April 9, 1963 A. NATHAN 3,084,862

INPUT CONVERTER AND SIGN DISCRIMINATOR FOR MULTIPLIERS

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FIG. 2

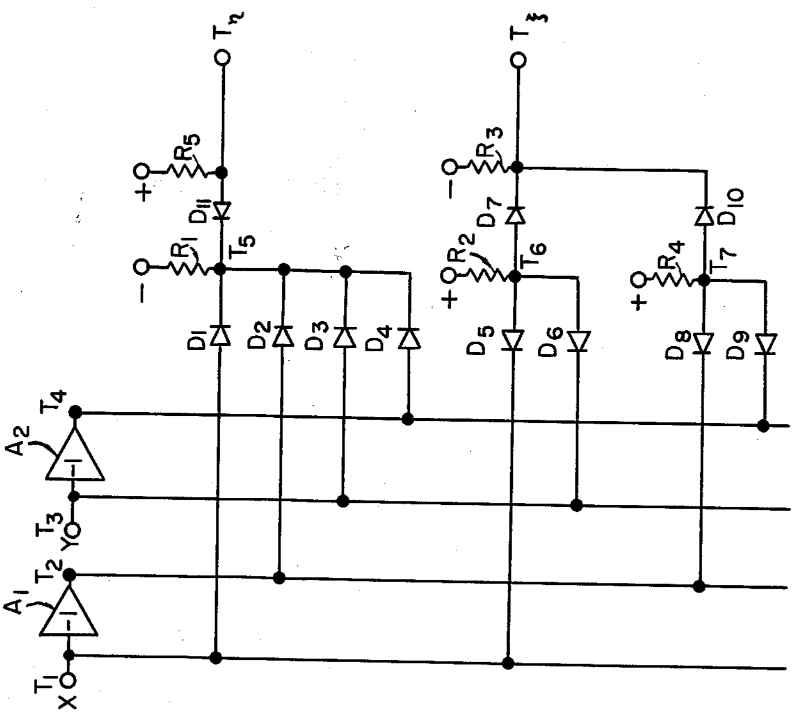

FIG. 1A

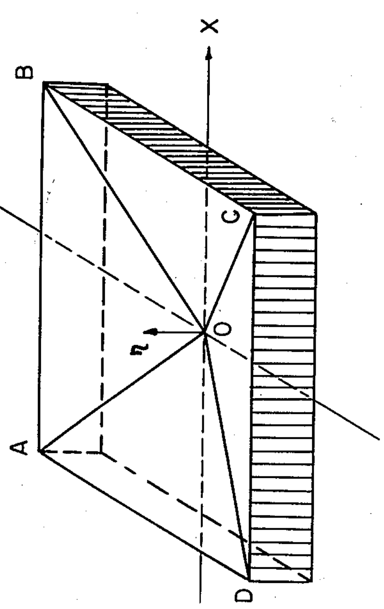

FIG. 1B

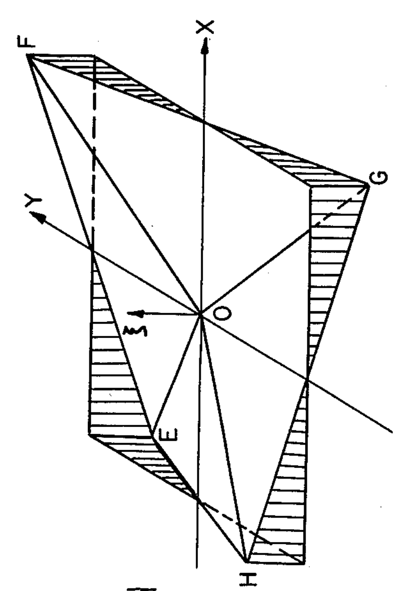

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FIG. 4C

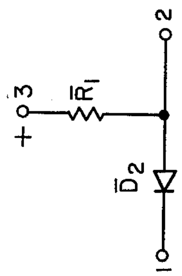


FIG. 4D

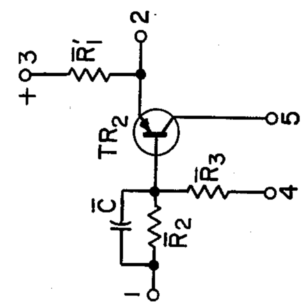


FIG. 4A

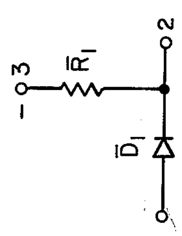


FIG. 4B

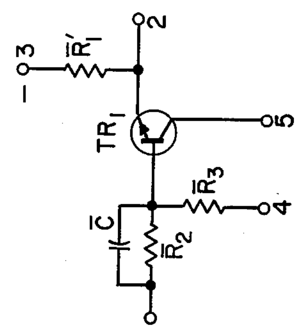
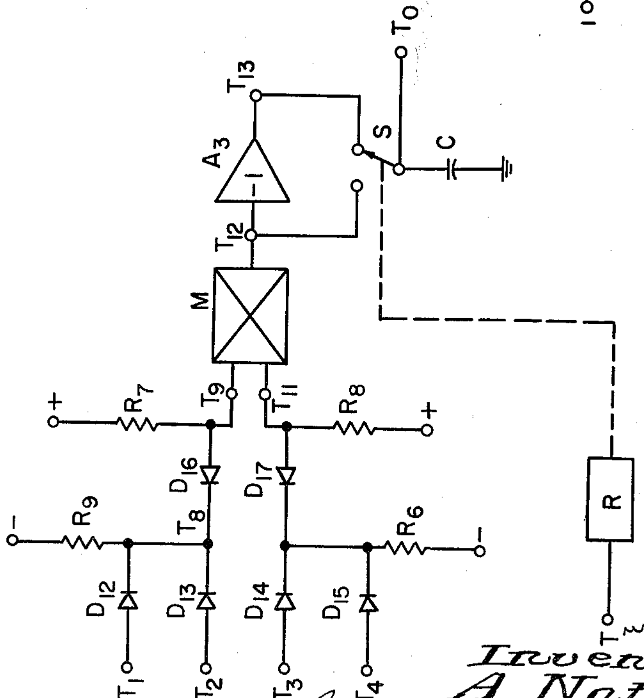


FIG. 3



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INPUT CONVERTER AND SIGN DISCRIMINATOR FOR MULTIPLIERS

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12 Claims. (Cl. 235—194)

This invention relates to an input converter and sign discriminator for electronic multipliers. More specifically, this invention relates to a device which, when connected to the input of any two-quadrant electronic multiplier, or to the input of some one-quadrant multipliers, permits four-quadrant operation. This invention also provides a unit which, when fed by two voltages, generates an output voltage whose sign is equal to the sign of the product of the two input voltages.

In general, an electronic multiplier is a device, which when fed with input voltages x and y, generates an output voltage which is proportional to xy. The following terminology is used to describe some aspects of the input ranges of multipliers: A multiplier is said to operate in the first quadrant, if $x\geqq0$, $y\geqq0$; in the second quadrant, if $x\leqq0$, $y\geqq0$; in the third quadrant, if $x\leqq0$, $y\leqq0$; and in the fourth quadrant if $x\geqq0$, $y\leqq0$.

A multiplier is said to have one quadrant or two quadrant operation if the permissible input range is restricted to one quadrant or to two adjacent quadrants, respectively.

The prior art provides input converters for one- or two-quadrant multiplication whose operation is such, that the correct sign of the output of the multiplier is not always preserved. For example, in a converter for a one quadrant multiplier operative in the first quadrant, x is converted into the modulus of x, $|x|$, and y is converted into $|y|$. In this case the sign of multiplier output is always non-negative.

It is an object of this invention to provide an input converter, which, when connected to the input terminals of any electronic multiplier, preserves both the value and the sign of the output of the multiplier and extends the operative range of one or both of the input variables in the case of multipliers which do not have four quadrant operation.

In particular, it is an object of this invention to provide two quadrant input voltages to an electronic multiplier, when fed with four quadrant inputs.

It is another object of this invention to provide means for producing an output voltage whose sign is equal to the sign of the product of two input voltages.

It is a further object of this invention to provide a device which, when used with conventional additional circuits, converts any one quadrant multiplier into a four quadrant multiplier.

It is yet another object of this invention to provide a device which, when used with additional conventional circuits, converts some half quadrant multipliers into four quadrant multipliers.

It is another object of this invention to provide an input converter for multidimensional function generators with certain symmetry properties.

Further objects and advantages of this invention will become apparent from the following description of a practical realization of the invention taken in connection with the accompanying drawings, in which—

FIGURE 1A is a three dimensional plot of converter output η as a function of its inputs x and y;

FIGURE 1B is a three dimensional plot of converter output ξ as a function of its inputs x and y;

FIGURE 2 is a circuit diagram of one embodiment of the converter and sign discriminator of this invention;

FIGURE 3 is a schematic diagram of one embodiment of a one to four quadrant converter using the sign discriminator of this invention; and

FIGURES 4A, 4B, 4C, and 4D are scrap circuit diagrams to show how the circuits may be transistorized.

FIGURES 1A and 1B illustrate functions, which if generated by the converter give the desired result. More particularly, in FIGURE 1A the equation representing plane OAB is $\eta=y$; the equation representing plane OBC is $\eta=x$; the equation representing plane OCD is $\eta=-y$; and the equation representing plane ODA is $\eta=-x$. Surface ABCDO can thus be represented as

$$\eta=\max.\{|x|,\ |y|\}$$

or, equivalently, as

$$\eta=\max.\{x,\ -x,\ y,\ -y\}$$

In FIGURE 1B the equation representing plane EOF is $\xi=x$; the equation representing plane FOG is $\xi=y$; the equation representing plane GOH is $\xi=x$; and the equation representing plane HOE is $\xi=-y$. Surface EFGHO can therefore be represented as

$$\xi=\max.\{\min.(x,\ y),\ \min.(-x,\ -y)\}$$

or as

$$\xi=\min.\{\max.(x,\ -y),\ \max.(-x,\ y)\}$$

The terms maximum and minimum are used in this specification to denote selection operators; thus max. (a, b, c . . .) is equal to the greatest of a, b, c, . . . ; and min. (a, b, c, . . .) is equal to the least of a, b, c, ...

Any pair of non-zero values of x and y having differing moduli must of necessity satisfy one, and only one, of the following four conditions:

(*a*) $y>x$; $y>-x$
(*b*) $y>x$; $y<-x$
(*c*) $y<x$; $y>-x$
(*d*) $y<x$; $y<-x$

Evaluating the functions ξ and η for each of these cases separately there is obtained respectively:

(*a*) min. $(x, y)=x$, min. $(-x, -y)=-y$ so that $\xi=\max.(x, -y)=x$
$\eta=\max.(|x|, |y|)=|y|=y$

(*b*) min. $(x, y)=x$, min. $(-x, -y)=-y$ so that $\xi=\max.(x, -y)=-y$
$\eta=\max.(|x|, |y|)=|x|=-x$

(*c*) min. $(x, y)=y$, min. $(-x, -y)=-x$ so that $\xi=\max.(y, -x)=y$
$\eta=\max.(|x|, |y|)=|x|=x$

(*d*) min. $(x, y)=y$, min. $(-x, -y)=-x$ so that $\xi=\max.(y, -x)=-x$
$\eta=\max.(|x|, |y|)=|y|=-y$

If either x or y is zero then $\xi=0$.
If $x=y$ then $\xi=|x|=\eta$.
If $x=-y$ then $\xi=-|x|$, $\eta=|x|$.

It follows, for all values of x and y,

(i) $\xi\eta=xy$
(ii) $\eta\geqq0$
(iii) $\eta\geqq|\xi|$
(iv) The sign of ξ is equal to the sign of xy

A device generating ξ, η as output signals when fed with x, y as input signals can therefore be used as an input converter for a multiplier, ξ and η being the input signals to the multiplier; because from (i), above, the output of the multiplier is not affected by the introduction of such a converter in the said manner. Moreover, because of (ii), above, the multiplier need only be of the two quadrant type, whereas the converter accepts inputs in four quadrants. The multiplier can actually be of an even more restricted type, for (iii), above shows that input signals ξ, η lie within one quadrant only, said quadrant being limited by the lines $\xi=\eta$ and $\xi=-\eta$. The part of the converter generating the ξ signal is a sign discriminator for the sign of xy, as follows from (iv), above.

FIGURE 2 is a schematic diagram of one embodiment of the device for the generation of ξ and η. T_1 and T_3 are the input terminals for input signals x and y, respectively. Input signal x is fed to sign changer A_1 whose output signal $-x$ appears at output terminal T_2. Input signal y is fed to sign changer A_2 whose output signal $-y$ appears at output terminal T_4. The anodes of diodes D_1, D_2, D_3, D_4, are connected to terminals T_1, T_2, T_3, T_4, respectively. Their cathodes are joined at terminal T_5 which is also connected to a negative D.C. voltage, at $-$, through resistor R_1. Except for a small transitional interval, only one of diodes D_1, D_2, D_3, D_4, conducts at a time; there thus appears at terminal T_5 a signal approximately equal to η. If the diodes have a voltage drop equal to ϵ when conducting, the voltage at T_5 will be equal to $\eta-\epsilon$. When using silicon or germanium diodes or transistors, ϵ is of the order of 0.1 to 1.0 volt. To correct for this offset voltage and for diode drift, diode D_{11}, of the same type as diodes D_1 to D_4, is connected with its cathode to T_5. The anode of D_{11} is connected to output terminal T_η and to a positive D.C. voltage, shown at $+$, through resistor R_5. The offset voltage of D_{11} cancels the offset voltages of diodes D_1 to D_4 and voltage η thus appears at T_η. This compensation device, comprising D_{11} and R_5, is needed only when high accuracy is required. Another way of compensating for said offset voltage consists of replacing D_{11} by a resistor having a resistance which is equal to the resistance of D_{11} when conducting.

Some types of diodes have considerable spread of voltage drops from diode to diode, when conducting. The errors thus introduced into the converter can be eliminated by first determining the voltage drop of that diode which has the largest drop, ϵ, when conducting, and then adding resistors of suitable values in series with each of the other diodes so that the drop across each series combination of said resistors and diodes is made equal to ϵ when the diodes are conducting. This compensation should be carried out for all diodes of the converter.

The cathodes of diodes D_5, D_6, D_8, D_9, are connected to terminals T_1, T_3, T_2, T_4, respectively. The anodes of D_5 and D_6 are joined to T_6 which is also connected to a positive D.C. voltage, $+$, through a resistor R_2. At T_6 thus appears a signal equal to $\min.(x, y)+\epsilon$. The anodes of diodes D_8 and D_9 are joined at T_7 which is also connected to a positive D.C. voltage, $+$, through resistor R_4. At T_7 thus appears a signal equal to

$$\min.(-x, -y)+\epsilon$$

The anodes of diodes D_7, D_{10} are connected to T_6, T_7, respectively. Their cathodes are joined at terminal T_ξ which is also connected to a negative voltage, shown at $-$, through resistor R_3. At T_ξ thus appears a signal equal to ξ. A two quadrant multiplier, or a single quadrant multiplier whose inputs lie within the quadrant $y\geqq|x|$, can therefore be connected to terminals T_ξ and T_η. No compensating diodes are required for the offset voltages of the diodes associated with the circuit for generating ξ, because, by virtue of the configuration, the offset voltages cancel.

The device generating ξ heretofore described is based on the expression

$$\xi=\max.\{\min.(x, y), \min.(-x, -y)\}$$

Analogously, a device with identical functions can be constructed, based on the given equivalent form for ξ

$$\xi=\min.\{\max.(x, -y), \max.(y, -x)\}$$

The description above is to be understood by way of example only.

FIGURE 3 shows one embodiment of the use of the sign discriminator of this invention to convert a one quadrant multiplier to four quadrant operation. In FIGURE 3, T_1, T_2, T_3, T_4, are the terminals which are at voltages x, $-x$, y, $-y$, respectively, as in the device described in connection with FIGURE 2. Terminal T_ξ is at voltage ξ. This voltage is generated by use of the part of the converter generating ξ, as heretofore described, i.e. by use of the device shown in FIGURE 2 less that part of it consisting of D_1, D_2, D_3, D_4, R_1 and T_η, and their interconnections. In FIGURE 3, M is a one quadrant multiplier whose input terminals are T_9 and T_{11}. T_9, T_{11} are fed with voltages $|x|$, $|y|$, respectively. The anodes of diodes D_{12}, D_{13} are connected to T_1, T_2, respectively; their cathodes are connected to T_8; T_8 is also connected to a negative D.C. voltage, $-$, through resistor R_9; the voltage of T_8 is approximately equal to $|x|$. Diode D_{16} is provided in order to compensate for the voltage drop in D_{12} and D_{13} and to compensate for diode drift. The cathode of D_{16} is connected to T_8 and its anode is connected to T_9 which is also connected to a positive D.C. voltage, $+$, through resistor R_7. T_9 is thus at a voltage equal to $|x|$. The anodes of diodes D_{14}, D_{15} are connected to T_3, T_4, respectively; their cathodes are connected to T_{10} which is also connected to a negative D.C. voltage, $-$, through resistor R_6. The cathode of compensating diode D_{17} is connected to T_{10} and its anode is connected to terminal T_{11} which is also connected to a negative D.C. voltage, $-$, through resistor R_8. T_{11} is therefore at a voltage equal to $|y|$. M is therefore fed with non-negative voltages and can be of one quadrant operation. At the output terminal T_{12} of M thus appears a voltage equal to $k|xy|$, where k is a positive constant. Analogous considerations apply when k is negative constant. This voltage is fed to sign changer A_3 whose output terminal T_{13} is therefore at voltage $-k|xy|$. Voltage ξ is fed from terminal T_ξ to a polarized relay whose actuating mechanism R connects terminal T_0 of its change-over switch S to T_{12} or T_{13} for positive or negative values of ξ, respectively. At T_0 therefore appears the required output voltage kxy. C is a capacitor, connected between T_0 and ground; C is required in some applications, depending upon the circuit fed from T_0, in order effectively to ground T_0 during the switching over of S. The relay consisting of R and S and their associated circuits is by way of illustration only; it can be replaced, in particular, by an electronic switching device.

Similarly, a half quadrant multiplier can be converted into a four quadrant multiplier. For example, to convert to four quadrant operation a multiplier operative in the half quadrant $y\geqq x\geqq 0$, said multiplier can be fed with signals $|\xi|$ and η. Referring again to FIGURE 3, this can be done by omitting D_{14}, D_{15}, D_{17}, R_6, and R_8 and their interconnections, and feeding T_1, T_2, T_{11}, with ξ, $-\xi$, and η, respectively, where ξ and η are generated as described above, whereas $-\xi$ can be obtained from ξ by sign changing means, or directly from x, $-x$, y, $-y$ from the expression

$$-\xi=\min.\{\max.(x, y), \max.(-x, -y)\}$$

The circuit for the generation of $-\xi$ according to this later expression is therefore identical with the circuit of FIGURE 2 for the generation of ξ, except that anode and cathode connections of each of diodes D_5 to D_{10} and the positive and negative voltages at $+$ and $-$, respectively, must be interchanged, and, because of the loading of the circuits generating ξ and $-\xi$, in the circuit generating ξ resistor R_3 and the negative voltage to which it connects must be omitted, and in the circuit generating $-\xi$ resistor R_3 must be halved. ξ or $-\xi$ are also used as control signals for output selection.

Alternatively $|\xi|$ can be generated according to expressions such as

$$|\xi|=\max.\{\min.(x, y), \min.(-x, y), \min.(-x, -y), \min.(x,-y)\}$$

or

$$|\xi|=\min.\{|x|, |y|\}$$

for example, and the manner of said generations will be quite clear from the above description.

In one embodiment of the invention the following components and component values were used:

All diodes are silicon junction diodes;
All voltages marked + are 250 volts D.C.;
All voltages marked − are −250 volts D.C.

In the device described in connection with FIGURE 2,

$$R_1=R_2=R_4=250 \text{ kilohms}$$
$$R_3=R_5=500 \text{ kilohms}$$

In the device described in connection with FIGURE 3,

$$R_9=R_6=250 \text{ kilohms}$$
$$R_7=R_8=500 \text{ kilohms}$$
$$C=200 \text{ picofarads}$$

In some applications, inputs x and/or y are restricted, or the multiplier has special input characteristics. It is then not always required to realize the complete surfaces of FIGURES 1A and 1B.

For example, if input variable y is always non-negative, $y\geqq 0$, the previous expressions for η and ξ simplify to

$$\eta=\max.(x, -x, y)$$
$$\xi=\min.\{\max.(x, -y), y\}$$

and the elements D_4, D_9, and A_2 may be omitted from the device of FIGURE 2.

Another example which realizes only a part of each of the surfaces of FIGURE 1 is required if the multiplier is such that it can accept only inputs x and y for which $y\geqq x$, the later restriction defining a particular two quadrant multiplier, said two quadrants covering half of the first, the whole second, and half of the third quadrants.

One embodiment of the modification sufficient in the latter case consists of the unit of FIGURE 2 with the omission of the following components: A_1, A_2, D_2, D_4, D_8, D_9, D_{10}, and R_4 and their interconnections.

Other modifications, realizing other parts of the surfaces of FIGURE 1 are obtained by the omission of selected components of the embodiment of this invention described in connection with FIGURE 2.

While the converter is described above as an input unit to a multiplier, it can also be used as an input unit to a two dimensional function generator, or to any two inputs of a multidimensional function generator; in the latter case several converters can be used as input units, each converter serving as input unit to one pair of input terminals of the function generator or its other input converters, or to a pair of terminals one of which is an input terminal of the function generator and the other one is an input terminal of an input converter, all this, provided the function generated has the same symmetry properties and/or the same input restrictions as a multiplier.

For example, if $f(x, y)$ is the function generated by the function generator when it is fed with voltages x and y, at its two input terminals, and if

$$f(x, y)=f(y, x)=f(-x, -y)=f(-y, -x)$$

the unmodified input converter can be used and only one quadrant of $f(x, y)$ need be realized in the function generator, said quadrant lying partly in the first and partly in the second quadrants, between $x=y$ and $x=-y$.

As a second example, if $f(x, y)=f(y, x)$, the modification of this invention described above in connection with multipliers for which $y\geqq x$ can be used as an input converter to the function generator and only two quadrants of $f(x, y)$ need be realized in the function generator, said two quadrants lying partly in the first and third quadrants, and covering the whole second quadrant, their limit being given by the line $x=y$.

As a third example, if

$$f(x, y)=f(y, x)=f(-x, -y)=-f(-x, y)$$

$|\xi|$ and η can be used as input signals and output switching must be provided, as described above in connection with the conversion of a half quadrant multiplier to four quadrant operation.

The embodiments of this invention and its modifications which have been described in connection with FIGURE 2 use diodes as non-linear elements. It is to be understood that the use of diodes is by way of example only; in particular, the diodes can be replaced by transistors connected in a so-called diode logic connection. The manner of said replacement will be described in connection with FIGURES 4A to 4D, in which FIGURE 4A represents the diagram of a typical diode, such as D_1, D_2, D_3, D_4, D_7, or D_{10} of FIGURE 2, together with resistor $\overline{R}_1$ connected to its cathode, which corresponds to R_1, or R_3, in the case of D_1, D_2, D_3, D_4, or D_7, D_{10} respectively. **3** is the terminal of the constant negative voltage, −. FIGURE 4B shows the corresponding transistor connection, in which terminals **1**, **2**, **3** are identical with terminals **1**, **2**, **3**, of FIGURE 4A. TR_1 is an NPN transistor. The parallel connection of resistor $\overline{R}_2$ and capacitor $\overline{C}$ serves as input network to the base of the transistor. The base is also connected to bias voltage V_3 at terminal **4** through resistor $\overline{R}_3$. The emitter is connected to terminal **2** which is also connected to a negative D.C. voltage V_3, at terminal **3**, through resistor $\overline{R}_1'$. The collector is connected to terminal **5** which is at the constant voltage V_5. FIGURE 4C corresponds to one of the diodes such as D_5, D_6, D_8, D_9, D_{11} in the embodiment of FIGURE 2, and consists of FIGURE 4A with diode $\overline{D}_1$ replaced by diode $\overline{D}_2$, where $\overline{D}_2$ is $\overline{D}_1$ with interchanged terminals, and with voltage V_3 of reversed sign. FIGURE 4D shows the transistor equivalent to FIGURE 4C and is identical to FIGURE 4B except for the substitution of PNP transistor TR_2 for TR_1 and the reversal of sign of voltages V_3, V_4, and V_5.

Combinations of transistors and diode elements can be used. For example, D_7, D_{10}, D_{11} may be diodes, all other non-linear elements being transistors.

The use of transistors has the main advantages of providing impedance conversion, from a higher input to a lower output value, and of improving the frequency response; its main disadvantage is the restriction of the useful voltage range of input voltages x and y.

Typical values for the embodiments of FIGURES 4B and 4D are as follows: $\overline{R}_1'=50$ kilohms; $\overline{R}_2=2.0$ kilohms; $\overline{R}_3=100$ kilohms; $C=570$ picofarads. Typical voltages in the embodiment of FIGURE 4B are as follows: $V_3=-22.5$ volts; $V_4=7$ volts; $V_5=2$ volts. In the embodiment of FIGURE 4D the same voltage values with reversed sign are used. The gain from input to output was found to be 0.98. The permissible voltage range at terminal **2** was −3 volts to +3 volts. Adjustment for zero output voltage with zero input voltage is obtained by a slight variation of V_4. For this purpose adjustable V_4 is provided.

As an alternative way of carrying out the invention, $-\xi$ as given above and $-\eta=\min.(x, -x, y, -y)$ may be used, or, for example, realization of $-\xi$ and η according to the expressions, which require only one sign-changer,

$$-\xi=\min.\{\max.(x, y), -\min.(x, y)\}$$
$$\eta=\max.\{\max.(x, y), -\min.(x, y)\}$$

and the manner of their generation will be quite clear from the above description.

What I claim is:

1. An input converter for a one or two quadrant multiplier or like function generator, comprising means for accepting first and second input signals, first means connected to said accepting means for producing from said input signals a first output signal corresponding with the maximum of the moduli of said input signals, and second means connected to said accepting means for producing a

second output signal having a modulus equal to the minimum of the moduli of the input signals, said second means including means for generating a sign for said second output signal wherein said sign is equal to the sign of the product of the input signals; said accepting means including means for generating a plurality of secondary output signals greater in number than said input signals; at least one of said secondary output signals being equal in magnitude and opposite in sign to one of said input signals; said first and second means being adapted to employ said secondary output signals to generate appropriate moduli signals.

2. The input converter of claim 1 wherein the means for producing the first output signal comprises first and second sign changer means for producing first and second secondary input signals equal to the inverses of the first and second input signals, and third means for selecting the maximum of said first and second input signals and said first and second secondary input signals.

3. An input converter for a one or two quadrant multiplier or like function generator, comprising means for accepting first and second input signals, first and second sign changer means for producing first and second secondary input signals equal to the inverse of the respective input signals, means for selecting the maximum of said first and second input signals and said first and second secondary input signals, means for selecting the minimum of said first and second input signals, means for selecting the minimum of said first and second secondary input signals, and means for selecting the maximum of the two minima so selected.

4. A four quadrant multiplier comprising means for accepting first and second input signals, means for deriving the moduli of said input signals, a single quadrant multiplier for multiplying said moduli to produce a first output signal, sign changer means to produce a second output signal equal to the inverse of said first output signal, and changeover means for selecting one of said first and second output signals as final output signal, said changeover means being responsive to the sign of a control signal derived from said input signals so that the output signal selected has the sign as well as the modulus of the product of the input signals.

5. A four quadrant multiplier comprising means for accepting first and second input signals, means for deriving the moduli of said input signals, means for multiplying said moduli to produce a first output signal, means for changing the sign of said first output to produce a second output signal, means for deriving a control signal having the sign of the product of the input signals, and changeover means, responsive to said control signal, for selecting that one of said first and second output signals having the sign of said control signal.

6. A four quadrant multiplier or like function generator comprising means for accepting first and second input signals, means for deriving a first secondary signal equal to the maximum of the moduli of the input signals, means for deriving a second secondary signal equal to the minimum of the moduli of the input signals, a half quadrant multiplier or like function generator producing a first output signal from said secondary signals, sign changer means to produce a second output signal equal to the inverse of said first output signal, and changeover means for selecting one of said first and second output signals as final output signal, said changeover means being responsive to the sign of a control signal derived from said input signals so that the output signal selected has the sign of the product of the input signals.

7. A multiplier or function generator for the generation of the modulus of a product or of another function, comprising means for accepting first and second input signals, means for deriving a first secondary signal equal to the maximum of the moduli of the input signals, means for deriving a second secondary signal equal to the minimum of the moduli of the input signals, a half quadrant multiplier or like function generator producing an output signal from said secondary signals, said output signal being the required modulus.

8. A multiplier as set forth in claim 5 wherein the means for deriving said control signal comprises first and second sign changer means for producing first and second secondary input signals equal to the inverses of the first and second input signals respectively, means for selecting the minimum of said first and second input signals, means for selecting the minimum of said first and second secondary input signals and means for selecting the maximum of the minima so selected, said maximum being the required control signal.

9. In a multiplier or like function generator, means for deriving a signal with the same sign as the product of two input signals, comprising first and second sign changer means for producing first and second secondary input signals equal to the inverses of the first and second input signals respectively, means for selecting the minimum of said first and second input signals, means for selecting the minimum of said first and second secondary input signals and means for selecting the maximum of the minima so selected, said maximum being the required signal.

10. A sign discriminator for use in multipliers or similarly symmetrical function generators, comprising means for accepting first and second input signals, first and second sign changer means for producing first and second secondary input signals equal to the inverses of the first and second input signals respectively, means for selecting the minimum of said first and second input signals, means for selecting the minimum of said first and second secondary input signals, and means for selecting the maximum of the minima so selected, said maximum having the sign of the product of the two input signals.

11. An input converter for a one or two quadrant multiplier or like function generator, comprising means for accepting first and second input signals, means for producing from said input signals a first output signal corresponding with the maximum of the moduli of said input signals, and means for producing a second output signal having a modulus equal to the minimum of the moduli of the input signals and a sign equal to the sign of the product of the input signals, the means for producing the second output signal comprising first and second sign changer means for producing first and second secondary input signals equal to the inverses of the first and second input signals respectively, means for selecting the minimum of said first and second input signals, means for selecting the minimum of said first and second secondary input signals and means for selecting the maximum of the minima so selected, said maximum being the required second output signal.

12. An input converter for a one or two quadrant multiplier or like function generator, comprising means for accepting first and second input signals, means for producing from said input signals a first output signal corresponding with the maximum of the moduli of said input signals, and means for producing a second output signal having a modulus equal to the minimum of the moduli of the input signals and a sign equal to the sign of the product of the input signals, the means for producing the second output signal comprising first and second sign changer means for producing first and second secondary input signals equal to the inverse of the first and second input signals respectively, means for selecting the maximum of said first input signal and said secondary input signal, means for selecting the maximum of said second input signal and said first secondary input signal and means for selecting the minimum of the maxima so selected, said minimum being the required second output signal.

(References on following page)

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"Electronic Analog Computer," GAP/R K2 Series, Philbrick Researches, Inc., received in Scientific Library Sept. 29, 1958. FIG. 1.1, p. 10 and FIG. 4.3, p. 23 relied on.

"Electronic Analog Computer" (Korn and Korn), 1952, McGraw-Hill Book Company, Inc., N.Y., FIG. 6.2, page 212 showing adaptation of two-quadrant multipliers to four-quadrant multiplication of interest.