A Simple Approach to Complex Circuits

Networks with resistance, capacitance and inductance in various series and parallel combinations are sometimes called "complex" circuits by engineers. Maybe that's because those engineers want to impress you with their knowledge, for complex in this case does not necessarily mean complicated.

By Jerry Hall,* K1TD

It was a bright, sunny weekend afternoon, and Gus was taking advantage of the nice weather by washing the family car. He had the 2-meter mobile rig turned on and was listening to the conversation going on through the local repeater as he sponged and hosed away. "Interesting," he mused to himself. "Most of those fellows on there are ones I got started in ham radio. I gave all but one or two of them their Novice tests. And now some of them even have two-letter calls." Suddenly his thoughts were interrupted as his wife shouted out the back door, "Gus! Telephone!"

Inside the house he learned it was Jack, the new Novice a few blocks away. Jack was studying diligently for his General test.

"I'm not sure I understand some of the questions in the study guide about parallel circuits. Can we get together sometime soon and go over them?"

"Sure, Jack, how about later this evening?"

"Fine! I'll see you after supper."

Jack arrived that evening with his study guide. He and Gus sat down at the dining-room table. Gus had a pad of paper and a collection of freshly sharpened pencils waiting in readiness.

"First," he said, "let's review what you know about circuits with just resistors. They're easier to understand than when you have inductors and capacitors too."

"Right," Jack agreed.

"What if you had two 500-Ω resistors in series? What would the equivalent value be?" As Gus asked the question he drew out the circuit shown at the left in Fig. 1A.

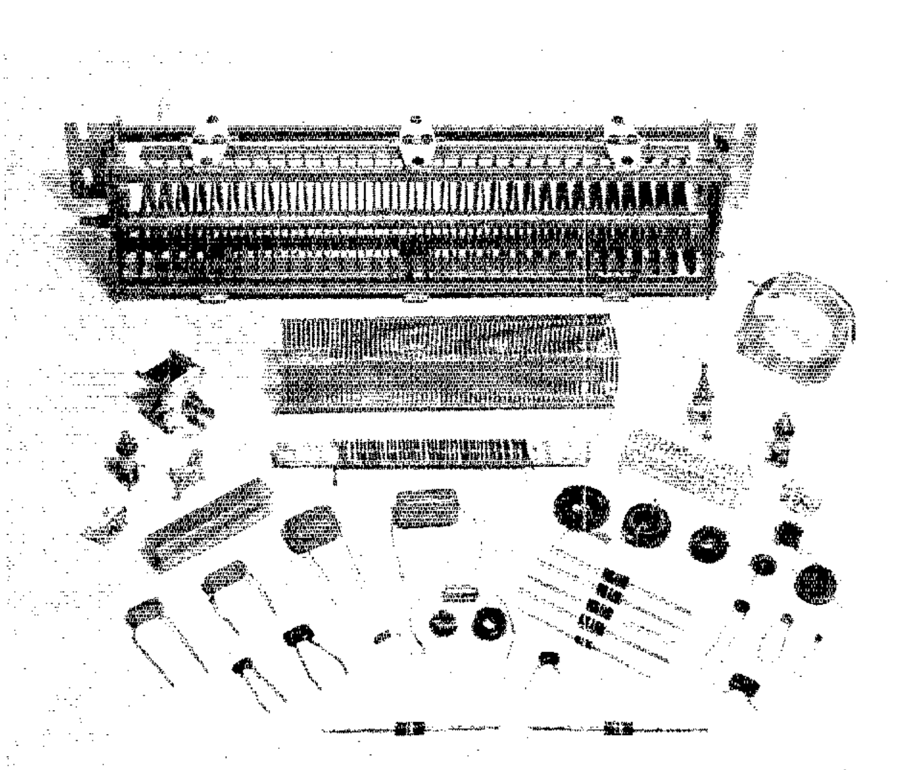
"That's easy, Gus. You'd have 1000 Ω."

"Right. Now, what if you had three 500-Ω resistors in series?"

"That's easy too; 1500 Ω."

"Okay, now let's try some practical values. What if you had three resistors in series? One is 2700 Ω, one is 5600, and one is 3900."

Jack reached for the pad of paper and a pencil and began adding up those three numbers, 2700, 5600 and 3900.



Resistors, capacitors and inductors come in all sorts of sizes and shapes. That big thing at the back in this photo is a variable capacitor, and just in front of it is a large inductor. These two components are typical of those you'll find in a matching network for an amateur hf antenna where the legal power limit is being used. On parade in the foreground is an assortment of other "complex" circuit components.

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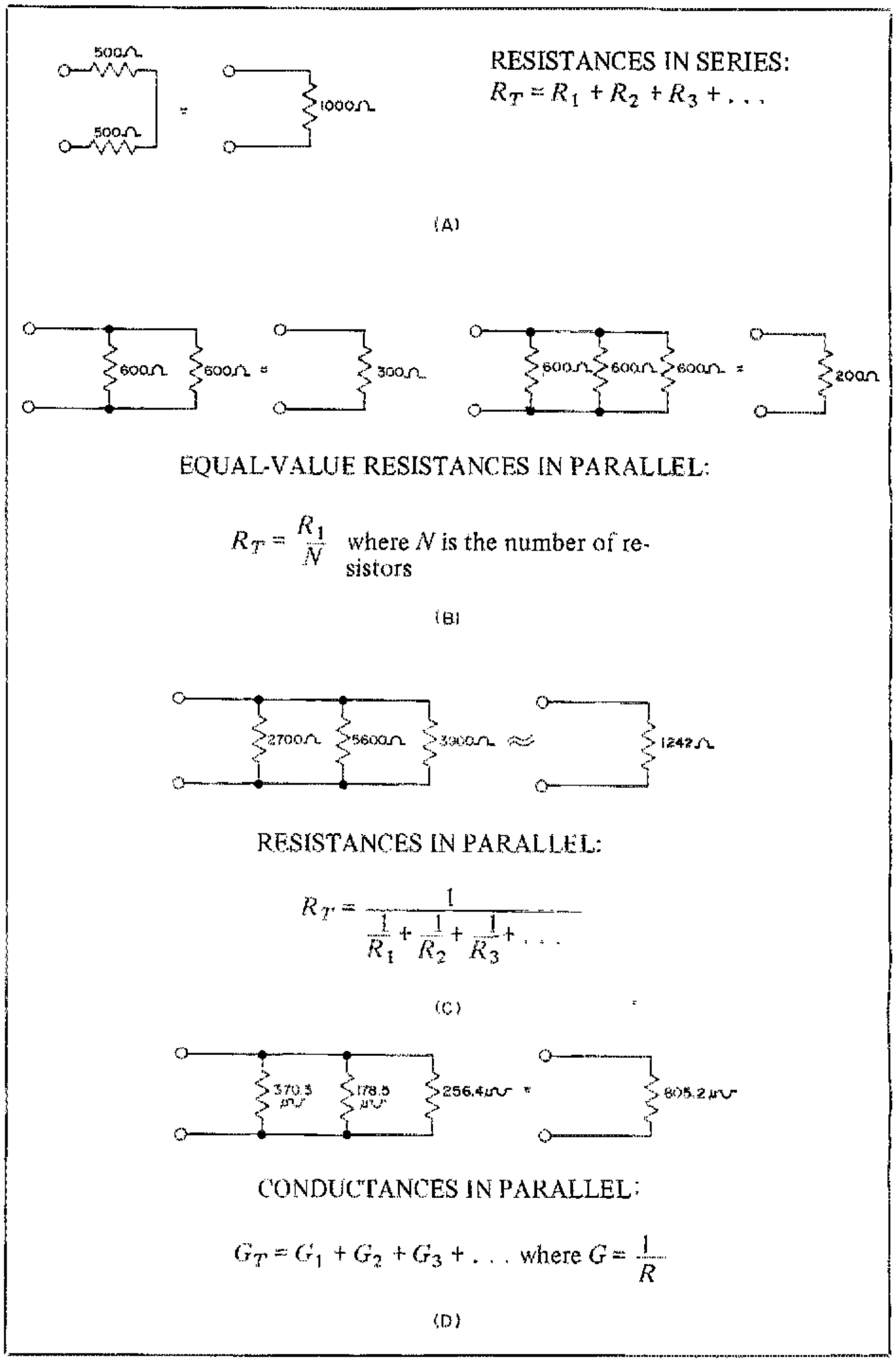


Fig. 1 — Circuits with resistance only. Equivalent resistance values (R_T) may be calculated for the type of circuit by using the appropriate equations. Parallel resistances can be handled easily if they're converted to conductances, as shown at D and as described in the text.

"You'd have 12,200 Ω."

"How'd you get that answer?" Gus asked, testing Jack.

"I just added up the three resistance values. That's right, isn't it?"

"Sure it is! I just wanted you to realize you're using a little mathematical equation. Are you telling me this is how you figure the equivalent total resistance when you have several resistors in series?" Gus asked as he wrote down the equation in Fig. 1A.

"Yep, that's what it says in the *Handbook*." He knew from Gus's smile that he was right.

"Okay, fine. Now how about resistors in parallel? What if you had two 600-Ω resistors in parallel? What's the equivalent value?" Gus drew out the circuit at the left in Fig. 1B as he asked this question.

Jack knew that one right away, too. "It'd be 300 Ω, half of 600."

"Why half?" Gus asked.

"Because there are two resistors," was Jack's reply.

"What if there were three 600-Ω resistors in parallel, like this?" and Gus drew the right-hand circuit in Fig. 1B.

"You'd have 200 Ω, a third of 600."

"One third because there are three resistors?" Gus asked.

"Yes, I think I read that somewhere," Jack said.

"That's right," Gus assured him. "Any time you have resistors of equal value in parallel, you can figure the equivalent resistance by dividing the value of one resistor by the number of resistors," and with that he jotted down the equation shown in Fig. 1B. "But what if they're not equal? Let's take those values we used a moment ago and see what we'd have if they were in parallel. That was 2700, 5600, and 3900 Ω," said Gus as he drew the circuit shown in the left of Fig. 1C.

Jack reached for the pad again and manipulated the pencil. After making a bunch of pencil marks, he scratched out what he's just done and started again. Later he scratched that out, too. Sheepishly he reached in his pocket and extracted a little 4-function electronic calculator. "You gotta use reciprocals to figure this one out," he explained, "and I'm not so good at doing them by hand."

"What's a reciprocal?" Gus asked, pretending he didn't know.

"That's when you divide a number into one," Jack said confidently. With his calculator he punched 1 ÷ 2700 = and the display showed 0.0003703. He jotted that down on paper. Similarly he divided 1 by 5600 and 1 by 3900 and jotted down those numbers, 0.0001785 and 0.0002564. Then with the calculator he added up the three numbers and jotted down the answer, 0.0008052. Next he divided 1 by that answer. "You'd have just under 1242 Ω," Jack exclaimed triumphantly.

"That's right!" Gus agreed as he came up with the same information on his more expensive calculator. Then Gus said to Jack, "Can you write down an equation for what you just did to get that value?" Jack correctly wrote the equation shown in Fig. 1C. "Good," Gus exclaimed.

And he added, "Here, Jack, let's try something with your calculator. If yours has a feature called an automatic constant, you won't have to punch in the 1 each time you take a reciprocal." On Jack's calculator he keyed in 2700, and then in sequence he keyed ÷ = =. After the equal-sign key was pressed the first time, a 1 appeared on the display, but after the second time the display immediately showed 0.0003703.

"Wow!" Jack exclaimed. "How'd you do that?"

"You can save yourself a lot of work when you're doing reciprocals," Gus told Jack, handing back the calculator. "Anytime you have a number in the display that you want to take the reciprocal of, just punch ÷ = =. It won't work on every calculator, but if yours doesn't have a reciprocal key it's worth a try to find out."

Conductance

"Now, Jack, can you tell me what those numbers are that you just jotted down on the paper?"

"Sure, those are the reciprocals of the resistor values."

"Yes, that's true, but there's another name for them. Those are conductance values."

"*Conductance!* What's that?" cried Jack.

"You just said it," Gus stated. "Conductance is the reciprocal of resistance. You know we use the letter *R* to represent resistance in a circuit or an equation, and we use the Greek letter Ω (omega) as the abbreviation for ohms. You probably wouldn't know it yet, but we use the letter *G* to represent conductance. And conductance is measured in mhos. Mho is ohm spelled backward. Jack, what symbol do you suppose we use for mhos?"

"1/Ω?"

At this reply Gus chuckled. "Not quite, but you're certainly logical. We really use an upside-down omega, but usually on drawings only. Most typesetting systems don't have an upside-down omega, so you see the word *mho* spelled out in print, rather than abbreviated."

"Strictly speaking," Gus went on, "resistance and conductance are reciprocals of each other *only when you're talking about parallel circuits*. It doesn't work out quite the same way when you have series circuits. And the mho is a pretty big unit of measure, something you wouldn't run into unless you had parallel resistances of less than one ohm. Mostly you'll see millimhos (mmhos) and micromhos (μmhos) whenever they're used. Now let's take a look at those numbers you just jotted down."

"Oh, I think I see," Jack interrupted. "This 0.0003703; that's really mhos?"

"Sure is. Most likely that value would be converted to 370.3 μmhos, by moving the decimal point six places to the right."

"Oh! And these other two would be 178.5 and 256.4 μmhos?"

"Right."

Jack thought for a moment and then frowned. "I understand what mhos are, but what *good* are they?"

"Well, look at it this way," explained Gus. "See how easy you figured out the equivalent resistance when you had several resistors in series. You just added up the individual resistance values and got the total resistance. Okay, when you have resistors in parallel, it's just as easy with conductance. You just add up the individual conductance values to get the total conductance." In saying this, he drew out the circuit shown in Fig. 1D. "See, these three values add up to 805.2 μmhos, which is just what you did with your calculator there."

"Oh, I get it," Jack exclaimed. "You're saying to use resistance when I'm working with series circuits and conductance when I'm working with parallel circuits."

"Right on! And the same idea applies when you have complex circuits. That's what circuits with resistors, inductors and capacitors are usually called, complex circuits. If you remember this little tip it'll simplify your calculations a lot . . . ohms for series circuits, mhos for parallel."

Reactance and Impedance

"Now let's talk about those so-called complex circuits. A complex circuit has a property we call *impedance*. Jack, can you tell me what impedance is?"

"Sure, that's what you get in a circuit with resistance and reactance."

"Correct," exclaimed Gus. "Now, what's reactance?"

"Uh . . . well — I sort of know, but I don't know how to explain it."

"Okay," said Gus with a smile. "I'll explain it for you. Reactance comes from circuit elements that do not absorb any power. Remember, Jack, only resistances can absorb power. Now, I'll bet you know what kinds of circuit elements I'm talking about."

"Inductors and capacitors?" Jack asked cautiously.

"Right! They used to be called coils and condensers, and sometimes you still hear those words. But the modern words are inductors and capacitors. You know that inductance is measured in henrys, and we use the letter *H* as the abbreviation for henrys."

"And we use the letter *F* for capacitance," chimed in Jack, "because capacitance is measured in farads."

"You *have* been reading the *Handbook*, haven't you Jack! Then of course you know that a farad is a very big unit, and the capacitors we use in ham radio are measured in microfarads, abbreviated μF, or else picofarads, abbreviated pF. And inductors for audio and rf work are usually measured in millihenrys (mH) and microhenrys (μH).

"At ac and rf," Gus went on, "inductors and capacitors have this property we call reactance. Like I said, reactances don't absorb any power, but in a circuit they can prevent some of the available power from being transferred to the resistance. And it doesn't have to be a circuit on a chassis or a circuit board, either. An antenna behaves like an electrical circuit."

"Oh! Like my antenna before you helped me cut it to the right length. My SWR was high and you said the antenna had reactance."

"That's right," Gus said. "That reactance wasn't absorbing any power, but it did prevent some of the power from being 'absorbed' or transferred to the radiation resistance of the antenna. That unradiated power went back down your feed line and that's why your SWR was high — higher than your transmitter could handle.

"Reactance is measured in ohms, just like resistance," Gus continued. "It is important to remember that for any inductor or capacitor, its reactance depends on the *frequency* you apply to it. The letter *X* is used for reactance, and usually there's a subscript letter *L* or *C*, X_L for inductive reactance and X_C for capacitive reactance. There are a couple of equations that you should memorize for figuring out reactance, because you'll be using them so often." And Gus wrote them down on a sheet of paper as he explained, "In these equations X_L and X_C are in ohms, *f* is the applied frequency in hertz, *L* is the inductance in henrys, and *C* is the capacitance in farads.

$$\text{Inductive reactance} = X_L = 2\pi fL \qquad \text{(Eq. 1)}$$

$$\text{Capacitive reactance} = X_C = \frac{1}{2\pi fC} \qquad \text{(Eq. 2)}$$

"Now, Jack, suppose we had a series circuit with a resistance and a reactance," and he drew out the circuit shown in Fig. 2A. "Do you know what the impedance of that circuit would be?" Jack scratched his head thoughtfully but said nothing. So Gus proceeded to draw out a little triangle, like that in Fig. 2A. "Here," he said, "this right triangle represents the circuit values. We'll let the base represent the value of *R*, 40 ohms, and the side represent the *X*, 30 ohms. Now the hypotenuse, this diagonal line, represents the overall impedance. We use the letter *Z* to represent impedance."

"I know," Jack exclaimed. "The impedance is the square root of R^2 plus $X_L{}^2$." He didn't even need his calculator to come up with 1600 plus 900 = 2500, and he recognized in his head that the square root of 2500 was 50.

"Yep, 50 is right," said Gus as he wrote down the equation Jack had just worked out, shown in Fig. 2A. "There's another way you can write it, too," and he added $= R + jX_L$ at the end of the equation he had just completed. "This is a kind of shorthand way of writing it. That little *j* in there is an *operative* function. Don't let it shake you up. All it means is that you do what's called a vector addition, like in the right triangle, rather than straight addition. You

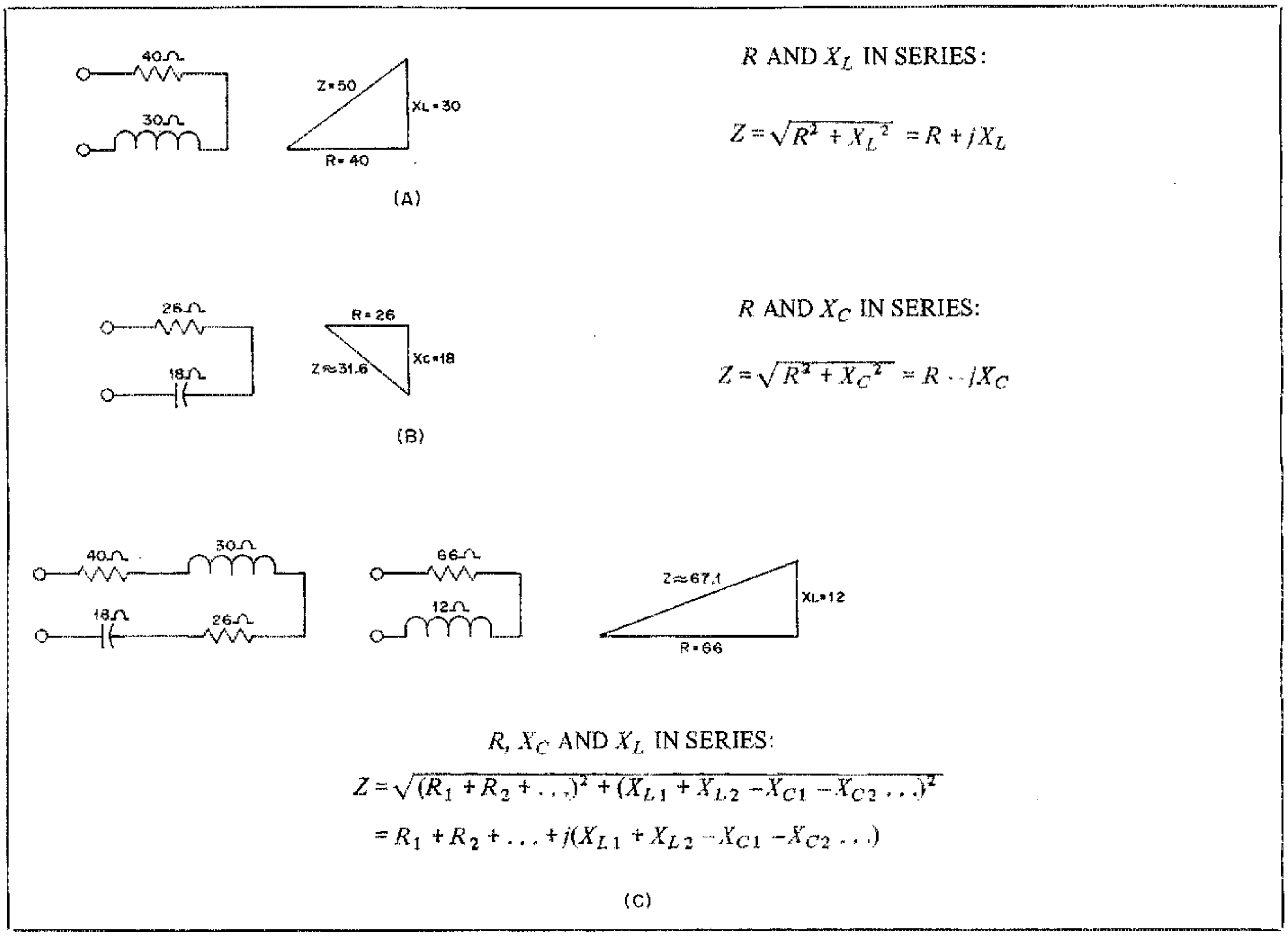


Fig. 2 — Series circuits using *R, L* and *C.* The overall impedance of the circuit, *Z*, can be found from the appropriate equations. The *j* in the equations is an operative function, a shorthand way of saying, "Don't add apples and oranges."

know that 40 + 30 = 70, but like you just figured out, 40 + *j*30 = 50. That's all the *j* means. It's telling you you can't add resistive ohms to reactive ohms directly, 'cause that'd be like adding apples and oranges. If you had a calculator like mine that worked trig functions, you could solve this kind of problem directly, but you can still do it with yours. Let's try another one," and Gus drew out the circuit shown in Fig. 2B.

With his little calculator, Jack squared the two numbers and added them; $26^2 + 18^2 = 676 + 324 = 1000$. Here he was stuck, for he didn't know the exact square root of 1000 and his little calculator wouldn't help him much unless he wanted to try several guesses and check each guess with the calculator. Hoping to satisfy Gus he stated proudly, "The impedance of that circuit is the square root of 1000."

Gus smiled and wrote down this little equation for Jack.

To solve for square roots, $\frac{A^2 + n}{2A} = B$ (Eq. 3)

"Here, use this to find out with your 4-function calculator what the square root of 1000 is. The *n* is the number you want the square root of, 1000, and the *A* is your guess as to about what the square root might be. This will give you a value for *B* which will be closer than your guess of the square root. You can put this value back in the equation for *A* and come up with an even closer number. Usually a couple or three times through the equation will give you the value for the square root as near as you'd want it."

With this, Jack took 30 as his guess for *A*, knowing that 30^2 was 900, not far from 1000. Plugging 1000 into the equation for *n* and 30 for *A*, he came up with a value for *B* of 31.666666, which he jotted down. Squaring this number to see how close it was to 1000, he decided to work through the equation again, substituting the 31.666666 for *A*. He already had A^2 on the display of his calculator, since he had just squared the value to check its accuracy. From there he merely added 1000 and divided by 2*A* in chain fashion to get 31.622804. Squaring this, he found the result was very close to 1000, so he beamed broadly as he told Gus, "It's 31.6 ohms."

"A+ for you," said Gus, grinning.

While Jack had been figuring out the square root of 1000, Gus had drawn out another little triangle to represent this circuit, shown at B in Fig. 2. Again he used a horizontal line to represent *R*, but this time he drew the reactance line down instead of up from the end of the resistance line. "By convention we say that inductive reactance is positive, and capacitive reactance is negative. That way, if we're solving an equation for the value of a reactance, we know by the positive or negative answer whether it's inductive or capacitive. Let's see how that works out. What kind of impedance would we have if we put the two circuits we just talked about in series?" And here he drew out the circuit shown at the left in Fig. 2C.

"Do you still add up the values of the resistors to get the total equivalent resistance?"

"That's right."

And with that, Jack drew out the beginnings of an equivalent circuit, saying "40 + 26 = 66 Ω." And after a moment of thought he said, "Can you add the reactances together directly?"

"Yes, you can, but don't forget to use plus and minus signs like I just told you."

"I get it!" Jack said excitedly. "There's 30 Ω inductive; that'll be positive. And 18 Ω capacitive; that'll be negative. Let's see, 30 plus a negative 18 is 30 minus 18. That's 12, and it's positive. Does that mean there'll be 12 Ω of inductive reactance in the equivalent circuit?"

"Yes, that's exactly what it means."

Jack then completed the drawing he had started, shown in Fig. 2C. From there it was easy for him to draw out the little triangle Gus asked him to do, and with his calculator he computed the overall impedance to be approximately 67.1 ohms.

"Here are the equations for what you just did," Gus said, writing down those in Fig. 2C. "They look more complicated than they really are, but just because I'm showing that you can have more components that we did in our circuit. Do you have any questions about impedances?"

"No, I think I've got it pretty straight. Impedances are made up of resistances and reactances, and the reactances can be either positive (inductive), or else negative (capacitive)."

"Perfect! You've got it!"

Admittance = Conductance + Susceptance

"But we haven't talked about parallel circuits with reactance yet, and that's what I came over here for."

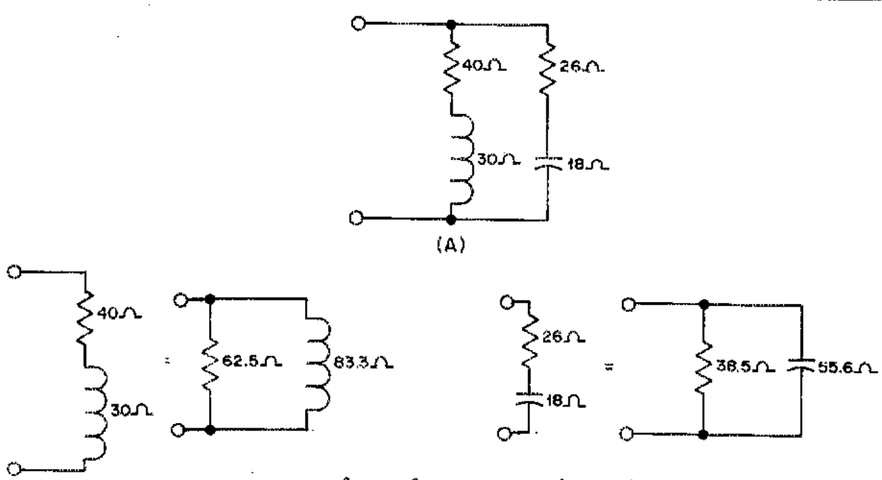
"Okay, Jack. Let's try this one. Suppose we took those two complex circuits we just had, 40 + *j*30 and 26 − *j*18, and connected them in parallel. That might be the kind of a situation we'd have if we tied the feed lines of two antennas together with a T connector at the back of the transmitter. What kind of a load would the transmitter see? Here's what the circuit would look like," Gus said, drawing out the diagram of Fig. 3A.

Jack looked at the drawing at length. Finally he confessed, "Gosh, Gus, I don't even know where to begin."

"Remember what I said a bit ago? Ohms for series circuits and mhos for parallel circuits."

"Yes, I remember, but here we've got two series circuits in parallel with each other. What do you do about that?"

"Well, you can handle it any of several ways. You can convert each series circuit to its parallel equivalent, and then convert the values to conduc-



$$R_p = \frac{R_s^2 + X_s^2}{R_s} \qquad X_p = \frac{R_s^2 + X_s^2}{X_s}$$

$$Z = \left| \frac{R_p X_p}{\sqrt{R_p^2 + X_p^2}} \right|$$

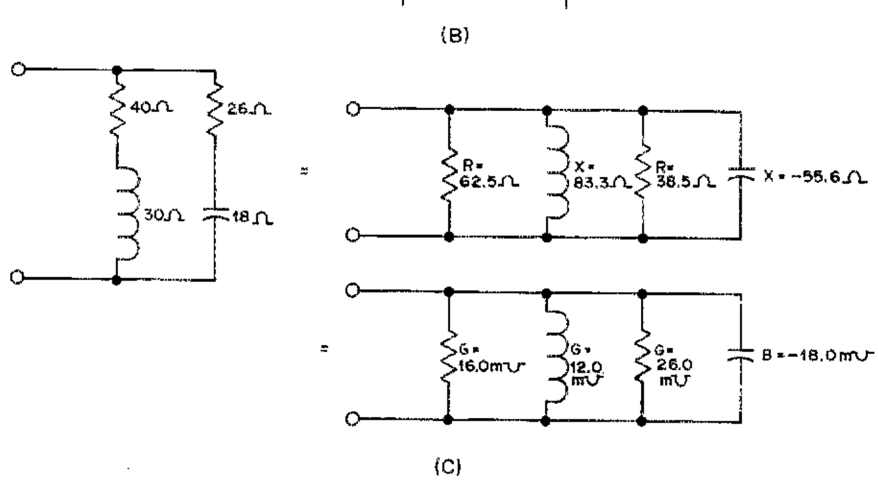


Fig. 3 — "Complex" circuits using values of *R, L,* and *C* in combinations of series and parallel circuits. Series circuits using several components may first be converted to a simple series equivalent, as shown in Fig. 2C, and the result may be converted to a parallel equivalent, as shown here at B. (The subscript, *s*, indicates series-equivalent values, and *p* indicates parallel-equivalent values.) The circuit at A is equivalent to those shown to the right of the equal signs in C.

tance and susceptance to figure out the overall admittance, or you can . . ."

"*Wait* a minute Gus. You lost me on that one! You've explained conductance, but what are those other things you're talking about, susceptance and what?"

"Admittance. Admittance is the reciprocal of impedance, or $1/Z$. We use the letter Y to represent admittance. And you just told me that impedances were made up of two kinds of components, resistance and reactance. In the same way, admittances are made up of two kinds of components, conductance and susceptance. Power is consumed in the conductances, but the inductors and capacitors which make up the susceptances don't consume any power."

"And you said admittance is the reciprocal of impedance?"

"That's right."

"And earlier you said conductance was the reciprocal of resistance?"

"That's right, too, as long as you're talking about resistors in parallel with all other components."

"Then is it true to say that susceptance is the reciprocal of reactance?"

"Yes, it certainly is," Gus stated emphatically, "as long as you're talking about a circuit having all components in parallel. By convention, all engineers used to change the sign as well as take the reciprocal, so that inductive susceptance was taken as negative and capacitive susceptance was positive. But now they're getting away from that convention, and take inductive reactance *and* susceptance as positive, capacitive reactance *and* susceptance as negative. I'm going to use the new style in what I show you. Either is okay, as long as you know which you're using."

Jack nodded his head in agreement but had a very puzzled look on his face.

Gus took the cue and went into some further explanation. "I was just about to tell you that we use the letter B to represent susceptance. Let's write out some equations showing everything I've just told you about admittance."

$$\text{Admittance} = Y = \frac{1}{Z} = \frac{1}{R + jX} = G + jB \qquad \text{(Eq. 4)}$$

"And for components in parallel"

$$\text{Conductance} = G = \frac{1}{R} \qquad \text{(Eq. 5)}$$

$$\text{Inductive susceptance} = B_L = \frac{1}{X_L} \quad \text{(positive)} \qquad \text{(Eq. 6)}$$

$$\text{Capacitive susceptance} = B_C = \frac{1}{X_C} \quad \text{(negative)} \qquad \text{(Eq. 7)}$$

"I don't think I understand all this," Jack admitted.

"We'll come back to it. Let's return to this circuit we were going to figure out." (See Fig. 3A.) "You know that each series circuit has a parallel equivalent – a circuit with different parallel values that behaves exactly the same way as the series circuit. Let's take just this 40 + j30 part of the circuit," he said, drawing what is shown at the left in Fig. 3B. "For now we don't know what values to put on the right side of the equal sign, but with these equations we can figure them out." And he wrote out the first two equations shown in Fig. 3B. "The s subscripts indicate components in the series-equivalent circuit, and the p subscripts for the parallel-equivalent circuit."

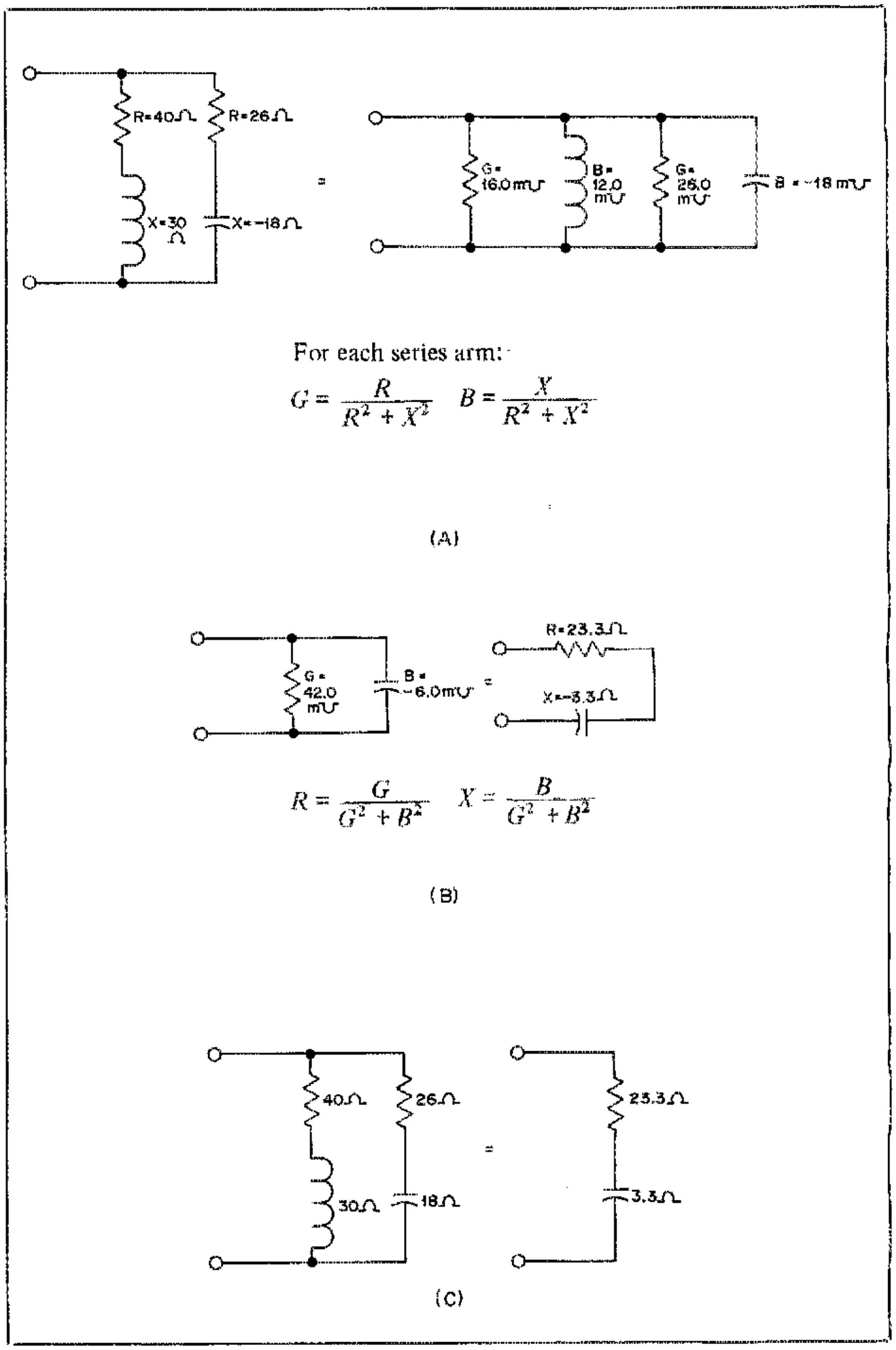


Fig. 4 – Series-equivalent circuits may be converted directly to circuits with conductance and susceptance, as shown at A, and the overall equivalent circuit converted back to a series circuit, as shown at B. If additional parallel arms consisting of a single R, a single L, or a single C each were included in the circuit at the left of the equal sign at A, their values could be converted to conductance or susceptance with Eqs. 5, 6 and 7 (see text). By using appropriate combinations of conversions from above and from Fig. 3, any complex circuit may be broken down into a simple series-equivalent circuit. The original and final equivalent circuits that Jack and Gus worked out are shown at C.

This was all the information Jack needed. Deftly he began punching keys on his calculator and soon he wrote in the values, 62.5 Ω for the parallel resistance value and 83.3 Ω for the inductive reactance. Gus confirmed those values with his own calculator. "Was that hard?" Gus asked.

"No, not after you told me what to do."

"Good, now do the same thing for that 26 – *j*18 part of the circuit." Jack drew the information shown in the right-hand part of Fig. 3B and calculated the values, 38.5 Ω for the parallel resistance and 55.6 Ω for capacitive reactance. Gus's calculations agreed, each of those parallel circuits on the right of the equal signs would perform identically to the series circuits at their left.

"Now," Gus exclaimed, "suppose you knew only the parallel values and wanted to figure the overall circuit impedance. Say we had this 62.5-Ω resistor and 83.3-Ω inductor and wanted to know the overall circuit impedance," he said, pointing to the parallel circuit in the left of Fig. 3B. "How would you figure that?"

"Well, you could convert it back to the series circuit and go from there."

"Yes, you could, but here's a simpler way," and with that Gus wrote down the third equation shown in Fig. 3B. "These vertical lines mean to take the absolute value. In other words, disregard the minus sign if you have capacitive reactance." Jack took the 62.5 and 83.3 values and tried them in the equation Gus had just written out. Finally he came out with the value of 49.99 plus a small fraction. "Pretty close to 50, isn't it? It's not exact because we rounded the values when we went to that parallel circuit. But you remember, 40 + *j*30 = 50. So you see, it checks.

"From here we can take the two parallel-equivalent circuits and put them in parallel with each other," Gus explained as he drew the top two circuits in Fig. 3C. "Now you can begin to see what kind of a load that transmitter would be looking into."

"Oh, yes. Now we can just add up the values for the resistors to get total resistance, and for the reactances to get the total reactance."

"Whoa! Wait a minute! Those are *ohms* there in that circuit. You can't add ohms to ohms and get the right answer unless you have a series circuit! And even then you've gotta keep resistive ohms and reactive ohms separate. Remember *mhos* for parallel circuits! Convert those values to mhos before you start adding."

"Can we just take the reciprocal of each value to do that?"

"Yep, that's how we do it," Gus confirmed, pointing back to Eqs. 5, 6 and 7. With that, Jack again went to work with his calculator and wrote in values for the circuit Gus drew, shown at the bottom in Fig. 3C.

A Simpler Way

"Before you go ahead and add up values, let me tell you about a little simpler way. I just showed you this because sometimes you need to make a conversion from series to parallel circuits using ohms. If you want to convert the other way, you can use these two equations."

$$R_s = \frac{R_p}{1+\left(\frac{R_p}{X_p}\right)^2}$$

$$X_s = \frac{R_s R_p}{X_p}$$

"But here's how you can convert from a series *R* and *X* circuit directly to a parallel *G* and *B* circuit without the intermediate step." He then drew the circuits and wrote in the equations shown in Fig. 4A, but omitted the values on the parallel circuit at the right of the equal sign. He asked Jack to fill them in. Sure enough, the values came out the same as Jack had jotted down earlier (Fig. 3C).

"*Alright*!" Jack exclaimed. By this time he was anxious to know what kind of a load that transmitter would be looking into, so he hurriedly combined the values and drew the circuit at the left in Fig. 4B. All the while he was watching Gus for a sign of any mistake he might be making. But Gus just sat there silently, grinning from ear to ear. "We add 16 and 26 to get 42 millimhos for the *G*s. That's conductance. And 12 plus a negative 18, that's a negative 6 for *B*, so that's capacitive susceptance."

"Right you are. From here you can go either of two ways. Most of us aren't used to thinking in terms of millimhos, so you'll probably want to convert that circuit to ohms. You can either take the reciprocals of *G* and *B* directly and come up with the equivalent parallel circuit, or you can convert directly to the equivalent series circuit with these two equations." He wrote down the equations shown in Fig. 4B.

Jack opted to go for the equivalent series circuit. After punching a few keys and jotting down some numbers, he came up with 23.3 ohms for the resistance and 3.3 ohms for the capacitive reactance. "Is that right?"

"You bet it is. That's the load the transmitter would see at the T connector."

About that time Gus's wife brought in two cups of hot chocolate. While they were sipping that, Gus reviewed what he had explained to Jack. To wrap up the last part, he summarized their calculations by drawing the circuits shown in Fig. 4C, including the values. "Okay, here's the circuit we started with," he said, pointing to that at the left of the equal sign, "and here's the equivalent circuit," pointing to the right.

"Gosh, I didn't know I knew how to do that!"

"Well, you do now. I've showed you a lot more than you'll ever need to know for your General test, but I'll bet if you study these notes you won't have any problems at all with those questions on parallel circuits."

"You know, I bet you're right," Jack agreed, gathering up the notes and his materials. "Goodnight, Gus, and thanks a lot!" QST

Strays

□ The "Father of Radio," Dr. Lee deForest, was recently inducted into the Inventors Hall of Fame at a ceremony held at the U.S. Patent Office, Washington, DC. According to his widow, Marie, WB6ZJR, the award will be displayed at the deForest Memorial Archives in Los Altos, CA, where many of his more than 300 inventions are to be found. Among them are the three-element radio tube called the Audion and electronic sound-on-film. The latter invention earned deForest an Oscar from the Academy of Motion Picture Arts and Sciences in 1959, two years before his death at age 87.

□ Do you realize that if you were operating SSTV moonbounce on an old Hy Gain rig in the Military Affiliate Radio System it is possible to have the following: your signal would go from Venus (SSTV) through the Galaxy (rig) via MARS to the moon and back to earth!! – *Michael Berlin, WB2FIG*

□ The Triangle Amateur Radio Club of East Liverpool, OH, has set up a plan to relay emergency information to the city hospital, through the club repeater which covers a 40-mile radius on 146.7 MHz. Rich Feldman, K8HGY, said the club is capable of sending two-man teams equipped with hand-held rigs to emergency sites. They then relay information to similar teams monitoring the repeater in control centers at the hospital.