Phase-noise nomograph eases power/bandwidth tradeoff

by R. S. Baggett
Rockwell International Corp., Collins Satellite Group, Richardson, Texas

The residual noise generated by a frequency- or phase-modulated system limits the amount of information that can be passed through a satellite communications network. But determining what tradeoffs to make in noise power versus bandwidth versus frequency can be tedious for those who must solve the defining equations repetitively. The nomograph shown is a quick way to relate the residual noise, also known as phase noise, to its equivalent noise power for a specified system bandwidth and frequency offset from the carrier.

More exactly, this nomograph converts phase noise in a 1-hertz bandwidth, which is measured in decibels below the carrier power (dBc/hertz), to decibels below a carrier that is undergoing a deviation of 200 kilohertz in a channel having a bandwidth of 3.1 kHz. The carrier deviation and channel bandwidth are industry standards.

The noise bandwidth, the frequency at which the measurement is taken (offset from the carrier), and the phase noise are related by:

$$\text{dBc/Hz} = 20\log(\Delta f_1/2^{1/2} f_m) \qquad (1)$$

where f_1 is the root-mean-square deviation of noise in hertz and f_m is the measurement frequency in hertz. Noise power in a bandwidth other than 1 hertz can be found with the aid of:

$$\Delta f_2 = (BW_2)^{1/2}\Delta f_1 \qquad (2)$$

where BW_2 is the actual bandwidth and Δf_2 is the new bandwidth of the noise.

When Equations 1 and 2 are combined, the result is:

$$\Delta f_2 = (2BW_2)^{1/2} f_m 10^{(\text{dBc/Hz})/20} \qquad (3)$$

When Δf_2 is related to the 200-kHz reference deviation by:

$$\text{dBm0} = 20\log(\Delta f_2/200{,}000) \qquad (4)$$

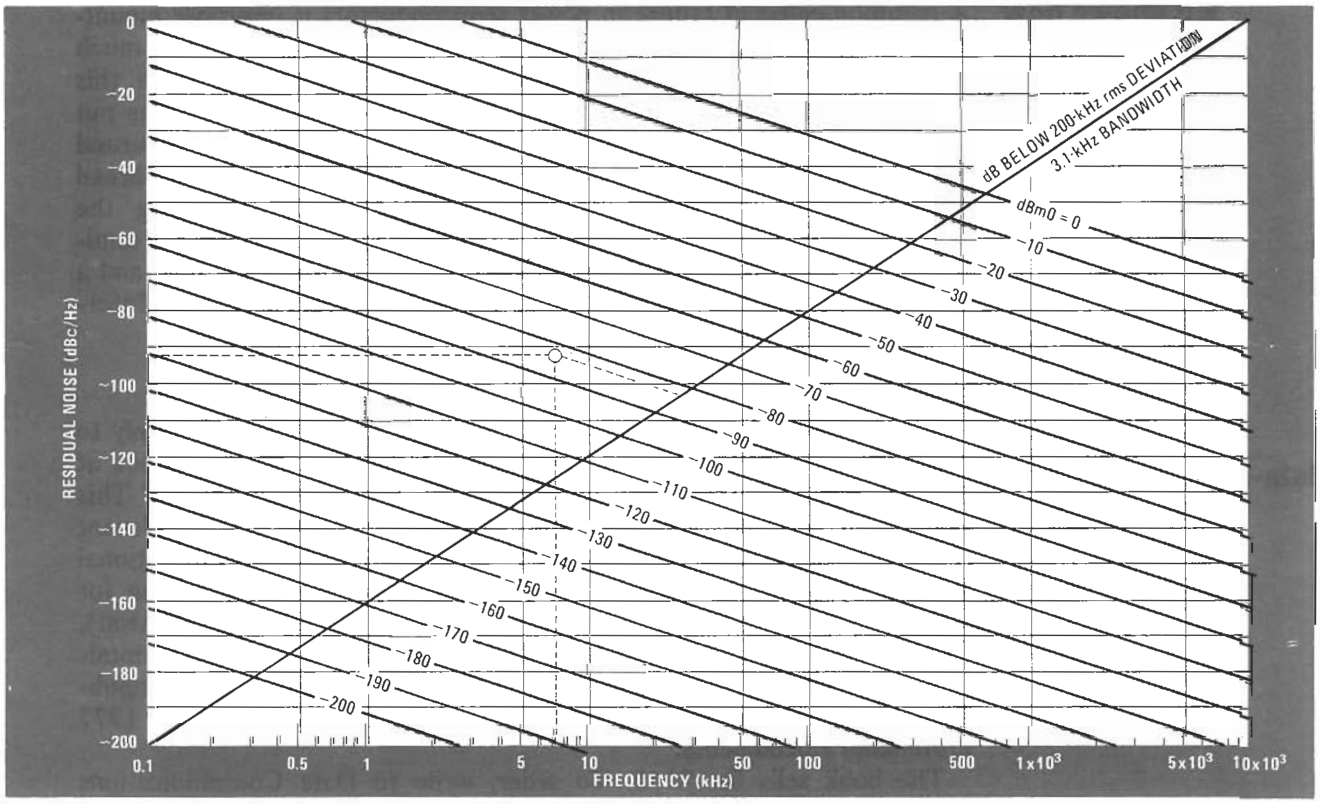
where dBm0 is defined as the equivalent noise power, and when BW_2 is made equal to 1.3 kHz and Eq. 3 is combined with Eq. 4:

$$\text{dBm0} = -68.10 + 20\log f_m + \text{dBc/Hz} \qquad (5)$$

Equation 5 is plotted on the nomograph using lines of constant dBm0.

Use of the nomograph aids the designer in converting from a given dB_c/Hz value to its dBm0. For example, a noise at 15 Hz in a standard 3.1-kHz-bandwidth system has a measured (and calculated) $\text{dB}_{c/Hz}$ of −91.3 when f_m = 7 kHz. As shown on the sample plot on the nomograph, −91.3 is equivalent to a dBm0 of −82.5. As a check, Eq. 3 is used:

$$20\log(15/200{,}000) = -82.5\ \text{dBm0} \qquad \square$$



Signal to noise. Nomograph relates phase noise to demodulated power for channel bandwidth of 3.1 kilohertz. In example, noise at 15 Hz produces phase noise of −91.3 dBc/Hz 7 kHz from carrier, generating an equivalent noise power of −82.5 dBm0.

PARALLEL-LINE IMPEDANCE NOMOGRAM

By **JIM KYLE**

Here is a simple-to-use design chart that can be employed by industrial technicians, amateur radio operators, and engineers who must construct impedance-matching stubs.

INDUSTRIAL technicians, ham operators, and electronics engineers frequently find it necessary to determine the impedance of a parallel-wire r.f. transmission line, especially in the construction of impedance-matching transformers or of u.h.f. resonant circuits.

While this impedance can easily be calculated by a simple equation, the equation requires that you know the value of a logarithm—and log tables aren't standard equipment on most benches.

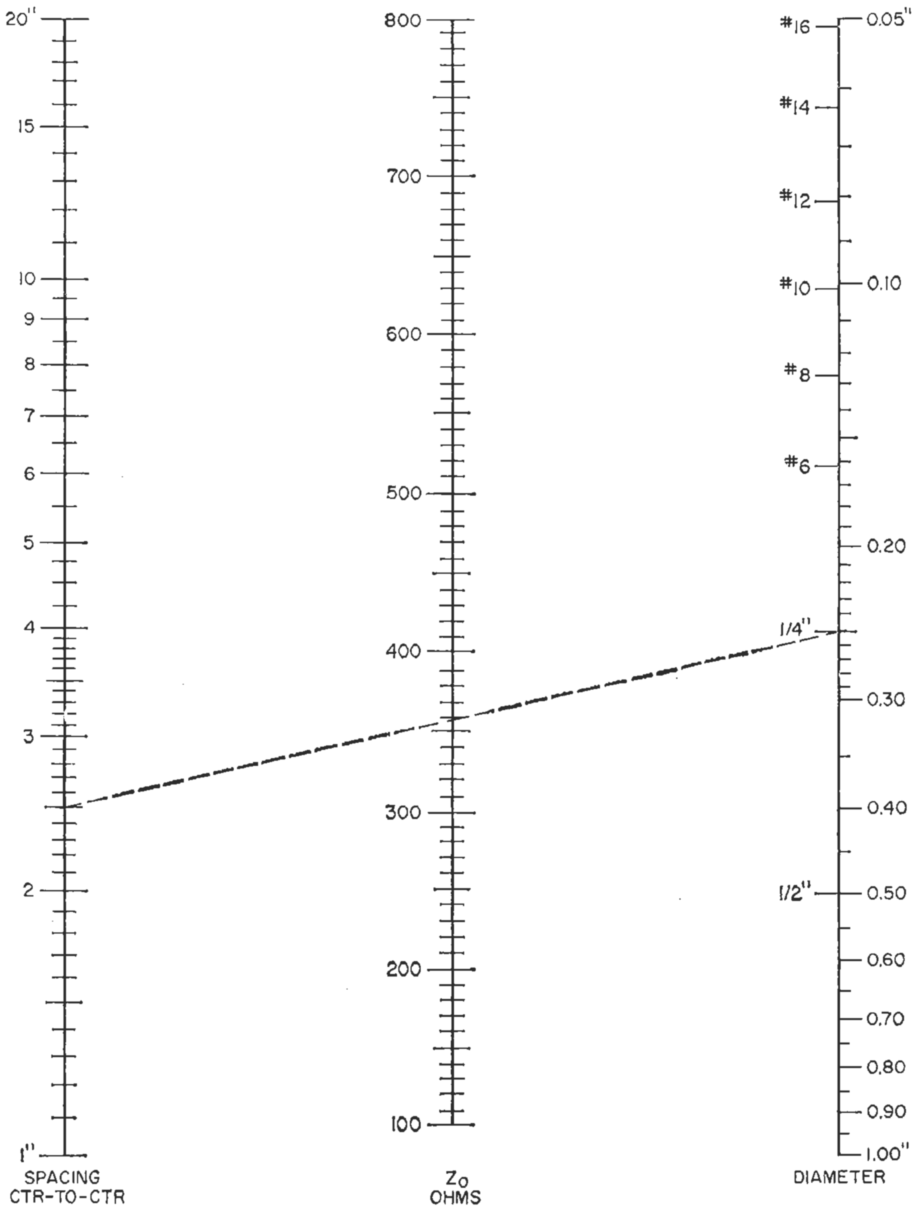
The accompanying nomogram will provide the answer for any air-dielectric parallel-wire line having conductors between .05 inch and 1 inch in diameter, spaced from one inch to 20 inches center-to-center. In addition, it allows you to pick the spacing necessary to build a line of any specified impedance, or to choose conductor diameter.

To use the chart, simply draw a straight line through the two known quantities and read the third quantity at the point where the line intersects its scale.

Example of Use

For example, suppose we have an air-dielectric parallel-wire line made up of ¼-inch tubing spaced 2½ inches center-to-center. Drawing a line from 2½ inches on the "spacing" scale to ¼ inch on the "diameter" scale, we find that it crosses the "Z_o" scale just below the 360 gradation. The impedance, then, of the line is approximately 359 ohms.

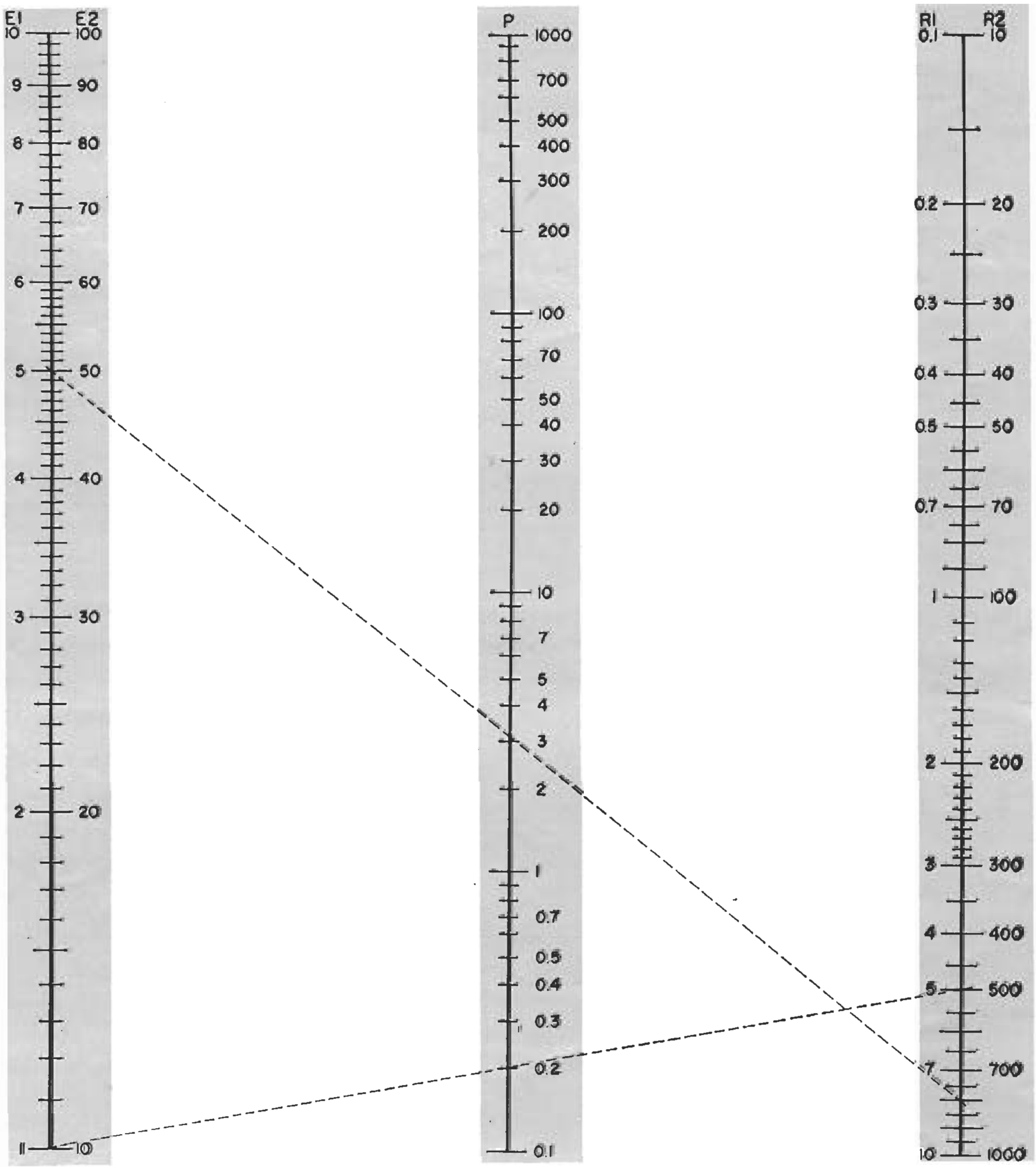
Had we been planning to build a 359-ohm line section, possibly for use as an impedance-matching transformer, using ¼-inch tubing, we would have drawn the same line—but this time we would read the center-to-center spacing as 2½ inches, from the appropriate scale. ▲



Versatile Voltage, Power, and Decibel Nomograms

By **JIM KYLE**

Two useful charts that enable the audio technician to find amplifier gains and losses even when voltage measurements are taken across different impedances.



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CALCULATIONS of power levels and decibel ratios from voltage readings often lead to confusion for both experienced technicians and beginners, since the conventional formula for determining decibel ratio from voltage readings assumes that each reading is taken at the same impedance level.

Many charts, tables, and graphs have been published to aid in solving such problems. However, the charts shown here offer features not to be found in such previous aids. With them, power corresponding to any voltage reading can be determined if resistance is known, voltage can be determined if power is known, and the gain or loss in decibels of any equipment can be determined if input and output voltages and resistance can be measured.

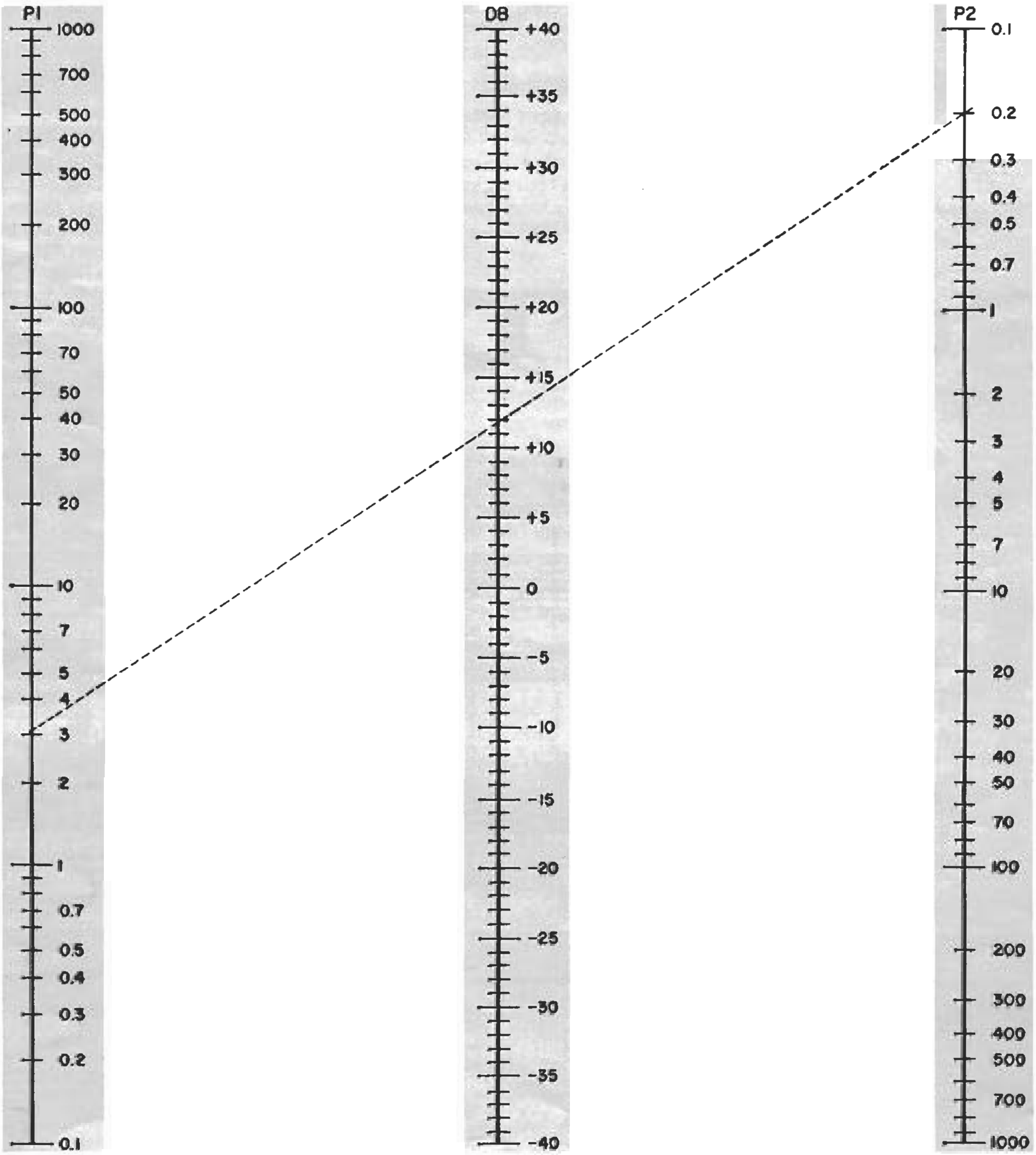
Chart 1 (at the left) is used for voltage-power-resistance calculations. Chart 2 (right) converts power levels directly to decibels gain or loss.

The voltage and resistance scales of Chart 1 bear two sets of graduations, labeled E1 and R1 and E2 and R2 respectively. Scales bearing the same suffix number are used together.

For example, suppose an amplifier is under test. A 10-volt signal applied to the 500-ohm input produces an output measured at 5 volts across 8 ohms.

First, determine input power from Chart 1. The line connecting 10 volts (E2 scale) and 500 ohms (R2 scale) passes through 0.2 watt. Output power is next. This time, the E1 and R1 scales of Chart 1 are used, yielding an answer of 3.1 watts.

Now we turn to Chart 2. Connecting the 3.1-watt output (P1 scale) and the 0.2-watt input (P2 scale) gives a total amplifier gain of just under 12 decibels. ▲



DELTA-Y TRANSFORMATION NOMOGRAM

By A. L. TEUBNER

A triangular connection of resistors (delta or pi) must be converted into a Y or T network in order to apply Ohm's law to the solution of resistive bridge networks. This chart solves the problem graphically.

MANY times a resistive circuit cannot be analyzed by the old standby rules for series and parallel resistances, because it contains a triangle of resistors called a delta or pi network, depending on how it is drawn. A familiar example of this is the so-called bridge circuit shown in Fig. 1 (top left). As the diagram shows, if the delta is transformed to a "Y" (or a pi to a "T"), the resistance between the two external terminals can be found.

This nomogram is designed to make the conversion. The formula on which it is based and which is shown on the chart, can be stated in words as follows: The impedance connected to any terminal of the T-network equals the product of the two impedances connected to *that terminal* in the pi-network, divided by the sum of the three pi impedances.

An example problem is solved on the nomogram to demonstrate its use. The three resistors in the pi circuit are 4,6, and 10 ohms. On the left side of the chart, a line is drawn between 6 ohms on the scale labeled "Z_A" and 10 ohms on the "Z_B" scale, and continued until it cuts the uncalibrated turning line in the center of the nomogram. A second line connects this intersection with 20 ohms on the "S" scale, the sum of the three pi-network resistors. This second line crosses the "Z_1" scale at the 3-ohm graduation. Thus, the terminal which had the 6- and 10-ohm resistors of the pi-network connected to it requires a 3-ohm resistor for the equivalent T-network. The same process is repeated for the other two terminals, giving 1.2 ohms and 2 ohms, as shown.

Several additional details should be pointed out. First, the "Z_A" and "Z_B" scales are interchangeable. In the solution described, the 10 ohms could have been on the "Z_A" scale and the 6 ohms on the "Z_B". Second, to solve problems with larger resistors, multiply all scales by the *same* power of ten. Third, the reverse problem, T to pi, can be solved by the same process if all impedances are first converted to admittances, where Y_i equals $1/Z_i$. The values found are, of course, admittances, and must be reconverted. ▲

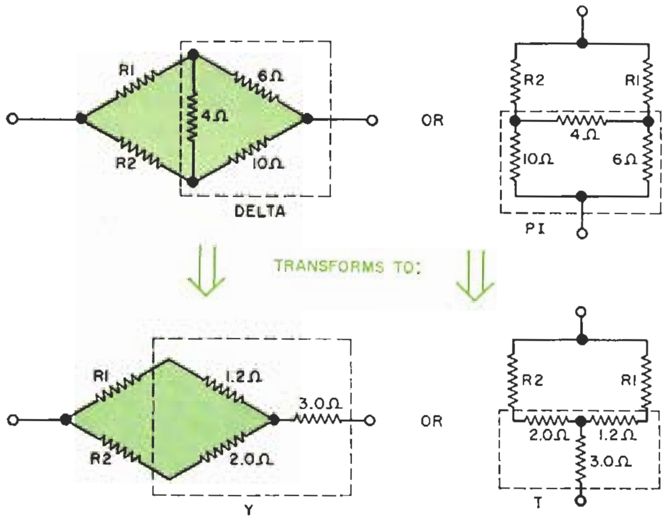
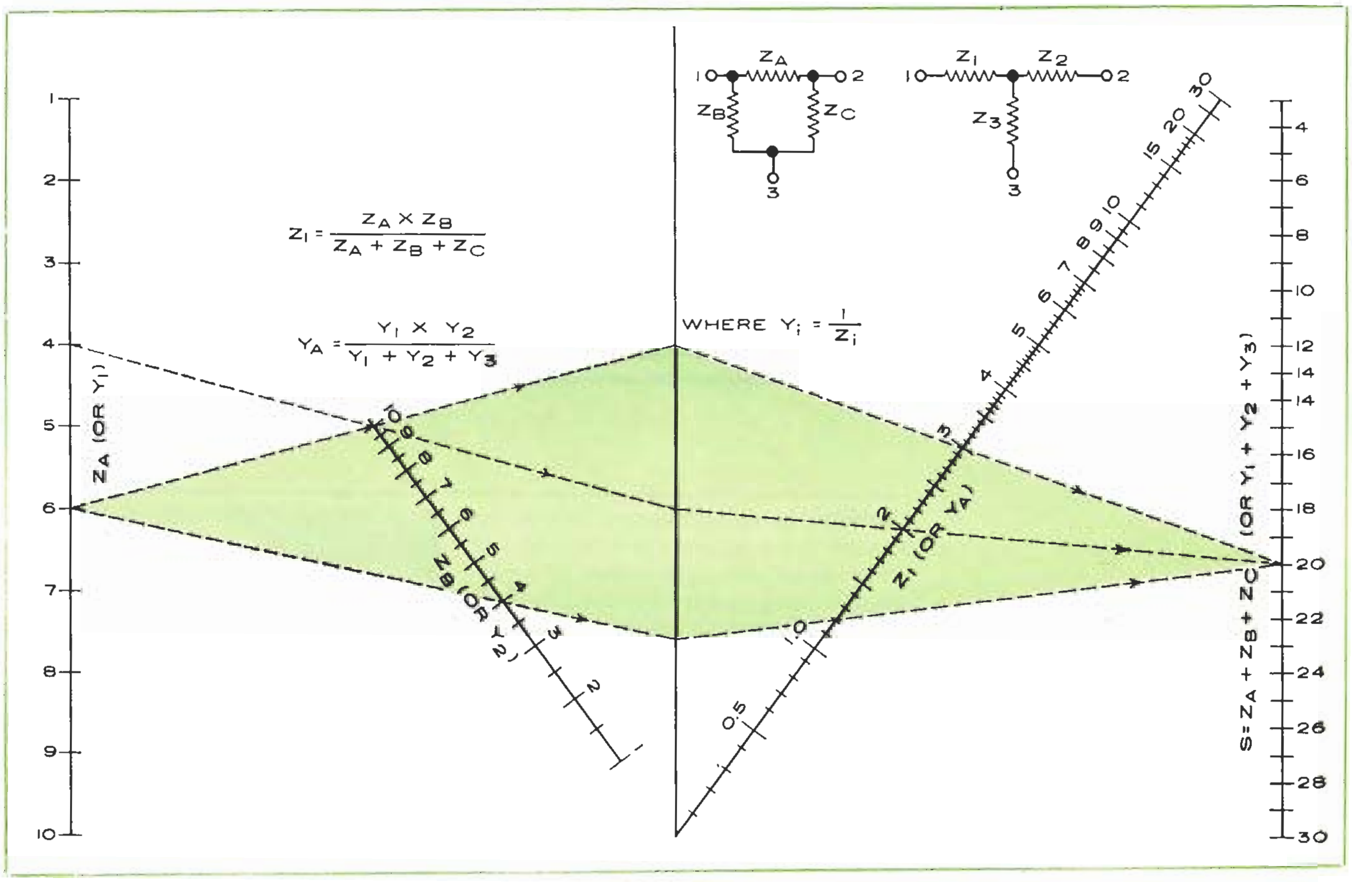


Fig. 1. Example of delta-Y transformation discussed in text.



TOLERANCE CALCULATOR

By ROBERT K. RE

Useful chart that can be employed to determine plus and minus values of a number within the tolerance limits of +100% to —75%.

MANY times during circuit testing and troubleshooting it is necessary to compute the tolerance of a component or parameter to determine if it is within limits. Specified, usually, as a per-cent of a nominal value, these calculations require the use of a slide rule or pencil and paper, in addition to taking up valuable servicing time.

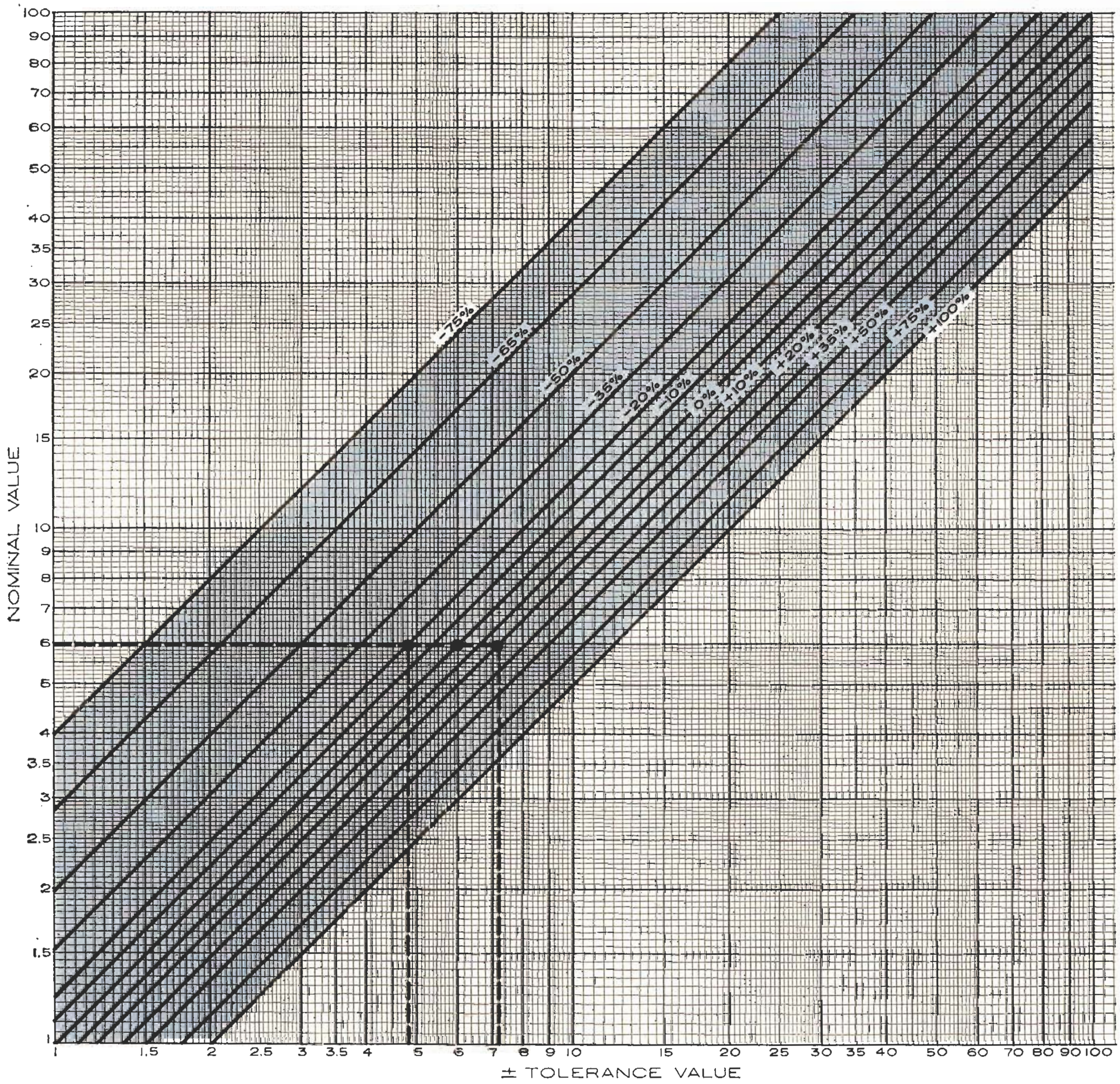
This tolerance calculator can minimize the time required for calculations giving the plus and minus values of a number within the tolerance limits of +100% to −75%.

Using the Graph

To use the calculator, find the number on the "Nominal Value" scale and go across to the ± % tolerance line desired. Drop down to the "Tolerance Value" scale and read the ± tolerance value. Thus the number 60 ±20% has tolerance limits of 48 and 72; this can apply to 6000 ohms, 600 kc., 0.6 mhy., $6.00, or just about any type of parameter or component value you may come across.

Don't worry about the decimal point: if you start out in kilohms, your answer will be in kilohms; if you start out in μf., your results will be in μf. (or their fractional parts).

Mounted on the wall near your bench, this calculator will always be ready to give you those tolerance values you require to help speed that servicing job. ▲



Useful nomogram for technicians, experimenters, and servicemen simplifies parallel-R, series-C problems.

By JIM KYLE

PARALLEL-RESISTOR CHART

TECHNICIANS, experimenters, and servicemen often find it necessary to determine the resistance of two or more resistors in parallel. While this can be done by using the classic sum-of-the-reciprocals formula: $1/R_T = 1/R_1 + 1/R_2 + \dots\dots\dots + 1/R_n$, the arithmetic involved frequently becomes cumbersome.

The more widely used formula $R_T = (R_1 \times R_2)/(R_1 + R_2)$ suffers the same drawback, when applied to standard resistance values, as anyone who has tried multiplying 39 by 18 and dividing the product by 57 knows.

This chart was designed to give a rapid answer to such calculations. In addition, it can be used to determine the value resistor which must be added in parallel with an existing component to reduce the total resistance to a specified amount—a procedure which becomes complex when standard formulas are employed.

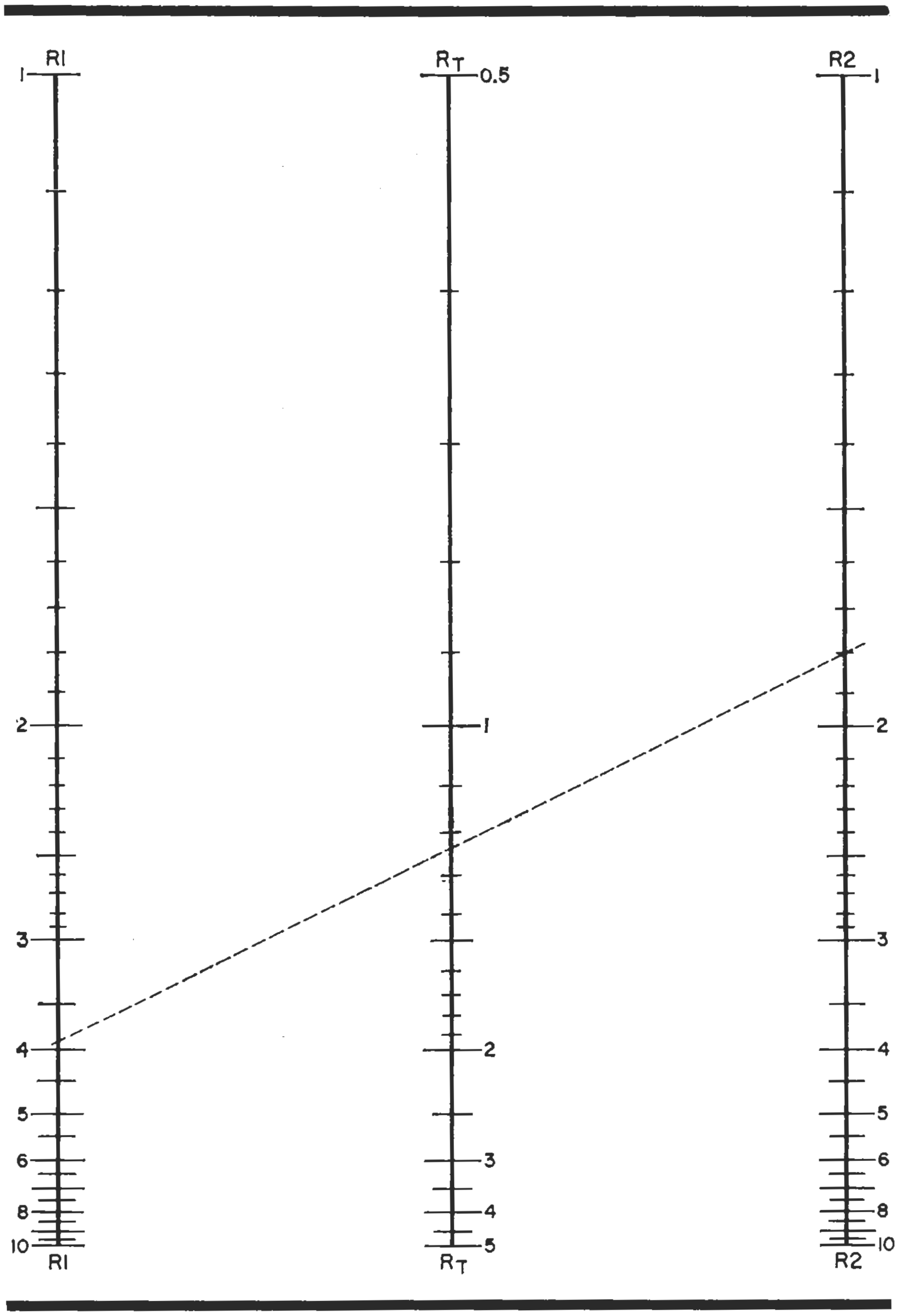
Using the Chart

To use the chart, draw a straight line from the value of *R1* to the value of *R2*. This line will cross the R_T scale at the value of total resistance. Note that all values have been normalized to the range from 1 to 10 to make the chart universal. You can multiply or divide the values given by 10, 100, 1000, etc. as needed.

For example, the total resistance obtained by paralleling a 39-ohm resistor with an 18-ohm resistor is 12.3 ohms, as shown by the dashed line on the nomogram.

If you want to find out what size resistor to use to reduce an existing resistor's value to some specified amount, draw a line from the existing value on *R1* through the desired final value on the R_T scale and read the value of the resistor that is to be added from the *R2* scale.

In addition to its uses with parallel resistors, the chart can be used without change to determine series-capacitor problems, since the same formulas apply. Simply replace the "R" symbols mentally with "C" and proceed as described above. ▲



parallel resistance calculator

By **M. A. HAMMOND**

A choice of the possible pairings that make up the value desired can be read off without calculation.

ANYONE who needs to make up a resistance value from what is on hand will find this chart useful. Series pairs can be worked out with mental arithmetic. Parallel pairs, especially when a choice of possibilities is wanted, involve time-consuming calculation. The chart quickly reveals the range of pairings, in EIA values, that equal or approximate the desired resistance.

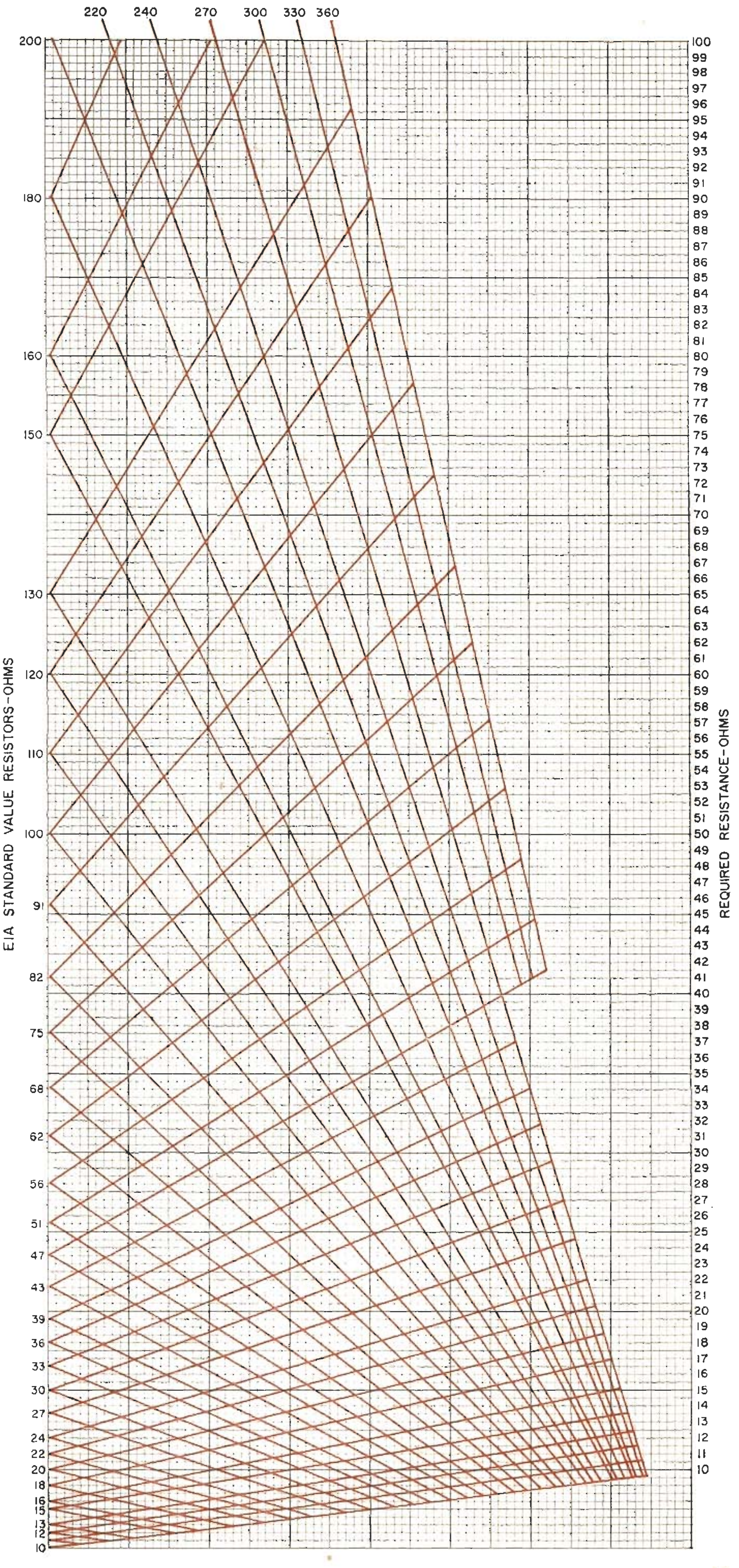
Starting with the needed value on the right-hand scale, read horizontally to the left until a point is reached where two diagonals intersect. Following each diagonal to its termination on the left reveals the two resistors required. For example, assume that 35 ohms is sought. A pair of intersecting diagonals on the 35-ohm line lead to 51 and 110 ohms.

Precision requirements and tolerance variations permit some flexibility in matching pairs. Thus other points of intersection close to the 35-ohm line yield such additional pairings as 43 and 200; 43 and 180; 47 and 130; 56 and 91; and 62 and 82. The least accurate combination is within 3 per-cent.

For values higher than those shown, add the necessary number of ciphers to the significant figure on the right; then add the same number of ciphers to each figure read on the left. Thus 350 ohms is obtained with 510 and 1100 ohms. However, only pairs in the same decade can be read. For example, parallel resistance for 330 and 330,000 ohms is not given.

Other uses: the parallel value of two known resistors is found by following their respective diagonals from the left until they intersect. It is also possible to find the value of a shunt for a given resistor to reduce it to a desired value: trace the diagonal for the given value to its intersection with the horizontal line for the desired value. Then find another diagonal that comes close to intersecting this point.

The author originally published another version of this calculator, based on preferred-value resistors used in England, in "Wireless World." This version has been adapted to EIA values and expanded. ▲



Nomograph shows bandwidth for specified pulse shape

by Franc E. Noel and James S. Kolodzey
IBM Corp., Poughkeepsie, N.Y.

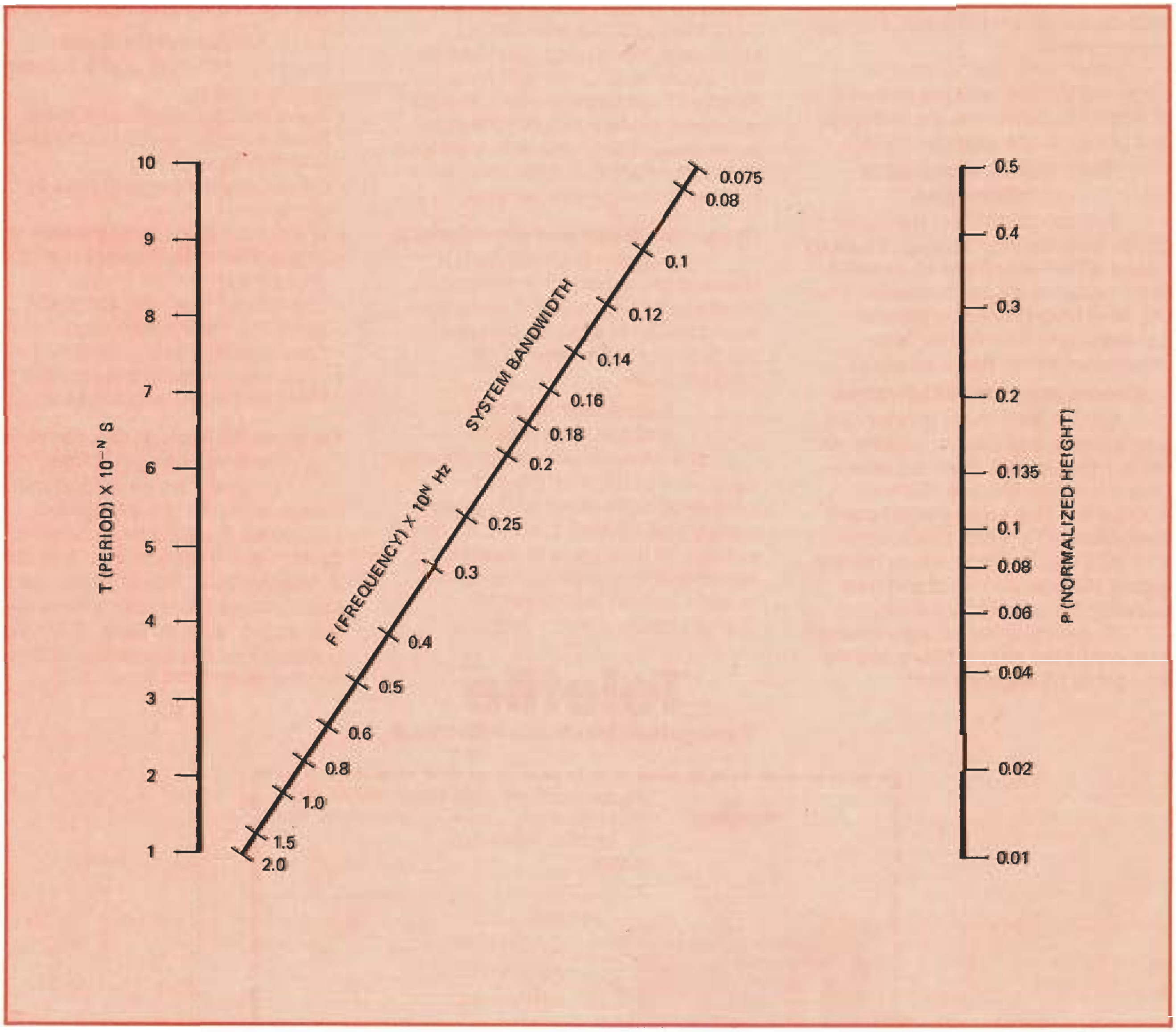
In a digital communications system, the bandwidth of the transmission channel determines the sharpness of a received pulse. For a communication channel where the received pulses may be treated as gaussian wave shapes, the system bandwidth required for a specified pulse shape is:

$$F = (2/\pi T)[2\ ln(1/P)]^{1/2}$$

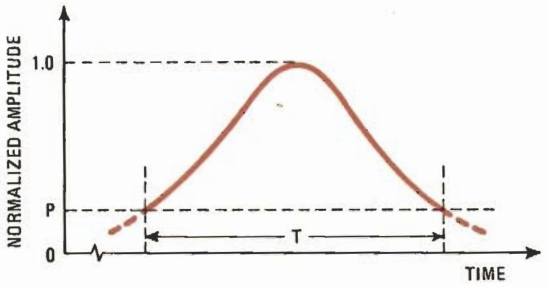
where, as in Fig. 2, T is the width of the time slot, P is the normalized height of the gaussian pulse at the ends of the time slot, and F is the 2σ bandwidth of the channel, where σ is the standard deviation of the pulse. The bandwidth that is given by this expression contains 95.45% of the pulse power.

The choice of the 2σ point is an arbitrary decision based on the fact that the frequency spectrum of the gaussian pulse is down 8.7 decibels at this point. Therefore, a linear system with a bandpass flat to this point provides a reasonable reproduction of the time-domain pulse.

The bandwidth required to pass a particular pulse is



1. How wide the band? This nomograph shows the bandwidth F that contains over 95% of the energy in the spectrum of a gaussian pulse, where the duration of the pulse is T and the normalized amplitude of its end points is P (as shown in Fig. 2).



2. Pulse parameters. Time-domain representation of gaussian pulse shows normalized amplitude P at edges of time slot T. A low value for P gives low spillover into next slot, and therefore low error rate, but requires large bandwidth in transmission system.

given by the nomograph in Fig. 1. The values of the time slot, T, and normalized amplitude desired at the ends, P, are connected with a straight edge to determine the frequency axis crossover. For example, a time pulse that is down to $1/e^2$, or 0.135, at the edges of a 12.5-nanosecond time slot can be passed with a system bandwidth of 102 megahertz. □

Amplifier Power Output for Different DC Supply Voltages