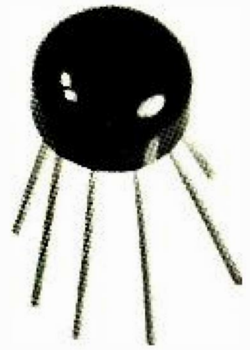


A pair of the new epoxy IC's. Units have eight leads and are about the same size as a TO-5 transistor case.

USING NEW LOW-COST INTEGRATED CIRCUITS

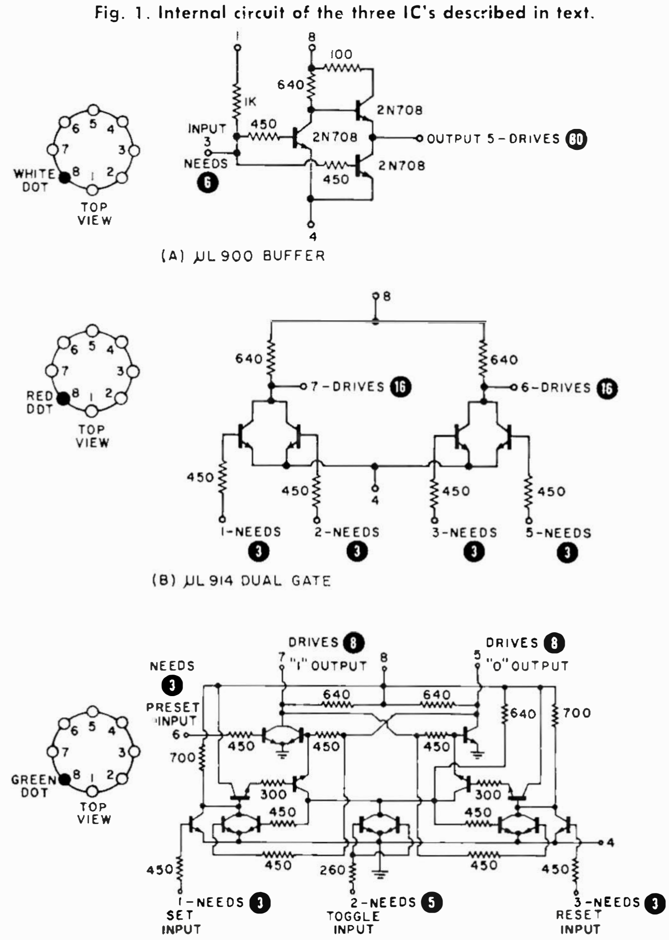
By DONALD E. LANCASTER

Some of the new integrateds have come way down in price and have many uses outside of computers. Here are techniques and circuits for these new IC devices.

THERE are two myths prevailing in regard to today's integrated circuitry. "Too expensive" and "only good for special computer circuits," are the hue and cry of many who simply do not yet realize the tremendous potential of in-stock integrateds applied to everyday circuits.

The facts are the exact opposite. Today there are very few basic circuits that cannot be fully integrated while substantially reducing the total cost, complexity, and assembly time. Improved reliability, temperature performance, and ruggedness are gained in the bargain. For instance, about $1.60 spent at a distributor's will buy the equivalent of three or four 2N708 transistors and five or six resistors, which separately might cost over five dollars, not counting the extra assembly time. For the same price, you also get an all-silicon circuit fully guaranteed and tested to operate over a specified temperature range into fully specified loads. This eliminates a large measure of the normal environmental testing, "burning in" of components, marginal resistance values, and expensive testing.

Fig. 1. Internal circuit of the three IC's described in text.



(A) μL 900 BUFFER

(B) μL 914 DUAL GATE

(C) μL 923 J-K FLIP-FLOP

Of the twenty or so major integrated-circuit (IC) manufacturers, six have widely distributed, low-cost lines. Of these, the epoxy micrologic series of *Fairchild Semiconductor* lends itself well to our purpose of developing a number of basic integrated circuits that can be used for both commercial and experimental purposes. By obvious changes in supply voltages, impedance levels, and pin connections, these same basic circuits are pretty much applicable to other manufacturers' IC lines.

The *Fairchild* series consists of three integrateds packaged in eight-lead epoxy packages, the same size as a TO-5 case transistor. As a family, the units may be directly connected to each other. One supply voltage of +3.6 volts is specified, but any voltage from 3 to 4.5 should suffice for many applications. The latter is easily obtained from two or three penlight cells.

The pin connections are numbered *counterclockwise from the top*, with a color-coded dot directly beside lead 8. The units are specified over a +15° to +55° C interval, useful for both room temperature and laboratory environments. Identical, wider-temperature units are available at premium cost. Although sockets are readily obtainable, the breadboarding technique shown in the photo is a good means of mounting experimental circuitry. This technique makes all connections readily accessible and well separated. To mount the IC, eight Teflon press-fit terminals are pressed into holes forming a circle ⅜" in diameter. The leads of the IC are all bent radially outward and soldered directly to the tips of the terminals. Printed circuits are impractical with integrateds unless two-sided or multi-layer board is used; otherwise too many jumpers are required.

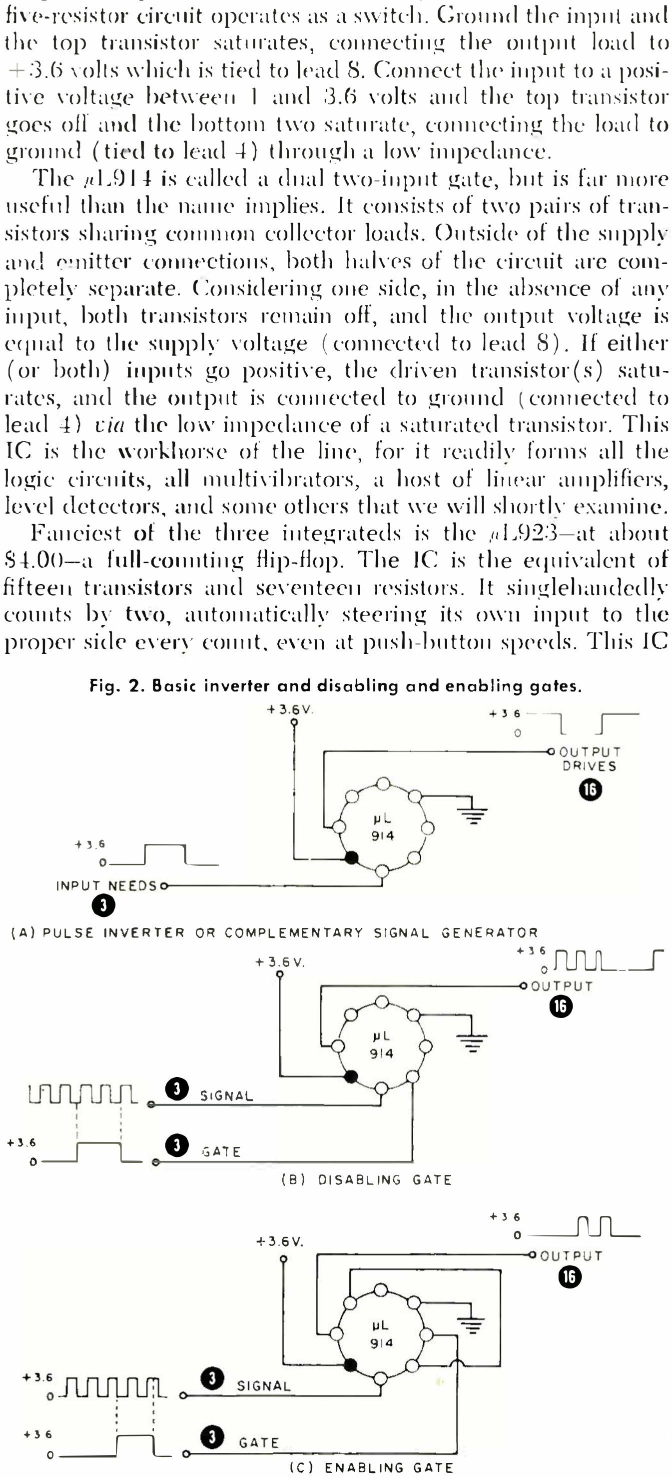
Rather than specify an input requirement as so many ohms or so many ma., and output requirements similarly, a much easier method is used on this IC line. Both input requirements and output drive capability are specified as so many "units," as indicated in the circles in the circuit diagrams. Any combination of inputs can be driven by an output whose drive capability exceeds the *sum* of the input units required. For instance, we will see that a μL914 requires "3" units of drive at an input and delivers "16" units of drive at an output. Thus one μL914 output can drive five μL914's inputs, with "1" to spare. All other requirements are determined in a similar manner, simply adding up the loads and keeping the load units equal to or less than the drive capability.

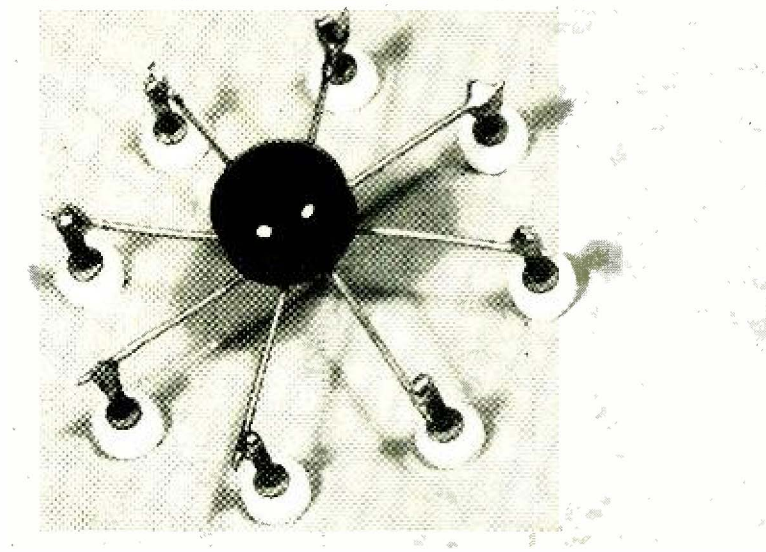
The three IC's are compared in Fig. 1. The μL900 (about \$1.60 each) is a buffer element designed to provide inversion and a high drive capability. This circuit finds use whenever a large number of inputs (up to a load factor of "80" units) is to be driven from a single circuit or when a low-impedance output is required for external circuitry. This three-transistor, five-resistor circuit operates as a switch. Ground the input and the top transistor saturates, connecting the output load to +3.6 volts which is tied to lead 8. Connect the input to a positive voltage between 1 and 3.6 volts and the top transistor goes off and the bottom two saturate, connecting the load to ground (tied to lead 4) through a low impedance.

The μL914 is called a dual two-input gate, but is far more useful than the name implies. It consists of two pairs of transistors sharing common collector loads. Outside of the supply and emitter connections, both halves of the circuit are completely separate. Considering one side, in the absence of any input, both transistors remain off, and the output voltage is equal to the supply voltage (connected to lead 8). If either (or both) inputs go positive, the driven transistor(s) saturates, and the output is connected to ground (connected to lead 4) *via* the low impedance of a saturated transistor. This IC is the workhorse of the line, for it readily forms all the logic circuits, all multivibrators, a host of linear amplifiers, level detectors, and some others that we will shortly examine.

Fanciest of the three integrateds is the μL923—at about \$4.00—a full-counting flip-flop. The IC is the equivalent of fifteen transistors and seventeen resistors. It singlehandedly counts by two, automatically steering its own input to the proper side every count, even at push-button speeds. This IC

Fig. 2. Basic inverter and disabling and enabling gates.





A convenient method of mounting for breadboarding circuits.

is also useful as a shift register or memory element and replaces some complicated binary and ring-counter circuitry.

Inverter and Gate Circuits

In all the circuits, we have purposely left out the inner connections of the IC's to emphasize the external system connections and the simplicity of using integrated circuitry. To study the circuits from a discrete equivalent standpoint, refer back to Fig. 1.

The simplest circuit is the inverter of Fig. 2A. Here a binary "1" input produces a "0" output and *vice versa*. Use this one to invert any digital pulse or generate a complementary digital signal. The circuit functions on the presence or absence of base current in one transistor. A positive input signal saturates the transistor and grounds the output. A grounded input signal turns the transistor off and the output goes positive. If desired, the other half of the μL914 may be used elsewhere in the circuit.

Using both inputs produces the disabling gate of Fig. 2B. Here the IC inverts the digital signal on lead 1 only if the input to lead 2 is grounded. A positive input at lead 2 grounds the output irrespective of the condition of lead 1, disabling the circuit.

If the opposite effect is desired, an inverter may be added to the gate input. Now, as in Fig. 2C, a grounded-gate input prevents any signal inputs on lead 1 from being inverted and appearing at the output. If the gate input, lead 3, is made positive, the inverter stage makes leads 6 and 2 grounded and thus passes the input signal. This is then an enabling gate.

Logic Circuits

There is always so much confusion over just what constitutes and "and," an "or," a "nand," or a "nor" circuit for, depending on how things are defined, one circuit can perform any two functions. In binary arithmetic, there are only two possible system states, the "one" state and the "zero" state. The rules for logic are simply:

If *any* "one" input produces a "one" output, the circuit is an "or" circuit.

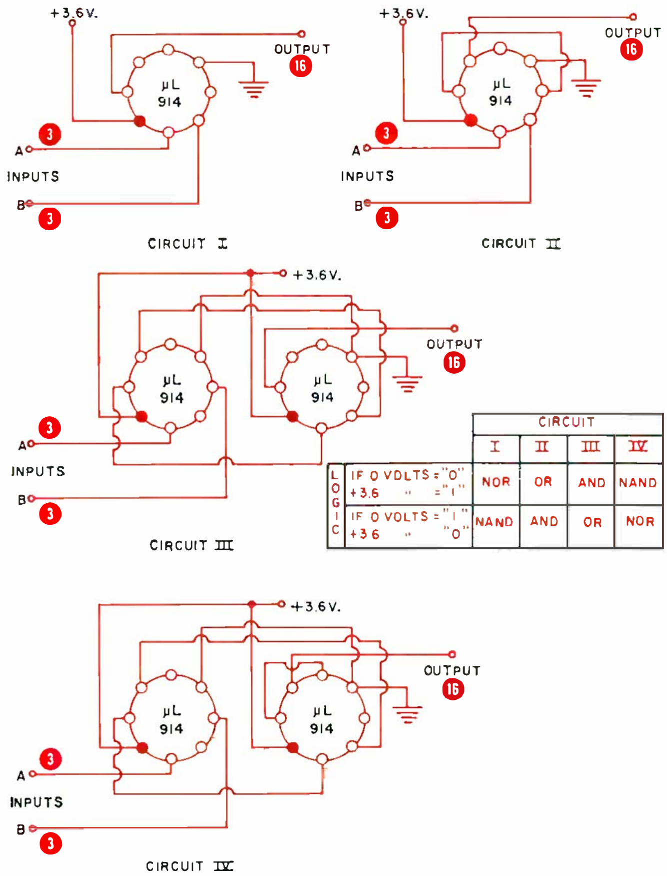
If *any* "one" input produces a "zero" output, the circuit is a "nor" circuit.

If *all* input "one's" have to be present to produce a "one" at the output, the circuit is an "and" circuit.

If *all* input "one's" have to be present to produce a "zero" at the output, the circuit is a "nand" circuit.

Note that all the rules are defined in accordance with the presence or absence of "one" inputs. There is nothing in the rules that concerns itself with "zero" inputs.

The trouble comes in when a "one" and a "zero" are defined in a system. Circuit people will usually define a "one" as a



		CIRCUIT			
		I	II	III	IV
LOGIC	IF 0 VOLTS = "0" +3.6 " = "1"	NOR	OR	AND	NAND
LOGIC	IF 0 VOLTS = "1" +3.6 " "0"	NAND	AND	OR	NOR

Fig. 3. Logic circuits along with their various designations.

positive input and a "zero" as a grounded input; the computer people will often do the exact opposite. Four basic logic circuits are shown in Fig. 3 along with a chart which defines the logic operations in terms of your choice of what a "one" or a "zero" is.

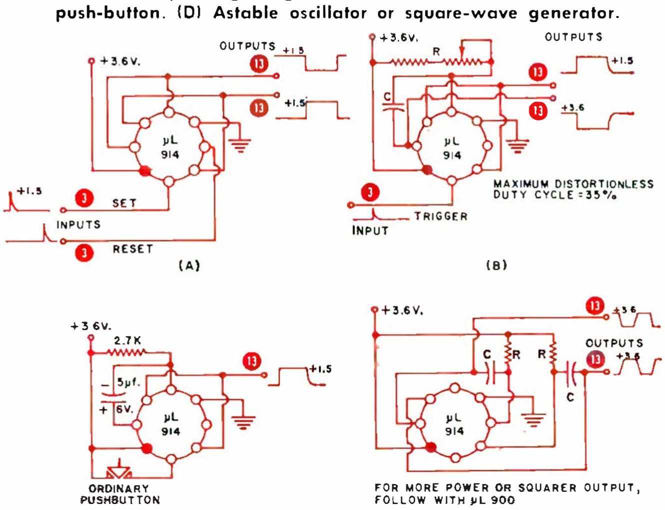
Circuit I produces a grounded output if either input is positive and a positive output only if both inputs are grounded.

Circuit II produces a positive output if either input is positive and a grounded output only if both inputs are grounded.

Circuit III produces a positive output if both inputs are positive and a grounded output if either input is grounded.

Circuit IV produces a grounded output if both inputs are positive and a positive output if either input is grounded.

Fig. 4. (A) Set-reset flip-flop, latch, or memory. (B) Monostable, delay, or gate generator. (C) Bounceless, noiseless push-button. (D) Astable oscillator or square-wave generator.



These logic circuits are the very basis of all digital computer circuitry and other areas where particular sequences or coincidences must be detected.

Multivibrators

All the conventional multivibrators (flip-flops) are easily built using the connections of Fig. 4. In 4A, the output of one half of a μL914 is connected to one input on the other half and *vice versa*. The two remaining inputs, one on either side, are brought out for external connections. This produces a bistable multivibrator or a set-reset flip-flop. A momentary set pulse consists of a positive signal briefly applied to lead 1. This momentarily grounds lead 7, the output of the set inverter. The grounding of lead 7 grounds lead 3 which lets lead 6 go positive. The positive output of lead 6 is connected to lead 2 which holds the multivibrator in the set state after the input trigger disappears. A reset pulse applied to the opposite input will transfer the output to the reset side, again holding itself in the new state until the next arrival of a set pulse. This circuit is useful as a latch or memory as well as a gate or interval generator.

If one of the feedback connections is broken and a capacitor and recharging resistor are inserted in its place, the

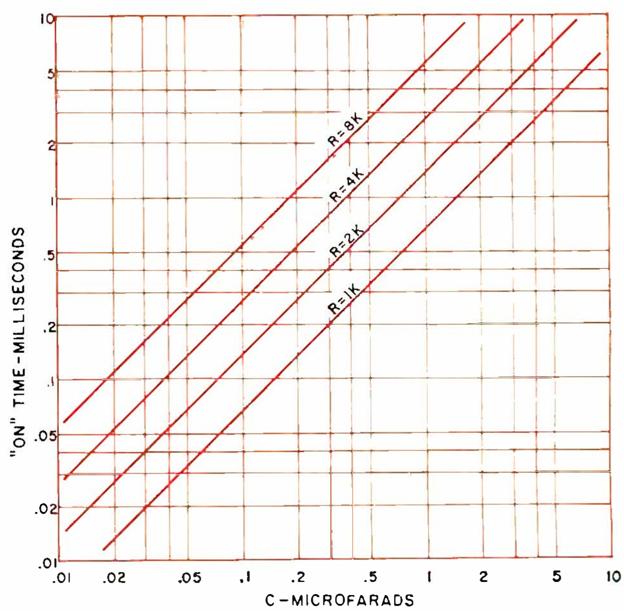


Fig. 5. Performance of the monostable circuit in Fig. 4B.

monostable multivibrator of Fig. 4B results. Here a set or trigger input pulse changes the state of the flip-flop, but it changes state back again after a time delay determined by the recharging time of capacitor *C*. When the input trigger arrives, lead 7 immediately goes to ground. The charge on *C* cannot instantaneously change, so *C* drives lead 5 negative, turning off the other side of the flip-flop and providing feedback to hold the output in the set state. *R* then slowly recharges *C*, making lead 5 more and more positive until finally lead 5 is positive enough to turn on its transistor and revert the state of the monostable back to normal. The net effect is a constant time interval or delay, in the form of a rectangular pulse, produced every time an input trigger pulse arrives.

Fig. 5 includes a family of curves that lets you choose values of *C* and *R* for required time delays. Varying *R* with a potentiometer gives control over the delay interval. The delay is largely independent of the supply voltage. The circuit will only operate on a 75% maximum duty cycle, and the duty cycle should be held to less than 30-35% if timing accuracy is important. For instance, a 300-microsecond multivibrator must have at least 100 microseconds to recover. If timing accuracy is important, it should have at least 700 microseconds; otherwise the earlier (*Continued on page 80*)

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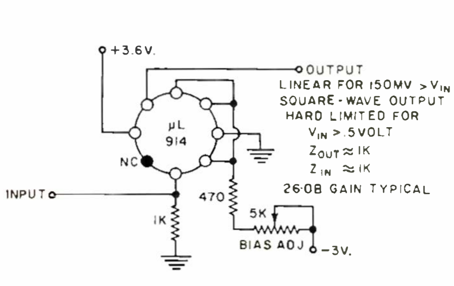

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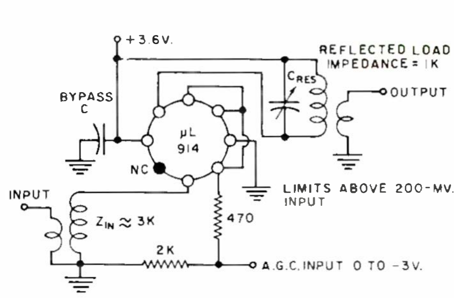


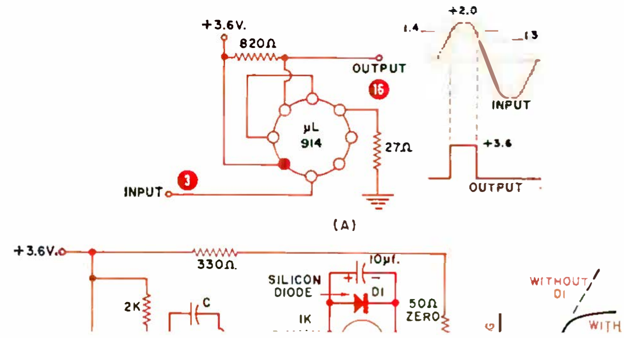
(C)

Using Integrateds

(*Continued from page* 52)

arrival of new trigger pulses will affect the timing interval.

One example of a monostable application is the noiseless push-button circuit of Fig. 4C. Ordinary push-buttons are both bouncy and noisy. In the first few milliseconds of contact, the contacts may alternately make and break as many as several hundred times. This is detrimental to any high-speed electronic circuit that faithfully follows every input pulse. With the monostable, the first bounce triggers the



ELECTRONIC CROSSWORDS

By JAMES R. KIMSEY

(*Answer on page* 102)

ACROSS

1. To vary the amplitude, frequency, or phase of an oscillation, usually at a signal frequency rate.
6. The fixed voltage applied between grid and cathode elements of an electron tube.
10. Aerial.
12. A buried object that serves as an anchor for a guy wire or rope.
14. Rodent.
15. Here (Fr.).
16. Hackneyed by constant repetition.
17. Switch position.
18. Dry seed fruit.
20. Type of communications system (abbr.).
21. Didn't work.
23. Timid.
24. An inert gas often used in discharge tubes and as a lamp filling.
26. American Indian.
27. A system of challenge and response developed for use with radar equipment (abbr.).
28. A bow of flame formed between two electrodes.
29. Unit of current (abbr.).
30. The thing mentioned.
31. Electrical current such as usually supplied by power lines (abbr.).
33. Confronted.
35. Some.
36. Crystal cut. Used extensively in r.f. transmitters from 4500 to 10,000 kc.
37. Linear measure (abbr.).
38. Widening of the volume range of an a.f. signal so that weak passages become weaker and loud passages become louder.
42. ....-loss insulator.
44. Shade tree.
45. .... compensation, a control device that compensates for voltage drop due to current flow.
46. In electron optics a hole in a plate electrode which separates two fields (2 words).

DOWN

1. Microwave term specifying the type of oscillation occurring in a line, waveguide, tube, or cavity.
2. Term used to indicate that current is being taken from a voltage source.
3. Amount of radiant energy emitted from a source.
4. Refractory metal used for grids and plates of power tubes.
5. Printer's measure.
6. Regularly recurring pulsation of amplitude resulting from the combination of two tones or electric waves of different frequencies.
7. General term used to signify the strength or value of a current.
8. Indefinite article.
9. The load, above the normal operating rating, to which a device can be subjected without failure (2 words).
11. A three-electrode vacuum tube.
13. Type of current (abbr.).
17. Paddle.
19. Television band (abbr.).
20. Curve formed by the intersection of a cone and a plane.
21. A thin, enamel-like insulation of high tenacity.
22. The seventh letter of the Greek alphabet.
25. Southern state (abbr.).
30. Money received from labor or services.
32. Crystal cut.
34. Beverage.
38. Female sheep.
39. Place.
40. Observe.
41. Sick.
43. Radioman (slang).
45. Part of "to be."