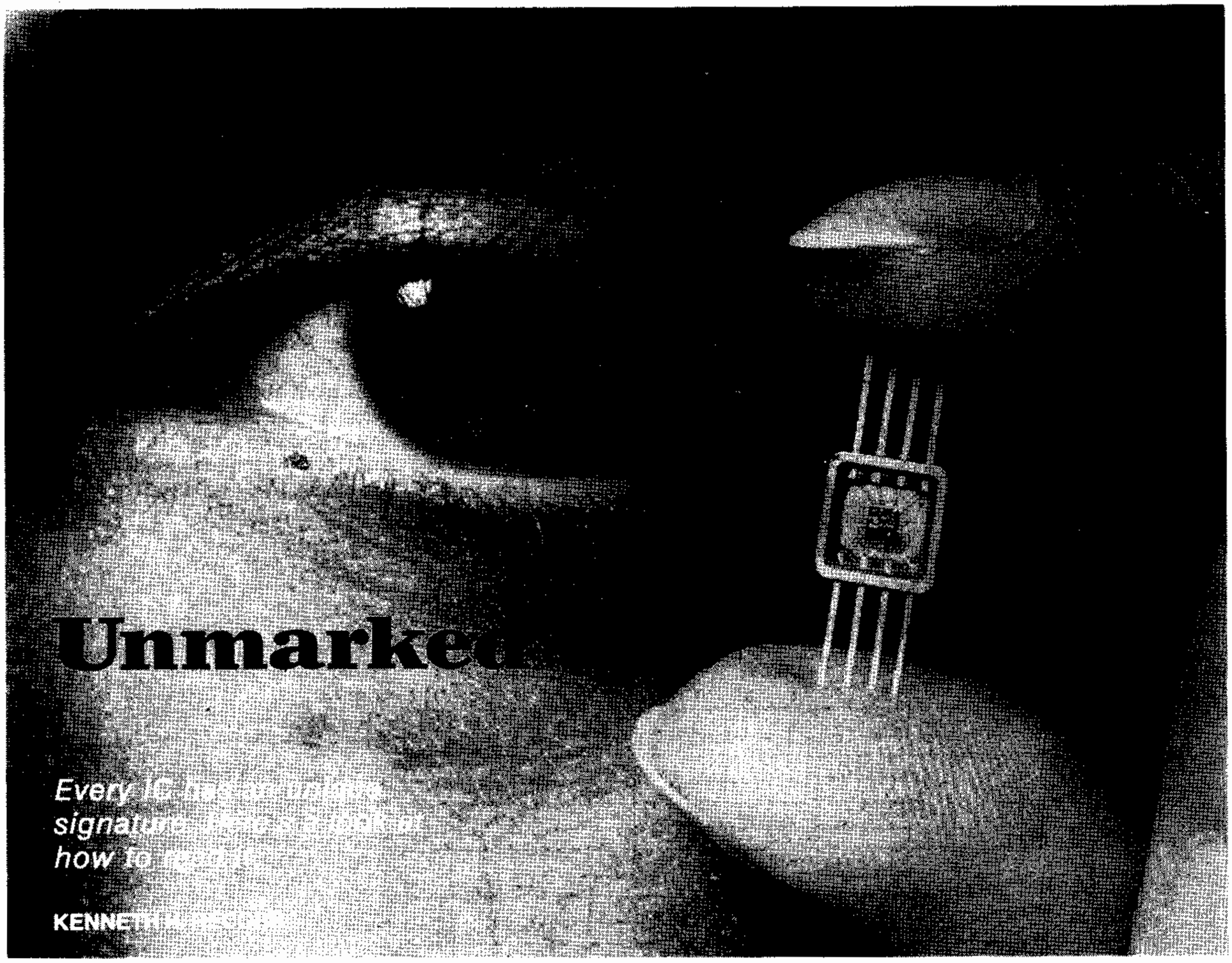


Unmarked

Every IC has a unique signature. Here's a look at how to read it.

KENNETH

TEMPTED TO BUY THAT GRAB BAG LOADed with unidentified IC's? Go ahead—those IC's have a signature that will tell you what pins are probably outputs. From there on it's easy—a few voltage measurements, some current measurements, and you should know what you've got. You should even be able to determine if the device is defective. So grab your trusty ohmmeter and get ready to record your first IC signature.

An IC signature is an array of resistance readings derived from the IC and displayed in an organized way. The ×100 range of an ohmmeter is used. (Be sure you know which ohmmeter lead is positive; some ohmmeters change polarity when switching from volts to ohms.)

The signature is obtained by recording the resistances between all terminal pairs of the IC. Use the form shown in Fig. 1. Connect the ohmmeter's positive lead to pin 1, and move the negative lead sequentially through the remaining pins. Record the measured resistances across the top row of the signature chart. A resistance measurement of over several hundred thousand ohms does not convey very much useful information, so there is no need to record it—put a dash through the box instead.

Move the positive lead to pin 2 and fill in the second row of the chart by moving the negative lead to pin 1, 3, 4, ..., etc. Continue in the same manner until every row of the signature chart is completed. If this is done properly, you should have as many rows in your chart as there are pins on the IC.

The steps that follow show how to use the completed signature to identify your IC.

Step 1: Examine the chart and circle each terminal-to-terminal resistor—you can tell which ones those are because each purely resistive connection between two terminals reads approximately the same in both directions.

For example: In Fig. 2 there are 12 circled boxes, 6 above the diagonal and 6 below. The circled number in Row 5, Column 3 has its mirror image on the opposite side of the diagonal in Row 3, Column 5. The resistance is 7K ohms in both directions and it is therefore a terminal-to-terminal resistance. That is noted to the right of the chart (Fig. 2), along with the other resistance values and identified as step one. The remaining terminal pairs show grossly different resistance measurements in opposite directions, indicating the presence of one or possibly several semiconductor junctions in the path.

It is highly unlikely that a TTL IC, or for that matter any linear IC, would contain 6 identically valued terminal-to-terminal resistances. (Maybe the IC is RTL or DTL?)

Step 2: Disregard all circled boxes and scan the signature to locate the row with the lowest resistance readings—Row 4 in this case. That uniquely identifies pin 4 as the substrate connection of the IC or, in other words, the most negative terminal of the IC.

Scan across Row 4 for the lowest uncircled reading—in this case it is the 750-ohms reading in Column 11. That tells us that pin 11 is the V_{CC} terminal of the IC. Record those numbers in the place provided at the right of the chart—Step 2, Fig. 2.

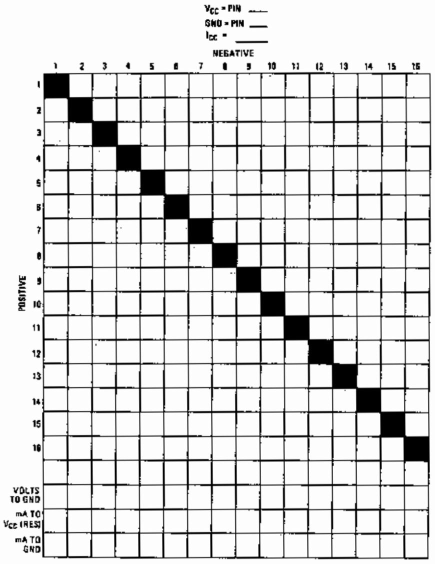


FIG. 1—THIS FORM is used to record all resistances between terminal pairs of the unknown IC.

The other uncircled low-resistance readings in the ground row usually identify transistor collectors; i.e., output terminals. That is an important clue to be used later.

Step 3: Before proceeding to the identification of other terminals we measure I_{CC}. Apply a low voltage, say 3.6 volts (RTL supply voltage), to the IC through a 100 mA milliammeter. The positive voltage goes to the V_{CC} terminal (in this case pin 11) and the return connects to the IC substrate (in this case pin 4).

To protect the IC and the equipment, place a 120-ohm resistor in series with the current meter. A dead short in the IC will only draw 30 milliamps. Remove the resistor and re-connect the current meter only when it is clearly safe to do so. Most standard TTL gates draw between 2 to 4 mA. Thus, a quad NAND or NOR would draw 12 to 15 mA. In the case at hand, there was no current flow at all. DTL or TTL would have shown some current—so again the evidence suggests RTL.

A third clue: If there is a normal current flow, raise the voltage to 5 volts, measure, and record I_{CC} in the space provided at the right of the signature chart.

Step 4: Remove the milliammeter and apply the selected voltage directly between the V_{CC} and ground pins. Measure volts-to-ground, mA-to-V_{CC} (through a 330-ohm resistor) and mA-to-ground for each pin of the IC. Record the measured values in the rows at the bottom of the signature chart.

The "volts-to-ground" row generally identifies all inputs and outputs. Voltages from about 2.2 volts up to the applied voltage indicate outputs in the high state (for a logic chip). Thus, pins 3, 5, 8, and 14 are likely candidates for output terminals. (You will recall in step 2 that

VCC = PIN 11 } 2
GND = PIN 4 } 2
ICC = 0 WITH ALL INPUTS OPEN AND NO LOADS APPLIED } 3

NEGATIVE

POSITIVE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	■	—	3.2	3.3	6.5	—	—	6.5	—	—	2.3	—	—	6.4		
2	—	■	3.25	3.3	7.0	—	—	7.0	—	—	3.3	—	—	7.0		
3	—	—	■	—	(7.0)	—	—	(7.0)	—	—	1.6	—	—	(7.0)		
4	—	—	.83	■	.83	—	—	.85	—	—	.75	—	—	.85		
5	—	—	(7.0)	—	■	—	—	(7.0)	—	—	1.6	—	—	(7.0)		
6	—	—	7.0	3.5	3.5	■	—	7.0	—	—	3.4	—	—	7.0		
7	—	—	6.4	3.3	3.25	—	■	6.4	—	—	2.3	—	—	6.4		
8	—	—	(7.0)	—	(7.0)	—	—	■	—	—	1.3	—	—	(7.0)		
9	—	—	6.0	3.2	6.0	—	—	3.1	■	—	1.7	—	—	6.0		
10	—	—	5.9	3.1	5.8	—	—	3.0	—	■	1.4	—	—	5.7		
11	—	—	3.75	—	3.7	—	—	3.7	—	—	■	—	—	3.7		
12	—	—	5.9	3.0	5.8	—	—	5.8	—	—	1.38	■	—	3.0		
13	—	—	6.0	3.1	6.0	—	—	6.0	—	—	1.7	—	■	3.0		
14	—	—	(7.0)	—	(7.0)	—	—	(7.0)	—	—	1.3	—	—	■		
15															■	
16																■
										3.6V APPLIED						
VOLTS TO GND	—	—	3.6	GND	3.6	—	—	3.6	—	—	VCC	—	—	3.6		
mA TO VCC (RES)	1.4	1.4	—	GND	—	1.4	1.4	—	1.4	1.4	VCC	1.4	1.4	—		
mA TO GND	—	—	1.0	GND	1.0	—	—	1.0	—	—	VCC	—	—	1.0		

3 TO 5 = 7KΩ
3 TO 8 = 7KΩ
5 TO 8 = 7KΩ
3 TO 14 = 7KΩ
5 TO 14 = 7KΩ
8 TO 14 = 7KΩ } 1

RTL } 5
MC717P } 8

3, 5, 8, 14 - OUTPUTS
1, 2, 6, 7, 9, 10, 12
AND 13 - INPUTS } 4

3 GOES LOW WHEN
1 OR 2 OR BOTH
GO HIGH.
5 GOES LOW WHEN
6 OR 7 OR BOTH
GO HIGH.
8 GOES LOW WHEN
9 OR 10 OR BOTH
GO HIGH.
14 GOES LOW WHEN
12 OR 13 OR BOTH
GO HIGH.
DEVICE IS QUAD, 2
INPUT NOR GATE IC. } 6

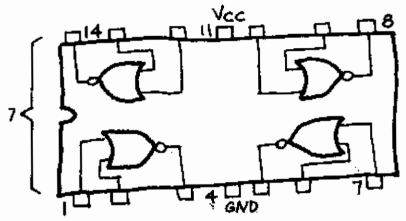


FIG. 2—COMPLETED SIGNATURE CHART for the unknown IC. It turned out to be an quad, 2-input NOR gate.

V_{CC} = PIN 14
GND = PIN 7
I_{CC} = 13 mA

NEGATIVE

POSITIVE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	■	—	—	—	—	—	—	—	—	—	—	—	—	—		
2	—	■	—	—	—	—	—	—	—	—	—	—	—	—		
3	—	—	■	—	—	—	—	—	—	—	—	—	—	—		
4	—	—	—	■	—	—	—	—	—	—	—	—	—	—		
5	—	—	—	—	■	—	—	—	—	—	—	—	—	—		
6	—	—	—	—	—	■	—	—	—	—	—	—	—	—		
7	1150	1150	850	1150	1150	850	■	850	1150	1150	850	1150	1150	720		
8	—	—	—	—	—	—	—	■	—	—	—	—	—	—		
9	—	—	—	—	—	—	—	—	■	—	—	—	—	—		
10	—	—	—	—	—	—	—	—	—	■	—	—	—	—		
11	—	—	—	—	—	—	—	—	—	—	■	—	—	—		
12	—	—	—	—	—	—	—	—	—	—	—	■	—	—		
13	—	—	—	—	—	—	—	—	—	—	—	—	■	—		
14	8K	8K	7K	8K	8K	7K	5K	7K	8K	8K	7K	8K	8K	■		
15															■	
16																■
VOLTS TO GND	1.6	1.6	0.1	1.6	1.6	0.1	GND	0.1	1.6	1.6	0.1	1.6	1.6	V_{CC} 5		
mA TO V_{CC} (RES)	—	—	18	—	—	18	—	18	—	—	18	—	—	V_{CC}		
mA TO GND	1.1	1.1	1.5	1.1	1.1	1.6	—	1.6	1.1	1.1	1.6	1.1	1.1	V_{CC}		

FIG. 3—SIGNATURE CHART for a TTL 7400 IC. All but a few TTL IC's have this typical two row signature.

those are the same terminals that were suggested as outputs by their low readings in Row 4.)

A voltage less than 0.2, but greater than zero, usually indicates logic outputs in the low state. None of those appear in Fig. 2.

Now is the time to remove and reapply power to the IC. Do that several times, each time comparing the voltage at each suspected output to its original recorded value. Often a flip-flop will reveal itself by changing the state of one or more of its outputs. A simple gate will never change state in response to that little trick. The IC in Fig. 2 did not change state so I assumed it was not a flip-flop.

Voltages from about 1.8 down to 0.8 usually indicate TTL or DTL inputs. The fact that there are no such voltages in the "volts-to-ground" row of Fig. 2 was certainly a surprise to me, but it did lead to a pretty solid conclusion: If the IC is not defective, then it is not TTL or DTL.

Currents in the low state should read 10 to 20 mA when measured between the output and V_{CC}. Currents in the high state can read anywhere from 2 to 30 mA when measured between the output and ground if the IC is TTL. As an example of a typical TTL signature, Fig. 3 shows the signature chart for a 7400 TTL IC.

Input currents for RTL, DTL and TTL fall between 0.8 mA and 2.0 mA. In Fig. 2 all the probable inputs draw 1.4 mA referenced to V_{CC} and nothing referenced to ground. That verifies that they are inputs and shows they are active (draw current) when the input is pulled high. RTL is active-high. DTL and TTL are active-low. Since their appear to be twice as many inputs as outputs, the chart suggests that our IC is a quad gate of some sort. It is reasonable to conclude that pins 1, 2, 6, 7, 9, 10, 12 and 13 are inputs.

The bottom row of the chart shows the outputs provide only 1 mA to ground despite the fact that the voltage measured at those terminals is 3.6. That suggests an internal pull-up resistor connected to the output terminal (see Fig. 4). If that is so, and the device is a quad gate (which seems very likely), there should be four identical resistors to V_{CC}—one from each output. And that implies we should read twice the pull-up resistor value between any two outputs. In that case, the circled 7K values in the signature point to 3.5K pull-ups in each output. With a V_{CC} of 3.6 volts applied, grounding any output through the current meter should cause a current flow of just about 1 mA. And that's what we got! List the outputs and inputs on the signature chart.

Step 5: The symmetrical pattern of resistances in the signature and the strong evidence for four independent outputs with logic-level voltages pretty much rules out any linear IC. Resistive pull-ups could be DTL, but DTL inputs are active-low and our IC is active-high. After reviewing all the evidence I felt there was absolutely no doubt that this device was RTL. That conclusion was recorded in Fig. 2.

Step 6: We now manipulate the inputs and observe the output responses to determine what kind of logic device we have.

With V_{CC} applied, we connect a voltmeter from ground to a terminal thought to be an output. Ground the inputs one at a time, noting the change, if any, in the metered output. If that output does not change state for any grounded input, repeat the procedure, this time connecting one input at a time to V_{CC} instead of ground. In this example it happened that pin 3 went low when either pin 1 or pin 2 was pulled high (to V_{CC}). None of the other outputs responded to changes in pin 1 or pin 2. This indicates that pins 1 and 2 are inputs to one gate whose output appears on pin 3. That procedure is continued until all inputs and outputs are related in some way. Truth tables can be consulted to identify the gates. This device turned out to be a quad, 2-input NOR gate.

The relationships between the inputs and outputs and the conclusion as to the type of device I was dealing with are listed in Fig. 2 as step 6.

Had the device not responded at all to any of the above techniques, I would have tried exercising two, or even three, inputs at a time and I would have begun to search for a possible "enable" or "inhibit" input. The more complicated devices require a little ingenuity and some intelligent guesswork.

Step 7: Use the results of step 6 to draw the schematic of the IC. At that point the device could be used in the average hobby project without needing to know anymore about it. But, if you feel compelled to assign a number to your IC, its time to consult the IC data books. That's what I did.

Step 8: It took quite a while to locate a

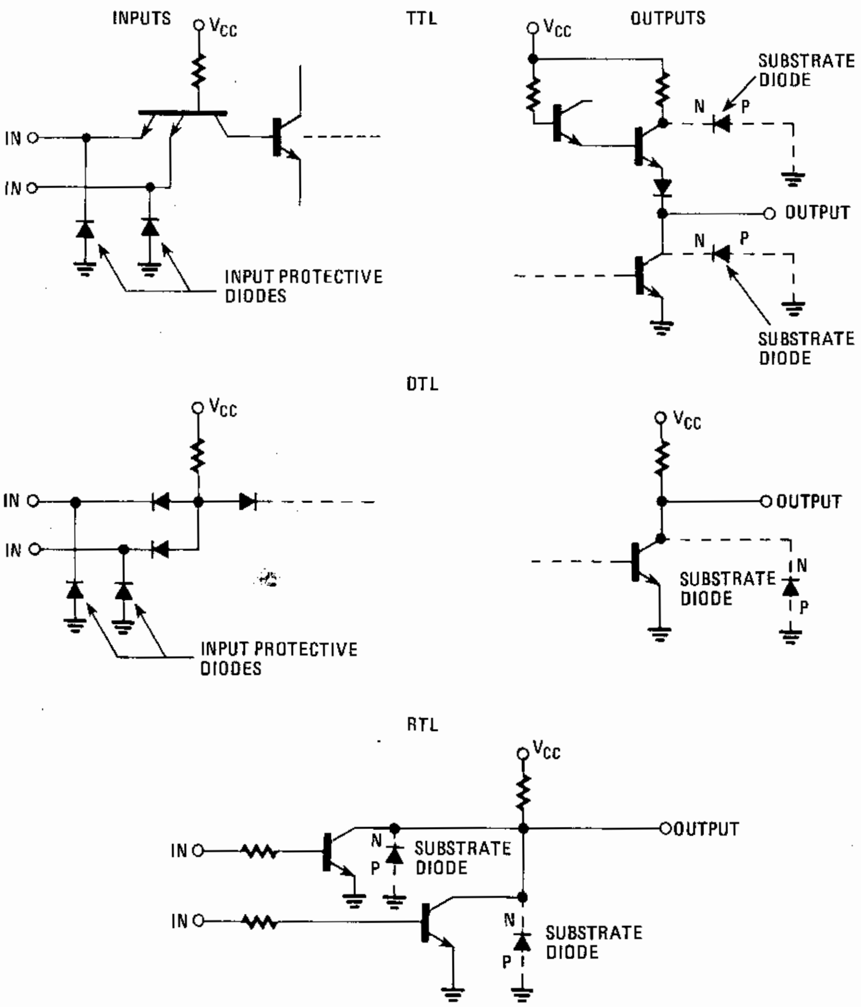


FIG. 4—LOGIC input and output circuits. Use these circuits along with your resistance measurements to determine the logic family of the unknown IC.

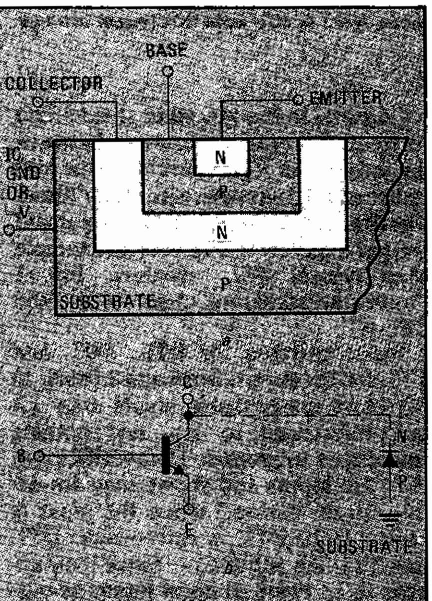
WHAT MAKES THE IC SIGNATURE POSSIBLE

Practically all IC outputs, linear or digital, are formed from transistor collectors. All NPN collectors are imbedded in a P-type substrate that is designated ground (−V for linear IC's). As shown in the accompanying diagram, the collector and substrate form a P-N junction that, like any other diode, conducts well in one direction and poorly in the other.

Connecting an ohmmeter from substrate to collector in the forward direction (positive lead to substrate) will cause the ohmmeter to indicate between 500 and 900 ohms. Other diodes in the same IC will read between 950 and 1300 ohms. Actual resistance values will vary with the type of ohmmeter and the degree of doping in the IC, but the IC outputs will always give the lowest readings.

Thus it is possible to locate every output terminal on an IC. The row containing all those low-resistance readings will be the ground (−V) row.

In every IC there are usually several transistors whose collectors are connected to V_{CC} either directly or through



some resistance. When reading forward resistance from substrate to V_{CC} (+V in linear IC's), that multiplicity of paths will give a lower reading than any other terminal on the IC.

Thus it is possible to identify the V_{CC} terminal.

A LOGIC-FAMILY TREE

Mention is made in this article of the RTL (*R*esistor-*T*ransistor *L*ogic), DTL (*D*iode-*T*ransistor *L*ogic) and TTL (*T*ransistor-*T*ransistor *L*ogic) families. Of the three, TTL is the only one that is still in common use, but a look at its predecessors is worthwhile. (Refer to Fig. 4.)

As advances in technology have made it possible to construct more complicated devices on a silicon chip, we have been able to take advantage of their sophistication to create faster and more elaborate logic families.

All three of those logic-families IC's work by causing their output transistors to go into saturation (a condition where no amplification takes place—only conduction) but differ in the way input signals are processed to bring about that state.

RTL was the first IC logic-family to find widespread use. Each input line going to the output transistor contains a resistor. Its purpose is to reduce the amount of current consumed by the device and to isolate the logic-gate inputs. The input voltage passed through the resistors drives the output stage into saturation, making the collector voltage of the output transistor drop and causing the output to go "low."

The resistors, though, slow down the switching speed of RTL devices because they increase the time needed to charge and discharge the input capacitance of the output transistor.

Typically, RTL has a switching speed on the order of 50 nanoseconds and operates from a 3.6-volt supply.

The next step in IC evolution was DTL. That family substitutes diodes for the resistors used in RTL. The diodes provide better isolation at the inputs and, because of their low forward resistance, make it possible for DTL circuits to switch more rapidly than their RTL equivalents.

DTL has a typical switching speed of 25 nanoseconds and requires a four-volt supply.

Finally, TTL uses multi-emitter transistors in the input stage. The base-collector junction of those transistors is never fully off, meaning that a state of saturation can be reached considerably more quickly than with either RTL or TTL.

Switching speeds for simple TTL IC's are frequently under 10 nanoseconds. TTL uses a five-volt supply.

While it is still possible to find RTL and DTL IC's on the surplus market, the TTL family is now the dominant one. Its two most common forms are standard TTL and "LS" (*L*ow-power *S*chottky) TTL, the latter being even faster and having a lower power consumption, at a small sacrifice in drive capability.

+ V_{CC} = PIN 7
−V_{CC} ~~GND~~ = PIN 4
I_{CC} = ______

NEGATIVE

POSITIVE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	■			750	1.5K	2.2K	1.9K									
2		■														
3			■													
4	850			■	750	950	750									
5	1.5K			850	■	2.2K	1.9K									
6				200K	200K	■	1K									
7	75K			75K	75K	20K	■									
8								■								
9									■							
10										■						
11											■					
12												■				
13													■			
14														■		
15															■	
16																■
VOLTS TO GND																
mA TO V_{CC} (RES)																
mA TO GND																

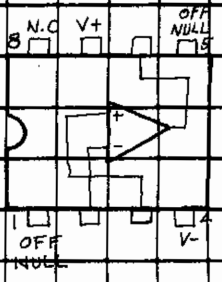


FIG. 5—LINEAR DEVICES can also be identified using the signature chart. This is the signature of a 741 IC.

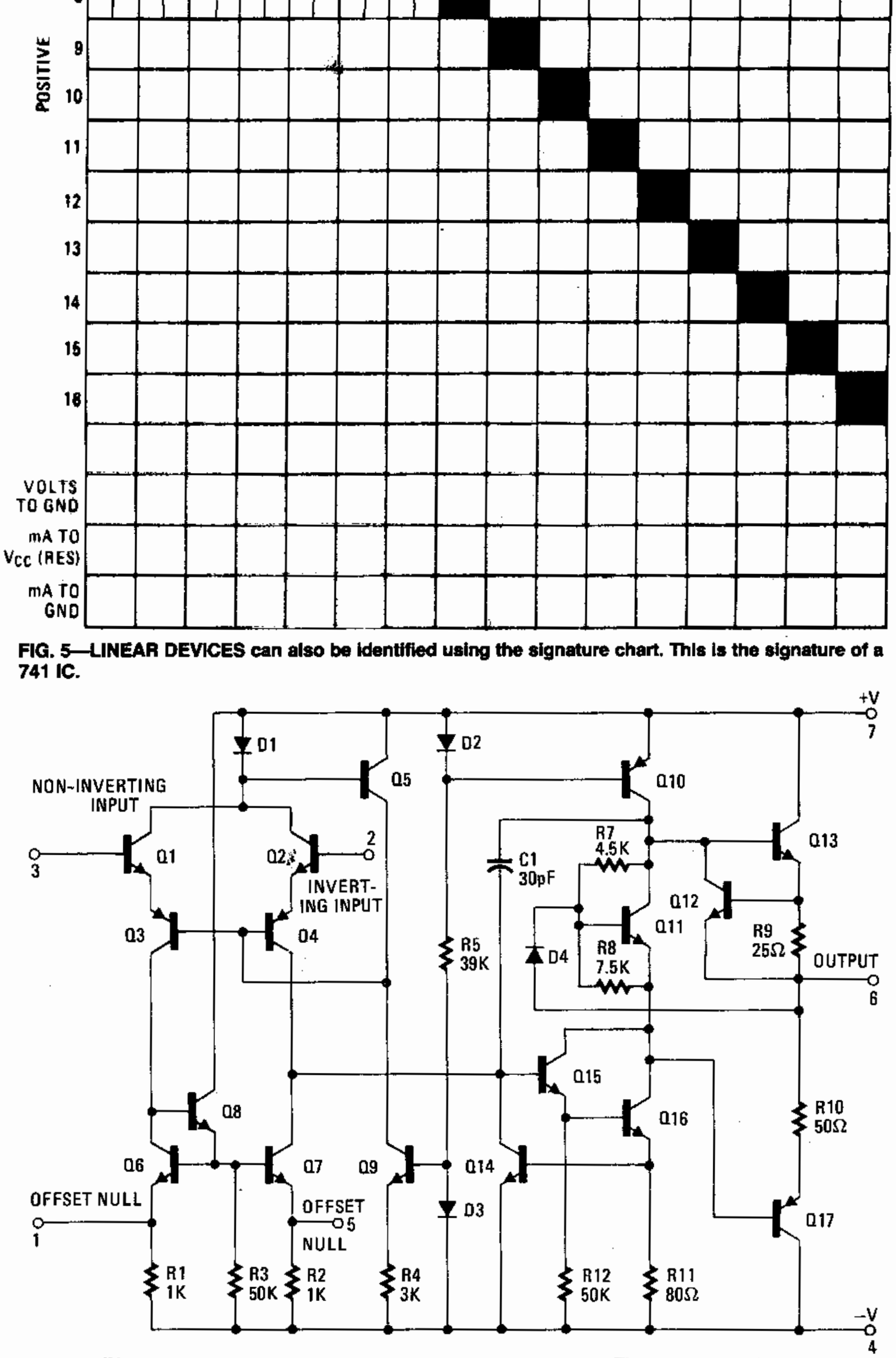


FIG. 6—PIN-OUT for the 741 IC is shown in this schematic diagram. There are 1K resistors between each offset-null terminal and −V.

Motorola IC book containing RTL data sheets. The electronics department at the local college was good enough to let me look through their copy. If you need that kind of assistance, let me urge that you make the local college your first stop. I wish I had—it would have saved a lot of time.

The Motorola book had 256 pages of RTL data—whew! Fortunately the plastic-case style of my IC eliminated two of the three RTL sections. The index of the remaining section listed only two IC's that were quad 2-input NOR gates. The collector pull-up resistors of the first IC type were nominally 640 ohms. The collector resistors in the second IC type were nominally 3.6K. *Bingo!* (We guessed 3.5K in step 4—not bad!).

The device is without a doubt an MC 717P/817P and all the information on that data sheet applies to this IC. I am unable to differentiate further between the 717P and its higher-performance counterpart the 817P. Since the safer move is to assume that the more restricted temperature range applies, I declared the device to be a Motorola RTL IC, type MC717P.

Those techniques work on linear devices as well as digitals.

For example: A signature of an 8-pin DIP 741 op-amp is shown in Fig. 5. Note that the low-resistance row still identifies the substrate, −V, for an op-amp, and also that the lowest reading in that row identifies +V. The only other uncircled reading in row 4 is 950 ohms in column 6, identifying pin 6 as the output terminal.

Figure 6 shows the 741 schematic with the 8-pin DIP pin-out. Note the nominal 1K resistors from each offset-null terminal to −V. The circled resistances in Fig. 5 illustrate some interesting facts about IC resistors: They do not always read the same in both directions—750 ohms one way, 850 ohms the other (pins 1 and 4, and 5 and 4), and they may deviate quite a bit from nominal (1K). Nevertheless the offset-null-terminals are clearly identified.

The op-amp inputs are almost impossible to identify from a signature, but the information already obtained is enough to identify the IC in the data books.

I highly recommend that all those interested in identifying IC's read Olson and Zevnik's excellent article in the January 1980 issue of **Radio-Electronics**, "How to Identify Unmarked IC's." The article is filled with useful suggestions for getting advance information from the PC board.

The smart tinkerer uses all the clues he can get. But when there aren't any advance clues—when there is no PC board—when there are no marking to go by—then the only alternative is the IC signature. **R-E**