value which exceeds the negative value of

long as the input remains more negative than Ebb. During this period of conduction, the output voltage of the circuit is equal to the value of Ebb, and that portion of the input signal which exceeds (is more negative) than the bias voltage is clipped, or limited, appearing as a voltage drop across the diode load resistor, R.



Parallel, Negative Lobe Diode Limiter Used as a Negative Peak Limiter

By reversing the polarity of Ebb, the parallel, negative-lobe diode limiter may also be used where it is desired to limit not only the entire negative peaks of the input signal, but also a predetermined level of the positive peaks, in order to furnish an output only when the positive peaks exceed this predetermined level. With the anode positive with respect to the cathode, the diode is maintained in a conducting state in the absence of an input signal, and the output voltage is held at a steady (positive) d-c level to equal to Ebb. With an input signal applied to the circuit, the output voltage continues to be held at this steady d-c level, with the input signal appearing across the diode load resistor, R, until the input signal becomes more positive than Ebb. When this point is reached, the diode no longer conducts; its resistance then increase to a very high value. As a result, the input signal which previously appeared across R, because R was much greater in resistance than CR, now appears across CR and the output terminals of the circuit, since CR is now much greater in resistance than R. The output signal, therefore, contains only the positive peaks of the input signal which are more positive than the biasing voltage, Ebb.



Parallel, Negative Lobe Diode Limiter Used to Pass Positive Peaks

FAILURE ANALYSIS.

No Output. A shorted diode or an open load resistor will cause a no-output condition to exist. The only other likely possibility is the absence of the input signal. Check the diode and the resistor with an ohmmeter, making certain to observe the polarities of the diode, since an erroneous indication may be obtained if the proper polarity is not observed. If both components check good, check for the presence of the input signal with a VTVM or an oscilloscope making sure that it is of proper amplitude. For the case where the diode is not completely shorted, but reads a very low resistance of say 200-ohms or less, the diode can be considered defective.

In the case of the biased limiter, check the bias for proper voltage with a voltmeter. In the case of a battery bias supply the voltage will be either weak or absent, but in the case of the bias supply being a separate power supply, it could also be high.

Reduced or Unstable Output. A defective load resistor, R, or a defect in the parallel branch of the circuit, consisting of CR and the bias supply, Ebb, can produce a reduced or unstable output. The only other likely possibility is a decrease in the amplitude of the input signal. The trouble can be localized in the same manner as described above for a no-output condition.

TWO-DIODE, POSITIVE AND NEGATIVE LOBE LIMITER

APPLICATION.

The parallel, two-diode positive and negative limiter, is used in transistorized equipment when it is necessary to limit a portion of both the positive and the negative parts of the signal waveform, and allow the remainder of the input signal to pass without modification of the waveform.

CHARACTERISTICS.

No amplification is realized in the circuit; because of circuit losses the output amplitude is slightly less than the input amplitude.

Limits a portion of both the positive and negative part of the input signal, or the entire negative or positive portion and a part of the other half, or any combination thereof.

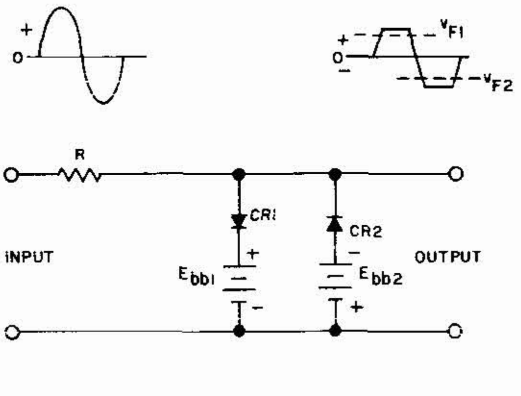
Phase of waveform is unchanged (output phase is same as input phase).

Utilizes two parallel diodes connected in opposite polarity with each other, and in shunt with the load.

CIRCUIT ANALYSIS.

General. The positive and negative lobe diode limiter *is used to accomplish any of the following functions:* to square off the peaks of an applied signal, to obtain a rectangular waveform from a sine-wave signal, or to eliminate the negative or positive portion of a waveform and clip the other portion. Our discussion here will primarily concern the equal clipping of both the positive and negative portions of a sine-wave, that is, the conversion of a sine-wave into essentially a square-wave.

Circuit Operation. The circuit of a parallel, positive and negative lobe diode limiter is shown in the following illustration. Diode CR1 limits the positive half cycle of the input and CR2 limits the negative half. Ebb_1 and Ebb_2 supply the bias for their respective diodes and the resistor, R, *acts as the load resistor.* Reverse biases are applied to the diodes so that the cathode of CR1 is positive with respect to its anode, and the anode of CR2 is negative with respect to its cathode.



Parallel, Positive and Negative Lobe Diode Limiter

As the signal is applied at the input and begins increasing in a positive direction, both diodes remain cut off, due to the bias, and the input signal is reproduced at the output. The output continues to follow the input signal, until a point is reached where the signal becomes more positive than the positive bias applied to the cathode of CR1. At this point, the anode becomes more positive than the cathode, and the diode conducts. When the diode conducts, it provides a low resistance path for forward current *to ground, and shunts* the output through the diode instead of the external load. It is at this point that the output waveform is flattened. Actually, even during its conducting period, the diode offers a slight opposition to current flow, and a small forward voltage drop adds to the load voltage. Thus, the output voltage is slightly higher than the diode bias by the amount shown as V_{F_1} on the output waveform.

As the input signal reaches its positive peak and begins decreasing towards zero, it again reaches a level which is less positive than Ebb_1, diode CR1 again cuts off and the input is again faithfully reproduced at the output. The input signal continues in the negative direction, and shortly becomes more negative than Ebb_2. When this occurs, the cathode of CR2 is made more negative than the anode, and diode CR2 conducts, duplicating the action which occured on the positive half cycle. The forward voltage drop of the conducting diode is shown as V_{F_2} on the output waveform. The input then reaches the negative peak and begins decreasing towards zero. As it becomes less negative than Ebb_2, CR2 ceases conducting, and the remainder of the input signal is reproduced at the output.

The amount of clipping which takes place at the output is dependent to a certain extent upon the type of diodes selected, but primarily upon the value of the bias. As Ebb_1 is made more positive, less clipping occurs on the positive half cycle, and as it is made less positive, more clipping occurs. By the same token, as Ebb_2 is made less positive, more clipping occurs. By the same token, as Ebb_2 is made more negative less clipping occurs on the negative half cycle, and as it becomes less negative, more clipping occurs.

FAILURE ANALYSIS.

No Output. An open load resistor R, or the absence of the input signal are the two most probable causes of a no-output condition. Check the value of R with an ohmmeter for proper value, and check for the presence of the input signal with an oscilloscope. Note that for the diodes to produce a no-output condition, both of them must be shorted, and that the loss of both bias supplies will produce an extremely low clipped output, caused by the voltage drops across the diodes.

Low or Distorted Output. Under most circumstances, the output will be either distorted or lost completely. Distortion may be caused by a change in the bias supply, by an open or shorted diode, or distortion of the input signal. Check both bias supplies for proper voltage with a voltmeter, and both diodes with an ohmmeter. Be sure to observe proper polarities when checking the diodes, as incorrect indications could be obtained by not doing so. The input signal should be checked with an oscilloscope to determine if the input waveform is at fault.

The possibility of both half cycles of the output being decreased by the same amount is unlikely. Both bias supplies must decrease by the same amount to cause this condition. If both supplies increase, the output will increase. The only other cause of decreased output is the load resistor increasing in value.

TRIODE, BASIC COMMON-BASE LIMITER.

APPLICATION.

A triode, basic common-base limiter is used in semiconductor circuits when it is desired to limit the amplitude of a relatively small input signal to a definite negative and positive output level.

CHARACTERISTICS.

Cutoff and plate saturation limiting are used by this limiter.

Base to emitter bias and base to collector bias values determine the proper limiting level.

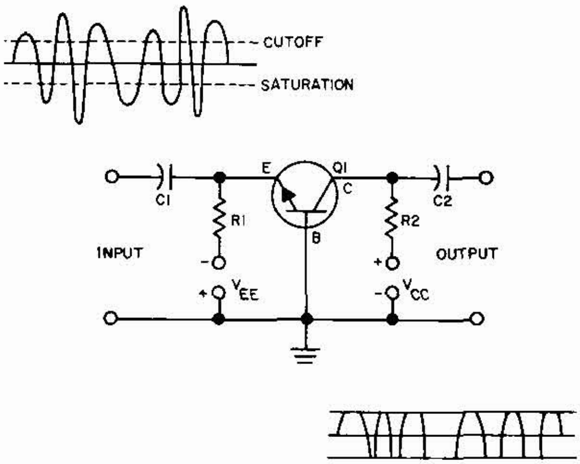
Low input impedance and high output impedance.

No phase inversion.

CIRCUIT ANALYSIS.

General. The triode, basic common-base limiter is essentially a transistor amplifier which is operated at a level which allows it to be cutoff and saturated at certain positive and negative amplitudes of the input signal. By using a specific emitter to base voltage a specific emitter current is obtained. This emitter current determines what signal level is required to cutoff and saturate the limiter. These cutoff and saturation values are the limiting levels.

Circuit Operation. A triode, basic NPN common-base limiter is shown in the accompanying illustration.



Triode, Basic Common Base Limiter (NPN)

Capacitor C1 and resistor R1 form a coupling network which couples the signal from the previous stage to the emitter of Q1. Bias supply VEE determines the emitter to base bias voltage. The value of base resistor R1 in conjunction with the bias supplied by VEE determines the emitter current. Collector load resistor R2 and collector supply VCC establish the collector current. Capacitor C2 couples the output of Q1 to the following stage. Q1 is an NPN transistor.

When the incoming signal is positive-going the positive signal voltage opposes the normal forward negative bias between the emitter and the base. This reduces the current flowing through the transistor. When the collector current of Q1 is reduced, the voltage drop across R2 is also reduced, and the collector voltage approaches that of the collector supply which, in effect, makes the collector more positive. Thus, for a positive incoming signal a positive output voltage is obtained.

When the positive incoming signal becomes sufficiently large that it cancels the forward bias entirely the transistor cuts off and collector current ceases. The collector voltage of Q1 is now at the supply value and cannot increase further. Hence, for any further positive increase in signal voltage there is no change in output voltage, which stays constant for any variation of input signal voltage beyond the cut-off level.

When the incoming signal is negative-going the emitter is driven negative with respect to the base. This increases the forward bias and current flow (electron flow) from emitter to collector. An increase in voltage drop across collector resistor R2 results, which drives the collector more negative. Thus, a negative input results in a negative output.

If the incoming signal exceeds a certain negative value, the current from emitter to collector reaches its maximum (saturation) value and the collector voltage reaches a minimum value. Any further increase in amplitude of the negative input signal does not affect the collector current or the voltage at the collector, since the transistor has attained a saturated level.

It is at these levels of saturation and cutoff that the output voltage is limited. Thus, to achieve limiting it is necessary to supply a large amplitude signal. Between the limits of cutoff and saturation the circuit will act as a conventional amplifier. Beyond these limits the peaks are cut off and the waveform is effectively "squared off".

FAILURE ANALYSIS.

No Output. In a triode, basic common-base limiter a no-output condition may be caused by any of the following (provided the input signal is present and correct): An open coupling capacitor C1, an open bias resistor R1, an open or shorted supply voltage VEE, an open collector to base resistor R2, an open or shorted supply voltage VCC, an open output coupling capacitor C2, or a faulty transistor Q1.

To determine which of these components is at fault first use an oscilloscope to determine if the input signal is present at the input terminals of the circuit. Then determine if the input signal is present at the emitter of the transistor. If the signal is present at the input terminals but not at the emitter, first check C1 with an in-circuit capacitor checker. If C1 is not open check R1 with an ohmmeter (after disconnecting one end of the resistor from the circuit). If R1 is not open, check bias voltage VEE by either replacing it with an equivalent voltage source which is known to be good, or by measuring VEE with a high resistance voltmeter. If VEE is not zero or shorted, check R2 with an ohmmeter (after disconnecting one end of the resistor from the circuit). If R2 is not open, check the collector bias voltage VCC with a high resistance voltmeter. Check C2 with an in-circuit capacitor checker. If C2 is not open and all other components check out, transistor Q1 must be at fault.

Low or Distorted Out. A low or distorted output may be caused by: input capacitor C1 being shorted, resistor R1 being shorted or beyond tolerance, voltage source VEE being other than the required voltage, resistor R2 being shorted or beyond tolerance, voltage source VCC being other than the required voltage, capacitor C2 being shorted, and transistor Q1 being defective.

To determine which of these components is at fault, first check the voltage between one plate of C1 and ground with a high resistance voltmeter, then check the voltage between the other plate of C1 and ground. If these voltage values are equal then capacitor C1 is shorted. Check the value of R1 with an ohmmeter (after first disconnecting one end of R1 from the circuit) for the proper ohmic value. If R1 is not within the required tolerance replace it with a resistor that is. Check voltage source VEE with a high resistance voltmeter. If the voltage has altered from the required voltage, either adjust the source to the proper value or replace VEE with a voltage source of the proper value. Check the value of R2 with an ohmmeter (after first disconnecting one side of R2 from the circuit) for the proper ohmic value. If R2 is not within the required tolerance, replace it with a resistor that is. Check voltage source VCC with a high resistance voltmeter. If the voltage has altered from the required voltage, either adjust the source to the proper value or replace VCC with a voltage source that is the proper value. Check the voltage between one plate of C2 and ground with a high resistance voltmeter, then check the voltage between the other plate of C2 and ground. If these voltages are equal capacitor C2 is shorted. If all of these components are good and the trouble still persists the fault must be in transistor Q1.