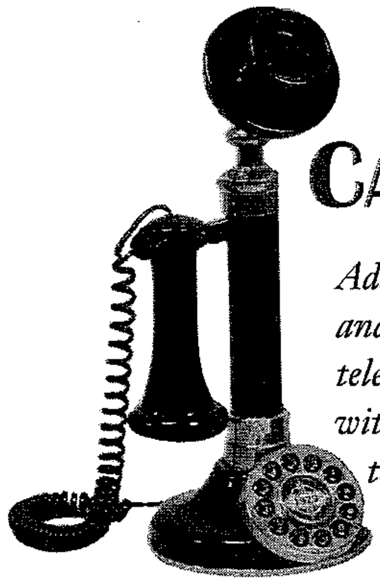
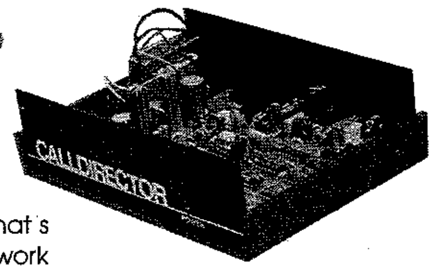
JOHN G. KOLLER



BUILD THE CALLDIRECTOR

Add the conveniences and features of a complete office telephone system to your home without having to change any telephone wiring.



The modern telephone has come a long way since the time of A.G. Bell, especially in the last ten years or so. Deregulation of the telephone company began the loosening of an almost monopolistic grip over user equipment. That, and an almost complete replacement of the Strowger-type rotary dial with tone-dialing equipment, has resulted in an explosion of available telecommunications features and choices of inexpensive user-owned equipment. From basic handsets to sophisticated wireless phones, today's home is all but fully connected from the kitchen to the garden. In fact, with the ease of connecting equipment to the public telephone network, it's not unusual today for a typical home to have five or more telephones.

All of those phones interconnected within the average home suggests a new and interesting way of thinking about the in-home telephone system itself. Consider that not only are all of those phones connected to the outside network, but they are also connected to each other inside the home forming a kind of internal network. For many years, businesses have made use of their internal phone networks for in-house use without accessing the public network. Those setups are called Private Branch Exchanges (PBX) and they exploit the fact that businesses often have a substantial investment in their many telephones and the wiring needed to connect them. A large part of the value of a PBX is really for providing internal communication services along with the normal interface to the public network.

Using the PBX idea, it might make sense in many homes to use the in-home wiring for more than just the singular purpose of connecting the phones to the public network. Why not use the home phone system as a kind of in-home PBX by allowing it to operate as a call dispatch system and as a very practical intercom system? In most homes nearly everything is already in place. All that's needed is some kind of network management device. And that's precisely what the CallDirector described in this article is.

Consider this common scenario. Your telephone rings while you are watching television. The call is for your teenage daughter who is in her room doing schoolwork. Ordinarily, you'd get up, go to her door, tell her that the call is for her, then go back and hang up your phone. Of course, that may be good exercise, but it can become a real nuisance if she receives the seemingly endless string of calls typical of many teenagers. And don't forget the times when you're in the basement, garage, patio, or maybe you have a cordless phone in the yard and need to get someone else in the house to answer the phone.

With the CallDirector, setting up your home for that type of PBX is easy and inexpensive. You don't need to get it from the phone company. Even if you did, you'd be paying a monthly service charge that over time would begin adding up to a considerable cost, with no end in sight.

Connect the CallDirector to your home phones and in the case of your daughter's call, all you need to do is advise the caller that she is home and that you will ring her. Then on your telephone keypad, press the "#" key twice followed by whatever ring number you've given her (say "3"), and simply hang up. The CallDirector will place the caller on hold and then after you hang up will ring all house phones with her special ring which in the example would be three short rings. All phones will continue to ring until either she answers or the caller hangs up.

Another feature of the CallDirector allows you to put a caller on hold. Using the same example as before, suppose that your daughter answers the call, but then wants to leave her room and continue the conversation from another phone. She would press the "#" three times and hang up, then pick up the call on any other phone in the house. Should she become sidetracked on her way to the other phone, the CallDirector will generate a normal ring after about 80 seconds to remind you that someone is on hold. The CallDirector even has a tuner-compatible music-on-hold input that will put music on the phone line while the caller is on hold.

Still another and perhaps just as important function of the CallDirector is its ability to use any phones in the home as a full-fea-

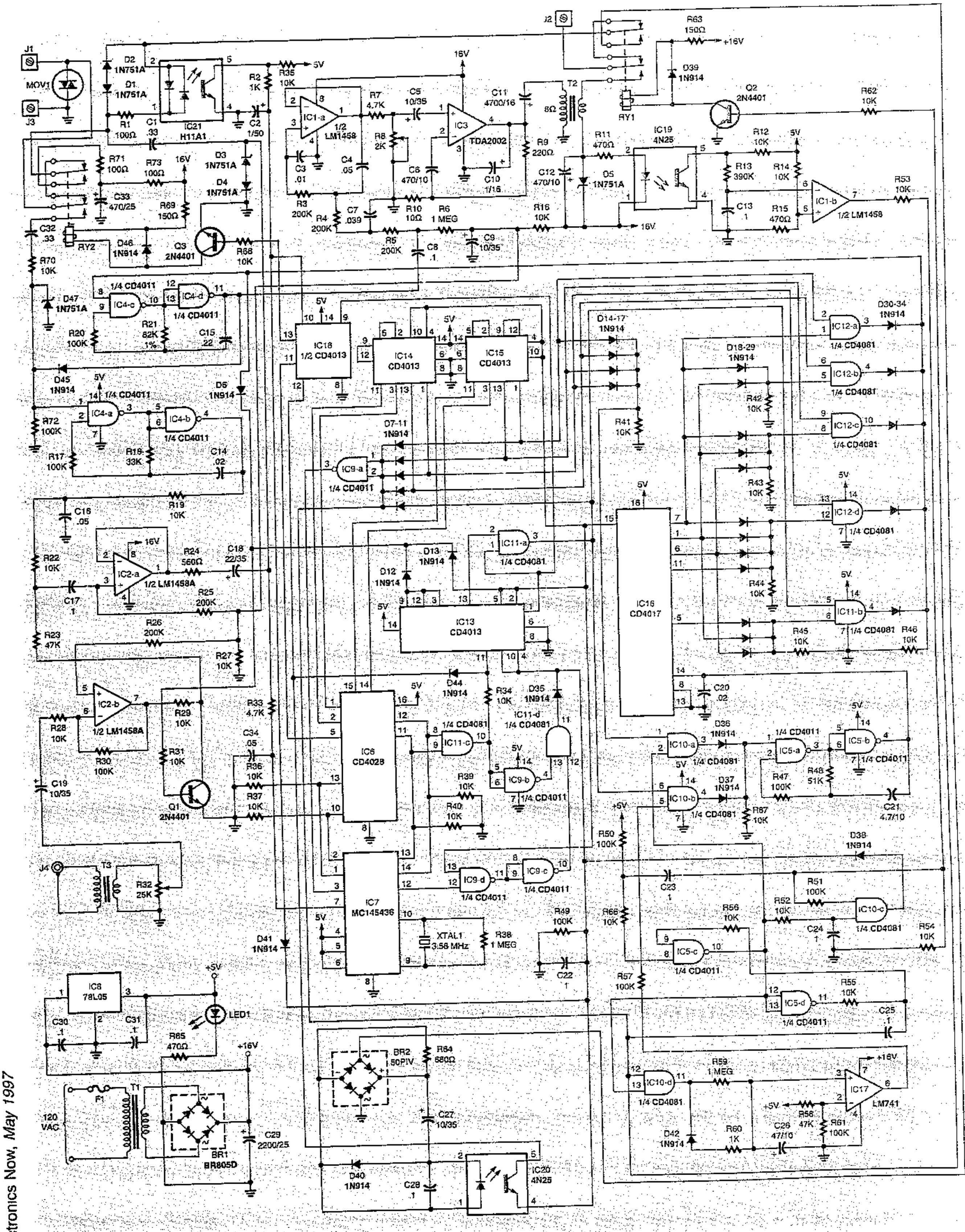


Fig. 1. The CallDirector circuit is very complex, but is also easy to use and quite reliable. Features of the CallDirector include a whole-house intercom, transferring calls to other members of the household, and placing callers on hold with music while they wait.

tured intercom Let's say you're in the basement, garage, or yard with your cordless phone, and someone else in the home needs to contact you. They would pick up any phone, press "##9", then your particular code (perhaps "2"), then hang up In a few seconds all phones, including yours will begin to ring with two short rings. You pick up your phone and wait a moment until the other person picks up At this point you can hold a normal phone conversation with another extension in your home for as long as you like without an annoying dial tone During the conversation, your outside line remains available to accept incoming calls If an outside call comes in while you are using your home phone intercom, you will hear a low level electronic ring signal in your receiver When that happens, one of you needs to hang up and the other simply presses the cradle button on the phone momentarily (sometimes called a "flash") to answer the incoming call.

It's that easy, foolproof, and convenient The CallDirector unit is simple to connect. It truly does allow a completely different way of thinking about how we use our home telephones And it significantly expands your use of what may be a substantial investment in your home telephone equipment and wiring.

How It Works. The CallDirector is a highly-sophisticated telephone-line hold control The unit is designed to be connected to the incoming telephone line in a basement, garage, or wherever the distribution of phone lines is made in the home. Any phone connected to its output can use any CallDirector feature by simply pressing the appropriate buttons on the telephone's keypad, so any telephone connected to the CallDirector must be able to use dual-tone multi-frequency (DTMF) dialing Two ways of putting a caller on hold along with a ringer circuit that can ring the phones with different patterns similar to the old-style "party line" telephone service are the key to the CallDirector's versatility.

The standard hold, activated by dialing "###", is used when an incoming call is to be parked as a normal hold function If the call remains on hold for more than about 80 seconds, a normal ring is generated on all phones The call will continue on hold until any phone on the line is picked up, even one not connected to the CallDirector, or the caller on hold hangs up

The selective-hold function allows a call to be placed on hold but with an immediate generation of one of four easily identifiable rings An incoming call is answered then passed to another member of the household by simply placing the call on one of the four selective holds which produces that person's specific ring. The ring pattern selected consists of from one to four short rings according to the number entered after two "#" keys For example, entering "##4" will generate a signal of four short rings followed by a short pause The caller on hold also hears a ringing signal while on hold

A telephone-based home intercom function is also provided by simply lifting the handset of any phone connected to the CallDirector, entering a "##9" plus a family member's code, then hanging up and allowing one or two ring cycles to complete By that time, the other person will have answered and a normal conversation of any length may be held That is very useful in larger homes where telephones are placed several rooms apart, where cordless phones are used, or where there are other buildings on the property equipped with telephone extensions. In the intercom mode, the CallDirector provides full local loop simulation for operation of the in home telephone network including "local battery" for operating the phone voice circuits, 90-volt rms ring-voltage generation, and hook-status management When using the CallDirector as an intercom, the outside line is still available for incoming calls Should an incoming call occur, the CallDirector will gently play a low-level electronic ring signal into the conversation.

The CallDirector uses central-office quality DTMF detection through a crystal-controlled DTMF-receiver chip That allows programmable phones to be pre-programmed so that various hold and intercom functions can be activated with a single push button on the phone.

The CallDirector also incorporates a power-fail-safe design that effectively removes it from the phone system should a power failure occur No phone operations are affected by the presence of the CallDirector in the system unless and until its features are accessed by its specific DTMF input

Theory of Operation. The schematic diagram for the CallDirector in Fig 1 should be referred to during this discussion The circuit is somewhat complicated, but can be easily divided into several sections. It will also be helpful to refer to the timing diagrams that show the logic levels at key circuit locations during either a standard hold (Fig 2) or a selective hold (Fig. 3).

The incoming telephone-company line is connected to J1 and J3 The house wiring is connected to J2 and J3. Terminals J1 and J2 are normally connected together by RY2, D1, D2, and RY1 If there is a power failure, the normally-closed contacts of RY1 keep the house phones connected to the telephone service Whenever a telephone is taken off the hook, loop current flows through R1 and the LED in IC21, which puts out a logic-low signal at pin 5 That signal removes the reset from IC18 pin 10 and IC13 pins 10 and 4 That enables the recognition of DTMF tones for only the "#" and "9" buttons A low-pass filter, R2 and C2, prevents the momentary loop-current drop occurring during the make-after-break action of RY1 when transferring to a hold condition from resetting IC13 and releasing the hold. The choice of component for IC21 makes the circuit insensitive to phone-line polarity.

The CallDirector and any other equipment on the phone line is protected from any transient voltages exceeding about 184 volts by MOV1. That protection is usually included in all telephone-line equipment such as telephones and answering machines. But when a caller is on hold, the CallDirector is the only device on the line, making

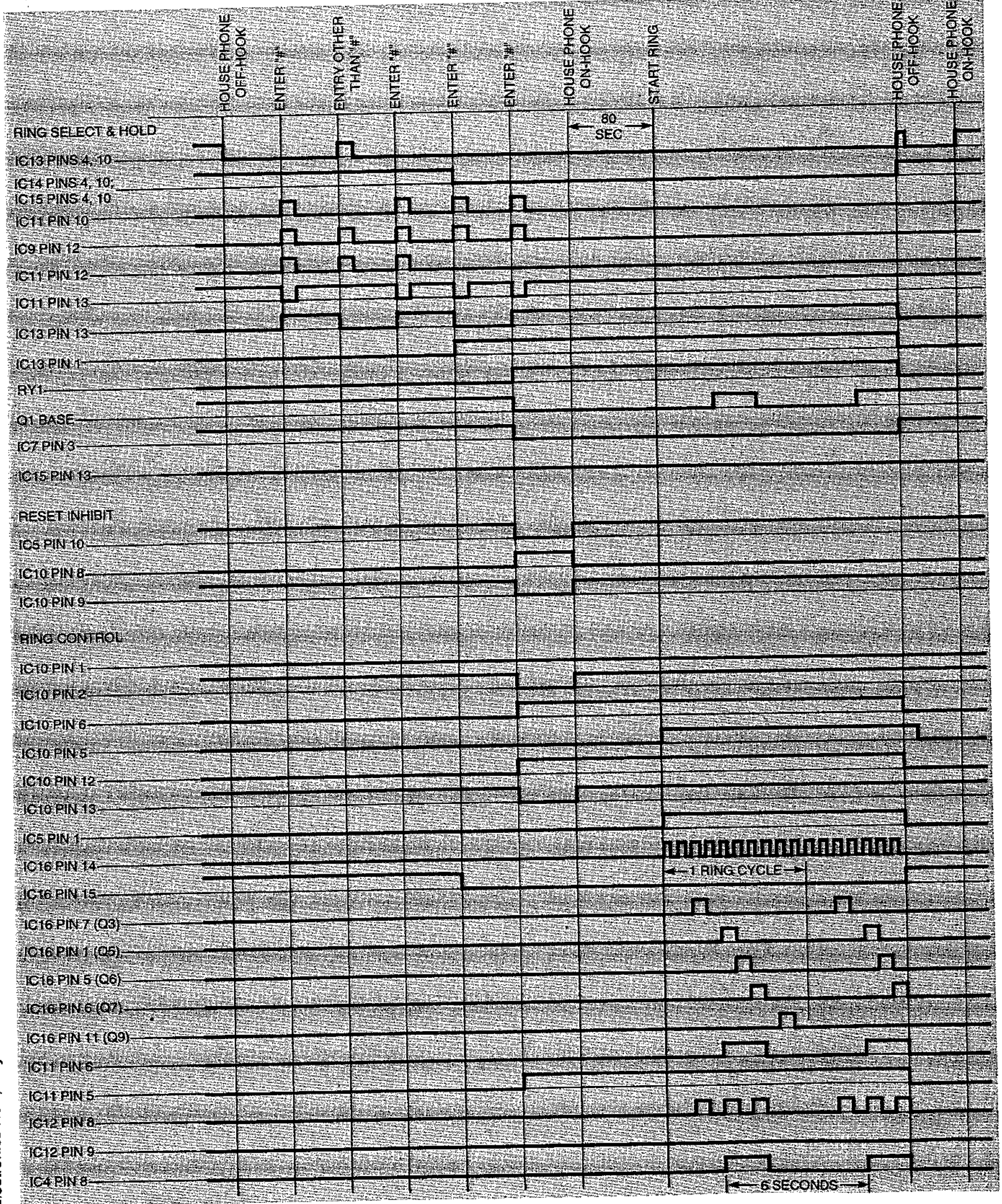


Fig. 2. This timing diagram shows how the CallDirector handles an outside call on hold. If a phone is not picked up in about 80 seconds, the CallDirector will start ringing the phones as a reminder that someone is on hold.

such protection for the CallDirector itself essential.

The CallDirector sends ring signals and music back to the outside phone line through C1. Those signals are amplified by IC2-a before being sent to the phone line. Capacitor C1 also brings tones from the house line to the analog input of DTMF receiver IC7. The input of IC7 is buffered by R33 to help protect IC7 from telephone-line transients. A small amount of equalization to improve balance between high and low tones (sometimes called "twist") is provided by C34. Phone-line voltages passing through R33 are clamped to ±5 volts by D3 and D4.

The house telephones are normally connected directly to the incoming phone line through the normally-closed contacts of RY1 and RY2. When a caller is put on hold, RY1 transfers the house phones to the secondary of ringer transformer T2 and the IC19/IC1-b off-hook detection circuit.

If any house telephone is picked up while a caller is on hold, a DC-current path is created from the 16-volt source at pin 1 of IC19, its LED, current-limiting resistor R11, the secondary winding of T2, and returning to ground through the low resistance of the off-hook telephone. The isolated output of IC19 is grounded, switching on IC1-b. Voltage divider R53 and R54 reduce the 16-volt output of IC1-b to about 8 volts for interfacing with CMOS logic circuitry.

That 8-volt level is greater than the supply voltage of the logic chips. Normally, that condition would damage the chips. However, all inputs to those chips are clamped internally with diodes so that any input voltages above the supply voltage or below ground will not destroy the ICs, as long as current-limiting resistors are put in series with any inputs where the voltages could exceed the IC's safe level. Resistors R51 and R66 are used for that purpose.

Operation of the off-hook detector while the 90-volt 25-Hz ring voltage is being generated is similar to that described above. In order to prevent the ring signal from triggering IC19, D5 prevents any reverse voltages of the ring signal from appearing across the LED in IC19. For the other portions of the ring signal, C12 bypasses most current around the LED up to the 5-volt breakdown level of D5. For protection, D5 places an absolute and unconditional limit on the current applied to IC19.

Some pulsing of the output of IC19 will occur. That is reduced by the low-pass filter combination of R13 and C13. The resulting DC level at IC1 pin 6 remains well above the comparator reference voltage on pin 5 developed by R14 and R15. However, when a house phone is picked up and a DC path is created, the resulting DC current component causes IC19 pin 5 to go solidly low, operating the comparator as discussed earlier.

Call-Holding Setup Logic. The CallDirector can receive DTMF tones at all times, but no recognition is made until at least one telephone connected to terminal 2 is off-hook. That causes the reset signal on IC18 and IC13 to go low. DTMF tones are decoded by DTMF receiver IC7 and converted to a binary-coded decimal (BCD) output. The data valid output on IC7 (pin 12) goes high whenever a valid DTMF tone pair is being decoded. Reception of the "#" DTMF tones produces a logic high on IC7 pins 13 and 14, and consequently on pin 10 of IC11-c. That signal clocks IC13 pin 11 and latches the first flip-flop, capturing the first "#"-tone input.

While the "#" tone is being received, pin 12 of IC7 goes high as does pin 12 of IC9. Meanwhile, pin 13 of IC9 is held high by pin 13 of IC13, which is the inverted output of the second flip-flop. The output at pin 11 of IC9 goes low, and through IC9-c places a high on pin 12 of IC11. When a "#" is being received, pin 10 of IC11 is high and pin 4 of IC9 is low, as is pin 13 of IC11. Under those conditions, pin 11 of IC11, which feeds into the reset line for IC13, does not go high. If, however, a DTMF entry other than "#" were to be received, the data valid signal passing through to IC11-d would not be blocked and would then appear as a reset at the reset lines for IC13.

The very same action occurs upon receipt of a second "#" input except that the first flip-flop in IC13 now clocks off, and in so doing clocks the second flip-flop of IC13 on. If some entry other than a second "#" is made, IC11-d would not block the data-valid signal. That signal would reset the first flip-flop, effectively canceling the entire sequence. That is necessary to assure that only two consecutive "#" inputs will initiate the CallDirector for the eventual third input which will establish the desired hold option.

When the second half of IC13 latches, its inverted output (pin 2) goes low, disabling IC9-d. That allows the full range of DTMF inputs to be received and decoded without resetting IC13. At the same time, the normally-high reset for selective-hold flip-flops IC14 and IC15 is enabled, allowing recognition of DTMF buttons 1 through 4. The non-inverted output of IC13 (pin 1) goes high, placing a logic high on the data input of intercom, activating IC18 pin 9, which will cause that flip-flop to latch if the next digit input is a 9. The only DTMF input recognized under those conditions will now be 1 through 4, 9, and "#". Finally, the reset on ring cadence counter IC16 pin 15 is removed in preparation for generating a ring.

Standard Hold. When a third "#" is received, indicating a standard hold, the first flip-flop in IC13 is clocked for the third time causing it to latch once again. Both flip-flops in IC13 are now latched, which means both of their non-inverting outputs are high. Several things occur when that condition is reached. First, both inputs to IC11-a go high so its output (pin 3) is also high. That enables ring-cadence-selection gate IC11-b for a normal ring when the 80-second ringer-start delay timer activates the ring clock. It also enables normal ring-enable gate IC10-b (pin 6) so that when the timer interval ends, the ring clock will begin producing gating pulses for ring generation.

Note also that IC9-a has both inputs high through D11. The output for that gate (pin 3) goes low, totally disabling the DTMF receiver, IC7, by way of its enable pin (pin 3). Any

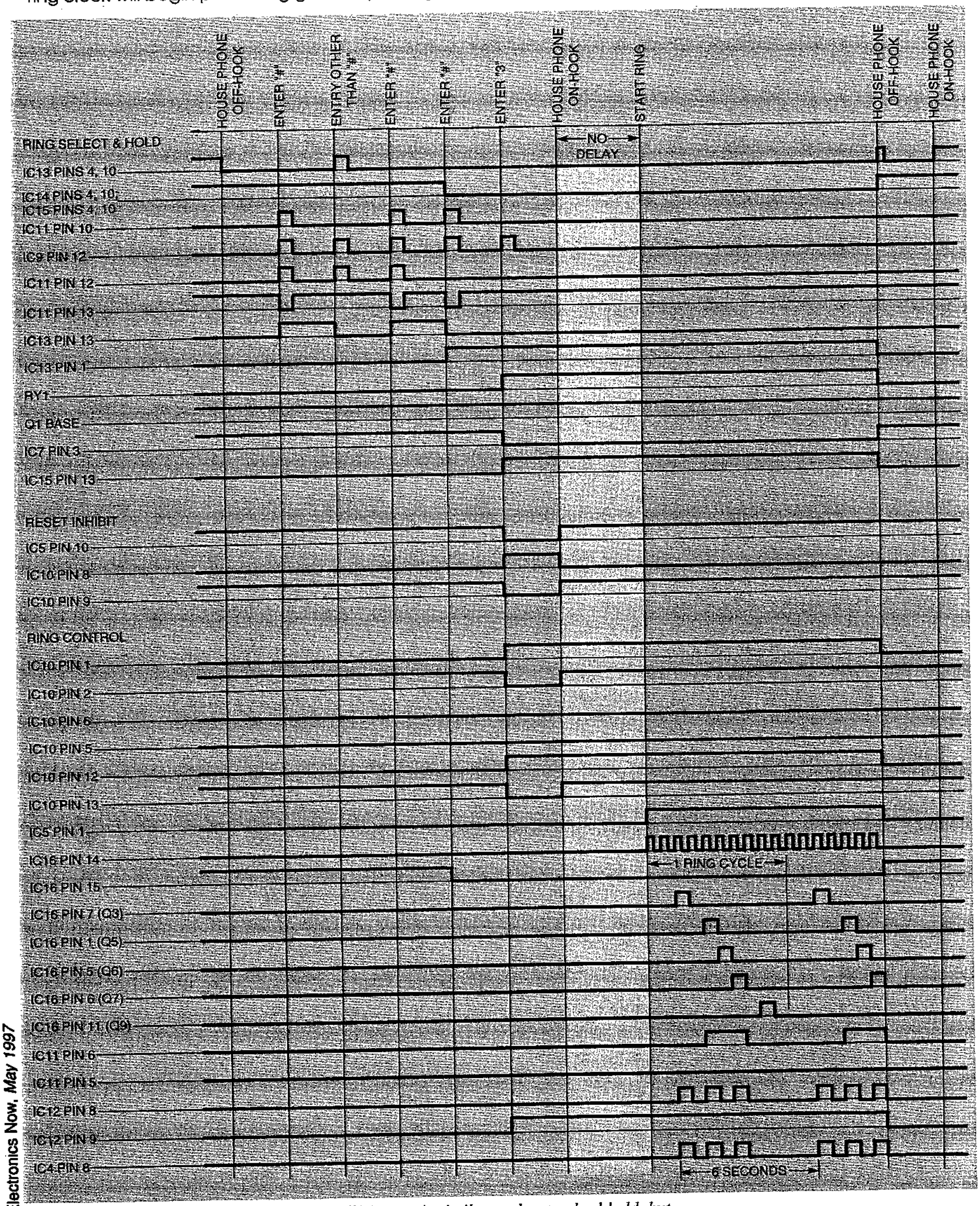


Fig. 3. The selective hold feature of the CallDirector is similar to the standard hold, but the phones are rung immediately with a pattern of 1 to 4 rings depending on which family member is to be alerted that the call is for them.

logic high appearing at the inputs to IC9-a also turns on Q2, which turns RY1 on When RY1 switches, the incoming telephone line is transferred to line-hold load resistor R64 Meanwhile, the house phones are connected to the output of ringer transformer T2 and the IC19/IC1-b off-hook detection circuitry.

When the outside telephone line is on hold, both inverting outputs of IC13 (pins 2 and 12) are low That interrupts current through D12, D13, and R31, which turns Q1 off. With Q1 off, audio from the music-on-hold input amplifier IC2-b is delivered to line driver IC2-a for placement on the outside phone line Note that Q1 is also turned on through D6 during periods when a ring signal is actually being generated. That momentarily quiets the music-on-hold during the ring-back interval, resulting in a clear ring signal to the caller on hold

A caller is placed directly on standard hold as soon as the third successive "#" is entered. However, the ringer start delay timer does not begin the approximate 80-second countdown until the house phone that placed the caller on hold is actually placed back on the hook, which raises the reset inhibit (IC10 pin 13) high.

Reset Inhibit. The reset-inhibit circuit keeps an off-hook house phone from initiating a reset just after it has put an outside caller on hold and has been transferred to the off-hook detector IC19/IC1-b with RY1 Once the house phone is placed on-hook, the reset inhibit allows the very next off-hook condition to produce a reset. It also activates the ring circuitry immediately after the house phone goes on-hook following a selective (1-4) hold activation. In the case of a standard hold, however, the start of an actual ring is delayed by about 80 seconds through the ringer-start delay circuit.

Operation of the reset inhibit circuit centers on the latching circuit of IC5-c and IC5-d Normally, pin 8 of IC5 is held high through R66, R50 and the 5-volt supply source, while pin 9 is low through R56, R55, and the logic-low output of IC5-d (pin 11) The output of IC5-c is therefore at logic high as is pin 13 of IC10, pin 9 of IC10 (through R52), and the special ring-enable gate IC10-a pin 2 Note that the normal ring-enable gate IC10-b is operated from IC5-c pin 10 also, but through the ringer-start delay circuit

When any hold is invoked, IC10-d pin 12 goes high, and a momentary high coupled by C25 appears at IC5-c pin 9 through current-limiting resistor R56. That causes IC5-c pin 10 to go low and IC5-d pin 11 to go high, creating a latch condition where pin 10 now remains low. A low on IC5-c pin 10 disables IC10-c a few milliseconds before the off-hook house phone being transferred to the off-hook detector causes a logic high to appear on pin 8 of IC10 For the time being, that blocks the resetting of the IC13 flip-flops from occurring because a house phone is off-hook from a hold condition. Note also that both ring-enable gates, IC10-a and IC10-b, are now disabled so that even if a ring should be selected, it would not begin until the house phone is placed back on-hook.

When the house phone is placed back on-hook after initiating a hold, the output of off-hook detector IC1-b drops to near zero, resulting in a logic low appearing on IC10-c pin 8 through resistor R51. That logic low transition is coupled by C23 as a momentary low to IC5-c pin 8 through current-limiting resistor R66 A momentary low on pin 8 releases the latch, causing IC5-c pin 10 to go to and remain high That re-enables IC10-c so that the very next time a house phone goes off-hook, a logic high will appear on IC10-c pin 10 creating a reset through D38 At the same time, the special ring-enable gate, IC10-a, is enabled so that if a special ring is selected, it will begin immediately. Pin 13 of IC10 also goes high, and since pin 12 is already high, pin 11 goes high initiating the 80-second time interval

Ringer-Start Delay. The ringer-start delay consists of an enabling gate (IC10-d) and IC17, which is wired as a comparator and whose output will remain at near zero volts until the voltage on its pin 3 exceeds the reference voltage on pin 2 set by R58 and R61. When IC10-d pin 11 goes high, C26 begins charging through R59 In about 80 seconds, the voltage across C26 will reach 3.4 volts, which is the comparator reference, and pin 6 will then switch to about 16 volts That is coupled by current-limiting resistor R57 as a logic high to normal ring-enable gate IC10-b pin 5 If a standard hold was initially set by the hold mode flip-flops, the normal ring will have been selected and will now begin

When an on-hold call is picked up by any house phone, the reset generated releases all flip-flops Any action or condition set by the latched flip-flops is discontinued-including the return of IC10-d pin 12 (and therefore pin 11) to logic low, quickly discharging C26 through R60 and D42 Other results of resetting the flip-flops include re-enabling the DTMF decoder; releasing RY1 through Q1, which transfers the house phones back to the incoming-phone line; disabling the cadence-selection gate; resetting ring-cadence counter IC16; removing music-on-hold audio from the input of line-driver IC2-a if the standard hold was selected; and re-enabling IC9-d so that "#" DTMF tones are the only recognized inputs

Selective Hold. If the third DTMF input is any number between 1 and 4 instead of 9 or "#", the binary-coded-decimal output from IC7 delivered to binary-to-decimal converter IC6 will cause one of IC6 pins 14, 2, 15, or 1 to go high. That will set one of the flip-flops in either IC14 or IC15 corresponding to that number. At that time, only the second # flip-flop in IC13 is latched along with one of the number-input flip-flops (IC14 or IC15)

A logic high on any of the IC14 or IC15 flip-flop non-inverting outputs will disable the DTMF decoder through one of diodes D7-D10 and

IC9-a. The same logic high will also enable special ring-enable gate IC10-a pin 1 through one of diodes D14-D17. Note that operation of Q2 and RY1 and the reset-inhibit function is the same as for a standard hold except that when IC5-c and IC5-d unlatch, there is no delay in activating the ringer. When IC5-c pin 10 goes high, IC10-a pin 2 receives a logic high and the ring sequencing begins immediately.

Ringer. The ringer circuitry is designed to generate a ring having a specific cadence depending on which one of five logic levels goes (and remains) high. The ringer output develops a 25-Hz, 90-volt-rms sine wave capable of reliably ringing house telephones with a total ringer equivalence number (REN) of 5.0.

Every telephone or line-connected device that can detect a ring signal will have its REN clearly labeled somewhere on the device. The total of all of the individual REN values is a measure of the ring load on a particular phone line. The design of the CallDirector matches the telephone company's standard of a maximum REN of 5.0 on any telephone line.

The CallDirector ringer begins with the ring clock, consisting of IC5-a and IC5-b. That oscillator generates pulses at a rate of one positive logic transition every 600 milliseconds. The ring clock sets the basic rate of all ring cadences produced by the ringer. The ring clock operates only when either IC10-a or IC10-b places a logic high through D36 or D37 on pin 1 of IC5. Output from the ring clock (IC5-b pin 4) drives the clock input of decade counter IC16. That counter sequentially places a logic high on one of its ten outputs, incrementing whenever a low-to-high logic transition occurs at its clock input.

The reset on pin 15 of IC16 is removed when the CallDirector receives a second "#" input. When a ring is selected and the ring clock is enabled, IC16 begins counting through its ten outputs fully completing a count sequence every 6 seconds, which is the standard ring cycle for telephone systems in the US. Each high level on the output pins of IC16 remains for 600 milliseconds before moving on to the next pin. Those outputs, of which only five are needed to develop all the rings needed by the CallDirector, are coupled in various ways by a straight connection and by steering diodes D18-D29 to create five different patterns of logic highs and lows. Those patterns, repeating every 6 seconds, correspond to the five different ring types needed for the standard and selective hold features of the CallDirector as previously described.

The five different logic patterns are delivered to ring-select gates IC12-a, IC12-b, IC12-c, IC12-d, and IC11-b. Depending on the desired ring cadence, only one of those five gates will be enabled by the latched flip-flop corresponding to the chosen hold condition. The resulting selection will produce a logic high/low pattern corresponding to the desired ring and will appear on ring-frequency oscillator IC4-c pin 8. Whenever IC4-c pin 8 is high, IC4-c and IC4-d will generate a 25-Hz squarewave. That signal is delivered through D45 to the ring-back oscillator and through capacitive coupling to active-low-pass filter IC1-a.

The ring-back oscillator generates a 600-Hz signal that is gated at a 25-Hz rate. That signal, filtered by R19 and C16 to soften the typically sharp sound of a squarewave, is then capacitively coupled by C17 to phone-line driver IC2-a. Telephone users have been conditioned over time to expect a ring back as an indication that a remote telephone is ringing. That is an important feature, as it prevents a caller from believing that the call may have been disconnected. The CallDirector generates that ring back for all ring conditions.

The 25-Hz signal is also coupled through C8 to operational amplifier IC1-a, which is set up as a third-order (18-dB/octave) active-low-pass filter. Bias needed to operate IC1-a from a single-ended power supply comes from voltage divider R16/R27, filtered by C9, and delivered to the positive input through R6 and filter resistors R5, R4, and R3. The 25-Hz output waveform from IC1-a pin 1 is almost a sinewave. Voltage divider R7 and ring-adjustment resistor R8 set the signal input level to IC3 for a ringer output of 90 volts RMS.

Using the LM383 ring-power amplifier (IC3) is a straight forward use of the device directly from the manufacturer's data sheet. The gain is reduced slightly through selection of R9 and R10 to ease the one-time startup adjustment of R8. The LM383 was chosen because of its ability to deliver high currents. That is an important consideration when working with both the inductive characteristics of T2 and a load whose impedance can vary. It also features an easy-to-use TO-220 package with the heat sinking tab at ground potential.

Transformer T2 is simply a 10-watt 70-volt line transformer used typically for connecting loudspeakers to paging-type public-address systems that have long speaker-cable runs. That type of transformer is readily available, inexpensive, and has the needed steel in its core to handle the 25-Hz ring frequency at the required amplitude levels. It is used in reverse with the 8-ohm winding considered the primary and the 0.625-watt tap the high-voltage secondary.

Music on Hold. The music-on-hold input, J4, is fully isolated from the CallDirector circuitry by T3. That is important because the CallDirector circuit is directly connected to the telephone line, and the music source, typically a tuner, cannot be guaranteed to be completely isolated from the AC power line. In the interest of safety, it is best to isolate any chance of accidental connection between the power lines and the phone line.

The music level for the phone line is adjusted by R32. The gain of IC2-b is set by R28 and R30 to about 10. Both IC2-a and IC2-b are powered from the single-ended 16-volt power

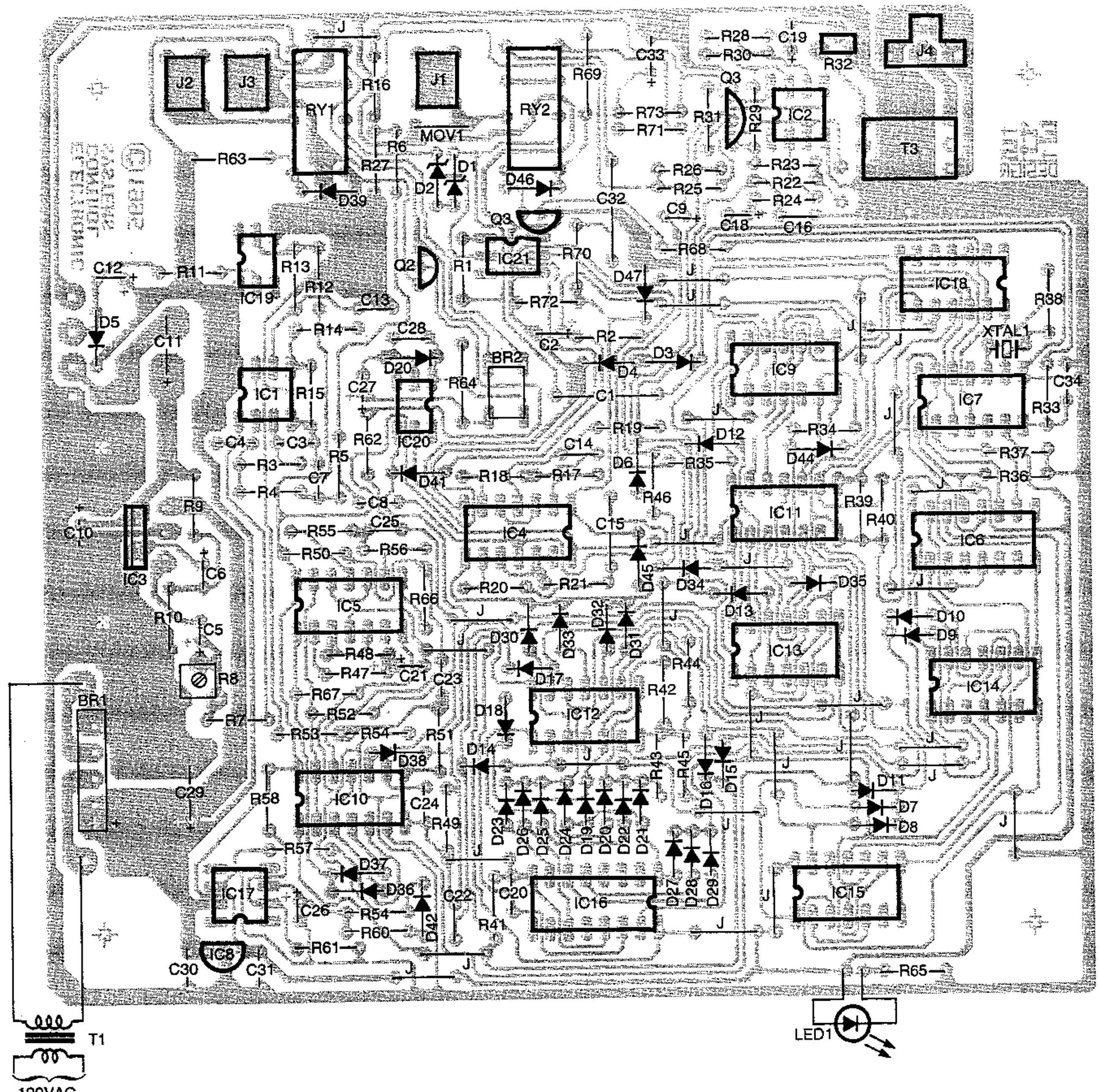
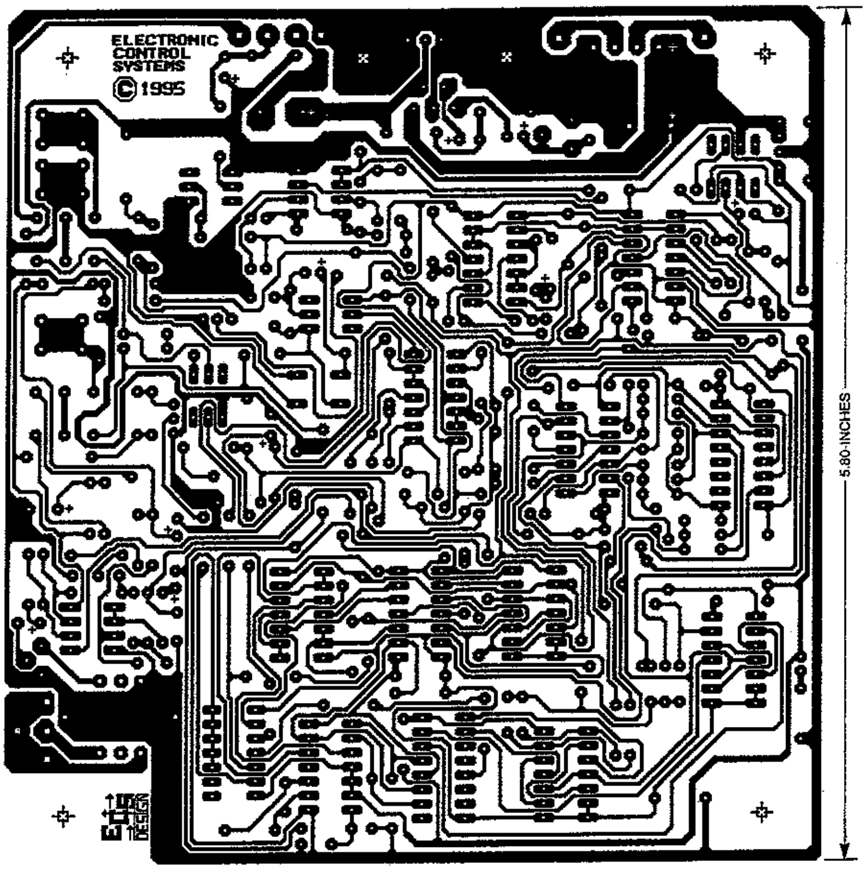


Fig 4. If you build the CallDirector on a PC board from the source given in the Parts List or etch your own from the supplied pattern, use this parts-placement diagram to locate the various components You might wish to mount LED1 on the CallDirector's enclosure.

supply source by biasing their non-inverting inputs through R25 and R26 respectively to one-half of the power-supply voltage Sufficient gain and level control are provided to accommodate line audio from a tuner, compact-disc player, or even the headphone output of an inexpensive portable radio.

The music-on-hold input and the audio path are both available to the phone line all the time To prevent the music-on-hold audio from appearing on the phone line at times other than when a caller is placed on hold Q1 is turned on, bypassing the audio signal from IC2-b to ground When both flip-flops of IC13 are set and their inverting outputs are low indicating a standard hold, current through D12, D13, and R31 is interrupted turning off Q1

As soon as the standard hold time exceeds about 80 seconds, the CallDirector generates a normal ring on all house phones along with an audio ring back as discussed earlier The logic high levels from the ring-select gates that enable the ring-frequency oscillator also appear through D6 at R31 turning on Q1 during the ring interval That disables music-on-hold only when the actual ring back is taking place



Here is the foil pattern for the CallDirector. Thanks to the use of many jumper wires, the CallDirector's entire circuit fits onto one single-sided board

Loop Current-Change Detector. When a call is placed on hold, RY1 transfers the telephone line to the AC inputs of BR2, which allows the polarity-sensitive circuitry of the loop-current change detector to operate even if the incoming phone-line polarity is reversed According to telephone-line standards, the green wire is the positive side of the 48-volt DC local-loop battery at the central office; the red wire is the return But those colors are sometimes accidentally reversed in the house wiring

The loop-current change detector generates a momentary reset whenever the CallDirector has a hold in progress and the phone-line loop current decreases. That feature allows the CallDirector to release the hold if another telephone on the local loop that is not connected to the output of the CallDirector is picked up If the CallDirector is placed at the central phone-distribution point and all house phones are connected to its output, the loop-current change detect circuitry is not needed It is included as a user-friendly feature to give the CallDirector additional versatility if not being used to operate all phones

When the actual transfer to hold takes place, central-office loop current flows through R64 and D40 to charge C27. Since the charging current forward biases D40, C28 and the LED in IC20 are effectively not in the circuit If the loop current decreases after having been established, C27 will partially discharge as the voltage across R64 decreases The discharge current will flow in a direction opposite the charge current, reverse biasing D40 and momentarily forward biasing the LED in IC20 When the phototransistor in IC20 turns on, a logic high will occur on the reset line releasing all flip-flops.

Using the Intercom. Operation of the CallDirector intercom is in nearly all respects the same as when in the selective hold except for one fundamental and important difference If just after the second of two "#" entries is made a 9 is entered, RY2 transfers the outside telephone line to an on-hook state The central-office battery to the house phones is then replaced by a power source within the CallDirector. That substitute battery is actually the CallDirector's 16-volt source filtered by R73 and C33, then given an impedance to audio signals of about 100-ohms by R71 That arrangement allows enough talk current for the local in home "loop" to operate two or three telephones

At the same time, C32, current-limiting resistor R70, and voltage-limiting Zener diode D47 couple any ring signals that may come in while the intercom is being used to the ring-back oscillator (IC4-a and IC4-b). With each incoming ring-voltage pulse, the 600-Hz oscillator is turned on, producing a low-level ring signal which is then injected into the CallDirector's home loop by line driver IC2-a

Relay RY2 is turned on by Q3, which is controlled by flip-flop IC18 Like all other flip-flops in the CallDirector, IC18 is a "D"-type flip-flop, which means it transfers the logic state of its data input to its outputs whenever the clock input changes from logic low to logic high. The non-inverting output is always at a logic state opposite that of the inverting output The reset input, when momentarily clocked high, will return the non-inverting output to its normal logic low condition.

The clock input of IC18 is operated directly from the decoded "9" output of IC6 Whenever a DTMF "9" is received by the enabled DTMF receiver IC7, a momentary logic high will appear at IC18 pin 11 However, a number of conditions must exist before the flip-flop will actually latch First, the reset on IC18 (pin 10) is removed whenever a house phone is off-hook. Next, the "D" input is logic low until the second "#" DTMF latches the second half of IC13, placing its pin 1 high. That normally-low condition on the input of IC18 prevents the flip-flop from changing its outputs until the entry of a second "#" because its clock would simply continue to transfer the logic low through to its output, which is already in a logic low condition

After the second "#" is received, the input of IC18 goes high If a 9 were to then be received, IC18 would transfer and hold that high on its output (pin 13). That would turn on Q3 through R68, operating RY2 At that point, the CallDirector can initiate a special ring and hold as described earlier Note that when the CallDirector goes into the hold mode in order to ring the phones with the desired ring, the reset on IC18 stays off because IC21 continues to detect an off-hook condition. When any phone is then picked up. the CallDirector resets all of the hold logic. but the off-hook phone keeps IC18 from resetting, which keeps the local talk "battery" supplying current to the in-house phones. When the last of the phones is placed back on-hook, IC18 is reset and the intercom feature is released

Note that when the intercom is activated, the standard hold is blocked by preventing any attempt at entering a third "#" from latching IC13 pin 13 That occurs when IC18 latches and its inverting output (pin 12) goes low, and through D44 holds IC13 pin 11 low, effectively disabling its clock input Note also that pin 12, which is normally high, provides operating voltage for the loop-current change detector IC20 When the intercom is active, that voltage is removed, disabling the loop-current change detector That function is unnecessary in the intercom mode and by deactivating it as soon as the intercom feature is started, a possible CallDirector reset is prevented when the loop current changes by transferring the RY2 contacts, or by any electrical disturbance on the public network side of the CallDirector

PARTS LIST FOR THE CALLDIRECTOR

SEMICONDUCTORS

IC1, IC2—LM1458A dual operational amplifier, integrated circuit
IC3—TDA2002 or LM383 power amplifier, integrated circuit
IC4, IC5, IC9—CD4011 CMOS quad nand gate, integrated circuit
IC6—CD4028 CMOS binary-to-decimal converter, integrated circuit
IC7—MC145436 DTMF receiver, integrated circuit
IC8—78L05 voltage regulator, integrated circuit
IC10–IC12—CD4081 CMOS quad and gate, integrated circuit
IC13–IC15, IC18—CD4013 CMOS dual D flip-flop, integrated circuit
IC16—CD4017 CMOS decade counter, integrated circuit
IC17—LM741A operational amplifier, integrated circuit
IC19, IC20—4N25 opto-coupler, integrated circuit
IC21—H11A1 opto-coupler, integrated circuit
Q1–Q3—2N4401 NPN transistor
BR1—Bridge Rectifier, 50-volt, 2-amp (Digi-key BR805D-ND or similar)
BR2—Bridge Rectifier, 50-volt, 1-amp
D1-D5, D47—1N751A, Zener diode
D6-D42, D44-D46—1N914 silicon diode
D43—not used
LED1—Light-emitting diode, red

RESISTORS

(All resistors are ¼-watt, 5% units, unless otherwise noted.)
R1, R71, R73—100-ohm
R2, R60—1,000-ohm
R3–R5, R25, R26—200,000-ohm
R6, R38, R59—1-megohm
R7, R33—4,700-ohm
R8—2,000-ohm, trimmer potentiometer
R9—220-ohm
R10—10-ohm
R11, R15, R65—470-ohm
R12, R14, R16, R19, R22, R27–R29, R31, R34–R37, R39–R46, R52–R56, R62, R66–R68, R70—10,000-ohm
R13—390,000-ohm
R17, R20, R30, R47, R49–R51, R57, R61, R72—100,000-ohm
R18—33,000-ohm
R21—82,000-ohm, 1%, metal-film
R23, R58—47,000-ohm
R24—560-ohm
R32—25,000-ohm, trimmer potentiometer
R48—51,000-ohm
R63, R69—150-ohm, ½ watt
R64—680-ohm, ½-watt

CAPACITORS

C1, C32—0.33-µF, polyester
C2—1.0-µF, 50-WVDC, electrolytic
C3—0.01-µF, ceramic-disc
C4, C16, C34—0.05-µF, ceramic disc
C5, C9, C19, C27—10-µF, 35-WVDC, electrolytic
C6, C12—470-µF, 10-WVDC, electrolytic
C7—0.039-µF, ceramic disc
C8, C13, C17, C22–C25, C28, C30, C31—0.1-µF, ceramic disc
C10—1.0-µF, 16-WVDC, tantalum
C11—4700-µF, 16-WVDC, electrolytic
C14, C20—0.02-µF, ceramic disc
C15—0.22-µF, polyester
C18—22-µF, 35-WVDC, electrolytic
C21—4.7-µF, 10-WVDC, non-polarized electrolytic
C26—47-µF, 10-WVDC, electrolytic
C29—2200-µF, 25-WVDC, electrolytic
C33—470-µF, 25-WVDC, electrolytic

ADDITIONAL PARTS AND MATERIALS

J1–J3—screw terminal, PC-mount
J4—RCA jack, PC-mount
MOV1—Metal-oxide varistor, 130 volts, 11 joules
RY1, RY2—double-pole, double-throw, 12-volt relay
T1—12-volt, 900-milliamp, power transformer
T2—70-volt, 10-watt, line transformer
T3—10,000-ohm/10,000-ohm, 200 milliamp, coupling transformer
XTAL1—3.58-MHz crystal, HC-18 case
Heatsink, wire, printed-circuit board, enclosure, hardware, etc.

Note: The following items are available from: Electronic Control Systems, RD2, Box 3308, Wernersville, PA 19565: Complete kit of all parts, printed-circuit board, and enclosure, $144.00; Printed-circuit board only, $22.00. Please add $6.00 for kit or $3.00 for PC board shipping/handling. PA residents should add 6% sales tax.

CallDirector Construction. Construction of the CallDirector is straight forward using standard assembly techniques Use of an etched and drilled PC board is recommended as it greatly reduces the chance of wiring error in what is a fairly complicated circuit Another benefit of a PC board is a very compact unit If you decide to etch your own board from the pattern provided here or purchase one from the source given in the Parts List, follow the parts-placement diagram in Fig 4 That board design is single-sided for easy etching and

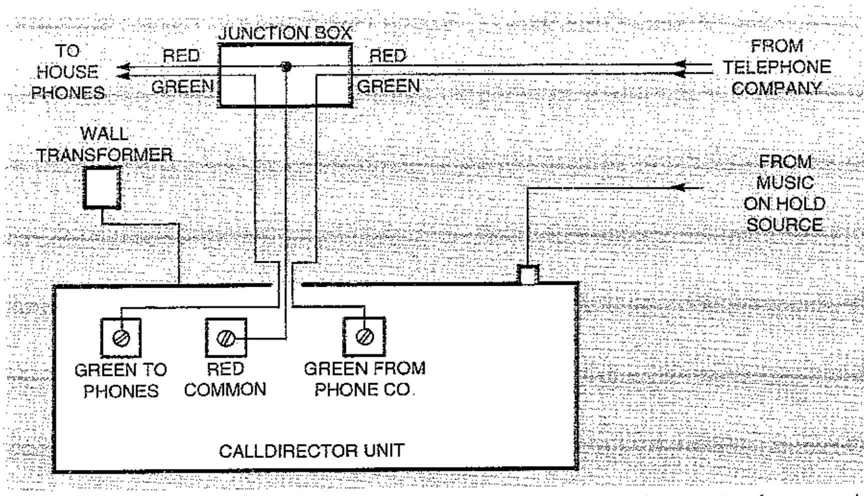


Fig 5. Because of the complexity of the CallDirector's circuitry, it is very simple to attach it to the telephone wiring Only one wire needs to be cut and both ends connected to the CallDirector. The other wire only needs to be branched into the unit

construction by the hobbyist

The use of a perfboard or other assembly method is certainly possible as no part of the CallDirector circuitry is especially sensitive to component spacing or orientation The only important considerations are that appropriate heatsinking for IC3 be provided. and C10 must be connected as close to IC3 as possible Since IC3 is in a standby mode at all times except when a ring is actually being generated, the heat sink need only be about 2 square inches of aluminum sheet metal bolted to IC3's tab with appropriate hardware Many commercial heat sinks are available for that device at very low cost The tab of IC3 is at ground potential so no mica insulator and shoulder washer insulation kit is needed

If you decide to use a PC board. it is a good idea to begin by loading the low-profile components (such as resistors) first Keep in mind that excess soldering heat can be damaging to semiconductors, such as diodes, transistors. and ICs. so those components are best installed last Another general reminder is the observance of component polarity. All components except resistors, ceramic-disc and polyester capacitors. MOV1. and T3 require a specific direction of installation

Many of the ICs used in the CallDirector are CMOS logic chips which are sensitive to static electricity. Always keep them in their shipping packages until you are ready to install them Experience over many years has shown that basic logic CMOS devices aren't nearly as electrically fragile as many believe. Still, caution and care are essential

The integrated circuits are oriented by either an embossed dot or a notch on one end of the case which identifies pin 1 Electrolytic capacitors are marked to identify polarity and many have one longer lead—usually the positive lead. Diodes have a dark band on one end of their case to identify the cathode Light-emitting diodes have a "flat" in the body which identifies the cathode Sometimes they also have a longer lead, which indicates the anode

The excess lead trimmings from the resistors capacitors, and diodes can be used as jumpers. The jumpers all have the same spacing, so that several can be formed together, speeding that part of the assembly Next, mount all diodes making sure to note the locations of Zener diodes Mount the transistors, bridge rectifiers, capacitors, and all other components except integrated circuits in that approximate order All ICs are then installed with IC3 and its heat sink being last

Before mounting IC3, attach the heat sink to the board The heatsink listed in the Parts List is secured with either two self-tapping machine screws or solder tabs at the base of the heat sink Orient the heat sink and place it on the board. If solder pins are provided. be sure the heat sink is tightly against the top surface of the board before soldering its pins. Soldering the heatsink will require more heat than that which is typically available from a small soldering iron of about 15- to 25-watt capacity considered safe for PC board work A 100-watt soldering gun will work nicely for the heatsink. Apply sufficient heat to thoroughly melt a generous amount of solder around each heatsink pin If you use a screw-mount heatsink. be sure to securely tighten the screws without overtightening them Once the heatsink is mounted, place IC3 in position Insert the pins through the PC board and attach IC3 to the heatsink with a 4-40 screw and hex nut and a small amount of heat-transfer compound

Cabinet choice is not critical since there are no special ventilating or shielding requirements and there are no exposed dangerous voltages if a wall-mount plug-in transformer is used

Hookup and Testing. Because all CallDirector control functions are performed through DTMF inputs from the house telephones, the unit is connected at a common point in the house telephone wiring between the telephone company and all of the telephones in the house That location is sometimes called the phone company "demarcation" point It is usually in an out-of-the-way place such as a basement or utility room Connecting all telephones in the house to the CallDirector is best so that hold. transfer, and intercom service is provided throughout the entire house In connecting the CallDirector to the telephone wires, follow the diagram in Fig. 5

There are only two adjustments needed for proper operation of the CallDirector: the ringer-voltage adjustment control (R8) and the music-on-hold volume adjustment (R32) Both of those adjustments are made after the CallDirector has been powered up and its main supply voltages are confirmed to be at their proper levels

Before applying power to the CallDirector for the first time, measure the resistance between both of the 16- and 5-volt supplies and ground Both should measure over 1,000-ohms. If they don't, check the PC board for misplaced components or solder bridges between the traces Once that check is done, connect a voltmeter across the 5-volt supply and ground and apply power to the CallDirector If the 5-volt supply doesn't come up, disconnect power immediately and troubleshoot the problem If the voltage is correct, measure the 16-volt supply. That supply is unregulated and should indicate nearly 18 volts without the ringer operating, but should not be less than 16 5 volts

For ring-voltage adjustment, connect a telephone to the CallDirector with a REN of as close to 1 0 as possible Set R8 at an initial position of about ten o clock. Connect a voltmeter capable of measuring rms voltages of 120 volts at 20 Hz across the CallDirector output phone line, or across the secondary of T2, whichever is more convenient. Note that most modern digital multimeters will be able to measure that voltage with sufficient accuracy.

Pick up the phone and dial "###" which will put the outside line on hold It's best to actually have someone call you during the test The reason is that many phone companies will drop loop current within a minute or so after a subscriber's phone goes off-hook without actually calling someone. If the CallDirector were in a hold condition on such a line, the loop current drop would be interpreted as a caller hanging up and would reset the CallDirector without its generating a ring after the 80-second delay. After the approximate 80-second delay, the CallDirector will begin generating a standard ring There should be enough time during the ring intervals to adjust R8 for a nominal ring voltage of 90-volts rms. Momentarily lifting the phone off-hook will reset the CallDirector and discontinue the ring

The music-on-hold level is most easily set through a trial-and-error procedure Connect a music source to J4. That can be any source having a line output such as a radio tuner. A small portable monaural radio with a 120-volt adapter and a headphone jack is a reliable and inexpensive music-on-hold source Buy or make a cable to mate the radio headphone jack to the jack used for J4 on the CallDirector Note that many monaural radios actually have stereo headphone jacks to accommodate inexpensive "Walkman" style headsets. Be sure to consider that when either buying the connector for making the cable, or choosing a pre-made cable

If a line level connection is to be made, simply plug the tuner into the CallDirector with a standard RCA patch cable If a portable radio is used, tune in the desired station and set the speaker volume to a comfortable listening level before plugging in the mating cable to the CallDirector Set R32 to about ¼-turn as an initial setting. Call a friend and place them on hold Pick up the phone after several seconds and readjust the volume depending on the report by the friend Repeat the hold and adjustment as needed until the music is at a comfortable level. The only caution is to not make music on hold too loud as crosstalk onto other phone circuits is possible if the line is overdriven.

The CallDirector should now be checked for all operating features and all ring selections The following is a test checklist The first part is performed with another party on the line.

1. "###"—Standard hold. After 80 seconds a standard ring begins. Pick up the phone.
2. "##1"—Selective hold There should be an immediate generation of 1 short ring Pick up the phone
3. "##2"—Selective hold There should be an immediate generation of 2 short rings Pick up the phone.
4. "##3"—Selective hold There should be an immediate generation of 3 short rings Pick up the phone Confirm with the caller that audible ring back could be heard
5. "##4"—Selective hold. There should be an immediate generation of 4 short rings This time have the helper hang up and confirm that the CallDirector stops ringing within no more than about one minute of the caller hanging up On most phone systems, the ring line current is interrupted much sooner, often within five or ten seconds
6. "##94"—Intercom and ring four. A caller is not needed for this test. There should be an immediate generation of 4 short rings, but the incoming phone line is not held off-hook Pick up a second phone and confirm that both telephone voice circuits are operational by speaking into one phone and hearing the voice in the earpiece of the other phone The earpiece should otherwise be silent Momentarily place the phone on-hook to return a dial tone
7. Repeat step 6, but this time coordinate the timing of the test so that an outside caller will call in while the intercom is being used When the call comes in, an electronic ring signal should be heard in the earpiece. Momentarily place the phone on-hook to connect to the caller
8. Repeat step 6, and while checking the telephone voice circuit, disconnect power to the CallDirector The phone should immediately connect through to the incoming phone line.

If all of those tests are completed satisfactorily, the CallDirector is ready to be placed into service. The CallDirector unit is rugged and dependable and is conservatively designed for many years of trouble-free service The more you use the CallDirector, the more you will like its step-saving features So go ahead enjoy, and be spoiled by your new phone system! But be ready, because your friends will probably want a CallDirector too. Unfortunately, they can't get one of these things at any price, not even from the phone company Ω