Steve Ciarcia

# Build a Trainable Infrared Master Controller

*This device can control all your home entertainment equipment*

First of all, this is not the second part of a two-part article. As you will come to understand, this month's project is the solution to a problem I aggravated by building last month's project (an infrared remote control for my home control system). Confused? Let me explain.

While people residing in warm climates tend toward Jacuzzis and hot tubs, some of us who live in colder climates prefer not to tempt fate and brave the elements for about six months of the year. Of course, I could succumb to the winter sports thing. You know, skiing, skating, snow this, and snow that, but it would be much too great a chore at this stage to reorient my sedentary lifestyle to enjoy northeast winters. I hibernate like most indigenous mammals and wait for the color outside the window to metamorphose from white to green.

About a year ago, I decided that holing up in the cellar for six months a year was antisocial. While the isolation proved beneficial in coming up with great projects for the summer and fall issues, I did find that by the time March rolled around, I looked very much like a bear that was leaving his cave, and I communicated just about as well.

In an attempt to improve the quality of winter life and break the cycle of hibernation, this last year I decided to spend some of the time aboveground (upstairs) in an environment that allowed me to observe the realities of my existence (through the windows) and absorb the cumulative knowledge of our culture (watch TV).

In layman's terms, I built a media room. Not just a TV den, mind you, but a room where I could be immersed in a synthesized environment so far from the ice and snow that six months seemed like overnight. Of course, this audiovisual experience was tastefully produced by massive amounts of electronic equipment.

The beautiful scene of the tropical island was accurately reproduced on a Kloss 2000 projection TV. You'd think you were sitting next to that tinkling waterfall as the music moves above and around you in complete surround sound. And when the warm breeze of island spring (actually the heat wafting from the seven amplifiers) is tumultuously interrupted by a hurricane faithfully reproduced with 2400 watts of Nakamichi audio power through a pair of B&W 808s (180 pounds each), two Speakerlab subwoofers, and 11 Canton surround speakers, you feel like the walls are about to explode. Sometimes it is good not to have neighbors.

Enough of warm breezes. I now had a new problem. In addition to all the audiovisual stuff, there were a couple of VCRs, an FM tuner, and a CD player. All this equipment required the 14 remote handheld controls shown in photo 1. Media rooms are a great idea, but you can't expect people to glue a dozen remotes on a long board. There had to be a better way.

## IR Master Controller to the Rescue

This month's project, an infrared Master Controller that takes charge of all your gadgets, can prevent "controller clutter." It "learns" the infrared signals for each function and plays them back on command. It uses a six-button keypad to select the device and functions, shown on a two-line LCD, and a single button, Do It, to execute what's selected.

I am not the first person to design a trainable remote control. More than a year ago, I bought a similar device made by General Electric, called Control Central. This device could be trained to simulate the functions of four remotes.

Control Central and similar commercial units have two major shortcomings. First, all the acquisition, data-reduction, processing, and memory circuitry is contained in the single hand-held unit. Given the finite physical size of today's integrated circuitry, there is a limit to the capacity of such a device that allows it to still be cost-effective. Second, it is designed for use by a mass audience assumed to have a finite set of electronic devices. The buttons have predesignated nomenclature, so it is not user-programmable.

You can still train your GE controller to simulate the remote control for your CD player. The Mute button on the GE unit could be trained to be the Auto Repeat on your CD player remote, for example. Unfortunately, every time you want to repeat a CD, you'll have to remember to press Mute since there is no Repeat button on the GE.

I am not criticizing the GE Control Central. I am merely making a case for designing something different for a very vertical, gadget-happy, affluent audience: BYTE readers. Why tie a design to the lowest common denominator. Instead, yell "let them eat cake" and demand the remote to end all remotes: the Circuit Cellar Master Controller!

The shortcomings of the GE and other trainable remotes are the strengths of the Master Controller. Rather than attempt to contain all the necessary intelligence and processing circuitry, the Master Controller temporarily utilizes an external computer

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*Infrared controllers are not compatible because each manufacturer speaks in a different language.*

as a user-programmable interface. Also, rather than having buttons with fixed-function nomenclature, the Master Controller incorporates a scrolling LCD to identify unit designations (devices) and functions (commands). Device designations like "Bedroom VCR" or "Nakamichi preamp" and commands like "CD repeat/all" or "slow motion" are used instead of remembering what the Mute button was supposed to do.

The Master Controller uses an IBM PC for training. After that, it is battery-operated and completely independent. The IBM PC is connected to the Master Controller via an RS-232 interface and is used to set up menus of devices (receivers, CD players, tape decks) and functions for each device (turn on, play forward, etc.). After a menu is downloaded to the Master Controller, each function is "taught" and tested. Next, the completed menu and synthesis data are then uploaded to the IBM PC and stored on disk (in case you want to load it into another Master Controller or add another device later without retraining all of them).

The Master Controller's IBM PC program can also combine sets of infrared signals once they are trained for their respective devices. I can now use a single Master Controller button to turn on the audio system, route the output to the living room, select the CD player, move to the third selection, and repeat it forever. Compared to other commercial controllers, the Master Controller solves the IR remote plague hands down. Because it uses an external computer for functional modifications by the user, more room is available for its ultimate task. Instead of four remotes, the Master Controller can be trained to simulate the functions of 16 individual remote controls complete with descriptive command designations.

### An Infrared Introduction

Most infrared remote controls are functionally similar. The microprocessor in the remote controller creates a stream of bits that is turned into on/off pulses of IR light from an IR LED. An IR-sensitive photodiode in the receiver turns the light pulses back into an electrical signal from which the original bits can be extracted.

The IR LED's fast on-and-off action creates a carrier signal. The carrier is then turned on and off to form the individual bits of the message. Each controller uses a different carrier frequency, sets different bit timings, and assigns different meanings to the bits in the message. The reason that controllers are not compatible is that there is no standard for the format of the bits in the message. Each manufacturer speaks in a different language.

The Master Controller sidesteps this problem by simply recording and playing back the infrared signals without attempting to decode the messages. It's just like a tape recorder. You can record English, Russian, and Spanish on the same tape because they all occupy the same frequency bands, and you don't have to understand the languages to play them back.

This scheme works because of a limited range of differences in the IR signals. The controllers I've tested had carrier frequencies ranging from 32 to 48 kilohertz. Each message bit has between 10 and 30 carrier cycles, and there are two different carrier modulation systems: pulse-width modulation and pulse-position modulation. Last month I explained pulse-width modulation. Pulse-position modulation works by determining the time when a bit occurs relative to a fixed starting point.

### The Heart of the Master

An Intel 8031 single-chip microprocessor running a program stored in a 2764 EPROM directs the operation of the rest of the circuitry. (See photos 2 and 3 and figure 1.) The menus and IR signals are stored in a single 32K-byte battery-backed static RAM. The user interface consists of a two-line LCD and a six-button keypad. The keypad is either a simple membrane matrix or individual keys arranged in a matrix that is scanned by the 8031. This eliminates the need for a keyboard encoder. Two keys each are used for device and function up/down scrolling on the LCD. A fifth button, Do It, executes the device/function command appearing on the display. A sixth button, Learn, is used for training.

The LCD has 20 characters on each of two lines. The interface to it requires only six wires: four data bits, one timing strobe, and an address line. The display's internal character generator converts ASCII data into character dots, so the 8031 can communicate directly in ASCII.

A TIL413 photodiode converts the IR signals from other remote controllers into a discernible logic signal. Because the Master Controller and the remote are placed close together during training, there is no need for the sophisticated signal processing that's required to detect weak IR signals across a room. The Master Controller photodiode circuitry was designed to accept strong IR signals only. You should position the remote-control unit within a few inches of the Master Controller's photodiode. If it's too far away, the Master Controller will "see" nothing. If it's too close, the Master Controller will receive a distorted signal. A little experimenting with each controller will locate the correct position.

An LM311 comparator converts the photodiode input signal to a TTL-level signal. A 74LS164 shift register samples the output from the LM311 at a 1-megahertz rate and converts the data into


**Photo 1:** *The six-button Master Controller can duplicate the functions of the 14 controllers shown in the background.*

parallel format. The 8031 reads the shift register every 8 microseconds while it is learning a new IR signal. This data is stored in RAM for later analysis.

At the transmitting end, the process is reversed. Although the 8031 is a fast microprocessor, it cannot generate both the carrier and bit timing of the IR signals instantaneously. To lighten the processing overhead, an 8254 programmable interval timer controls the IR carrier frequency and duty cycle as well as the duration of each message bit. The 8031 sets up the 8254's registers for each bit of the IR message.

A pair of TIL39 infrared LEDs produce the IR signal. Because the human eye cannot see IR light, a visible LED is connected in parallel as an indicator. The LEDs are switched by a field-effect transistor driven by a standard logic gate. The FET is an efficient way to interface logic levels with real-world devices because it directly translates an input voltage into an output current.

## Power

Power is an important consideration in any battery-operated device. The Master Controller was designed to use either 74LS or 74HC devices at 5 volts. The 5 V is derived from a 6-V battery (four AA cells) using a special low-dropout voltage regulator. While LS takes considerably more power than HC, the duty cycle is low. The Master Controller need only be powered up long enough to set the device and function and press Do It. It can be shut off afterward. Admittedly, I could have spent more time developing automatic power up/down circuitry, but it would have complicated the design and added more software. Feature-specific circuit tailoring will have to wait.

Turning the power on and off is not a problem. The 8031's system software is contained in a 2764 EPROM, and the LCD and IR data are contained in battery-backed RAM. The memory is a 32K by 8-bit static low-power CMOS RAM chip. The backup circuit consists of two 3-V lithium batteries and a Dallas Semiconductor DS1210 battery-backup controller chip. The DS1210 senses loss of the +5-V supply voltage and automatically write-protects the RAM as it switches power to the battery. The second battery is necessary only if the first one fails.

## Signal Processing

As you can see from the schematic in figure 1, most of the Master Controller's functions are done in software. It's worthwhile to look more closely at the processing required for the learning and reproduction of the IR signals. The IR carrier frequency is about 40 kHz, giving a period of about 25 $\mu$s. The particular frequency used by a controller must be measured precisely because each microsecond of error changes the reproduced frequency by about 4 percent. While this doesn't sound like much, when the Master Controller reproduces the IR signal, the receiver could completely ignore it. The reason for this is that the IR receivers in consumer electronic gear must detect faint IR signals.

Generally, the receivers use a phase-locked loop, tuned to the remote unit's carrier frequency. The PLL can handle a 10 to 20 percent frequency error, but the design margins include errors due to temperature, voltage, and other effects.

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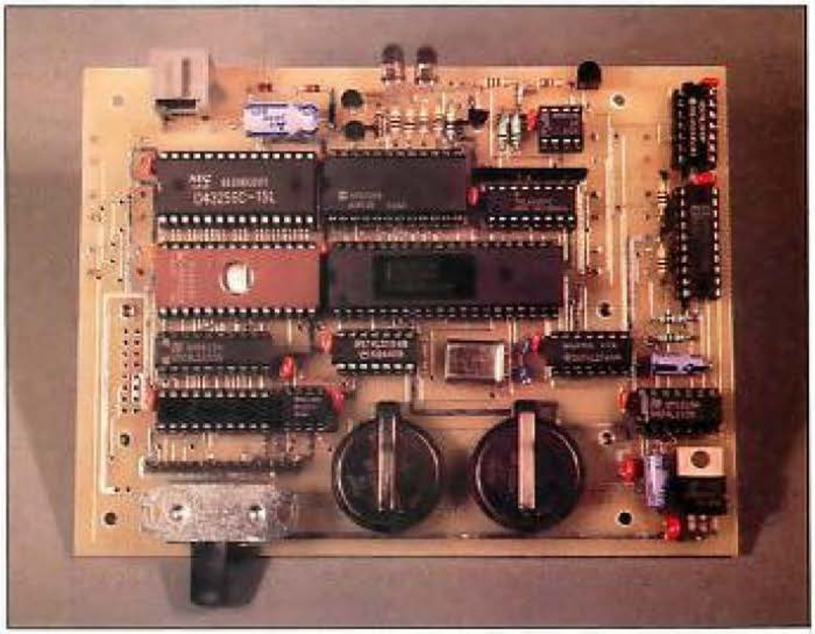


**Photo 2:** *Component side of the Master Controller, showing the 2764 EPROM and 8031 CPU (center left and right). The backup batteries and Dallas Semiconductor DS1210 battery controller are in the bottom center and right.*

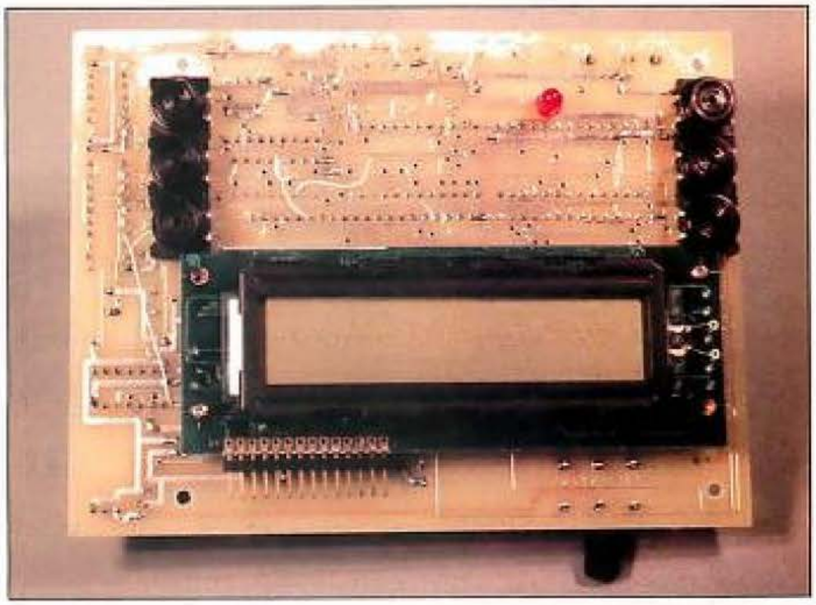


**Photo 3:** *The etch side of the Master Controller showing the 2-line by 20-character LCD and six control buttons.*

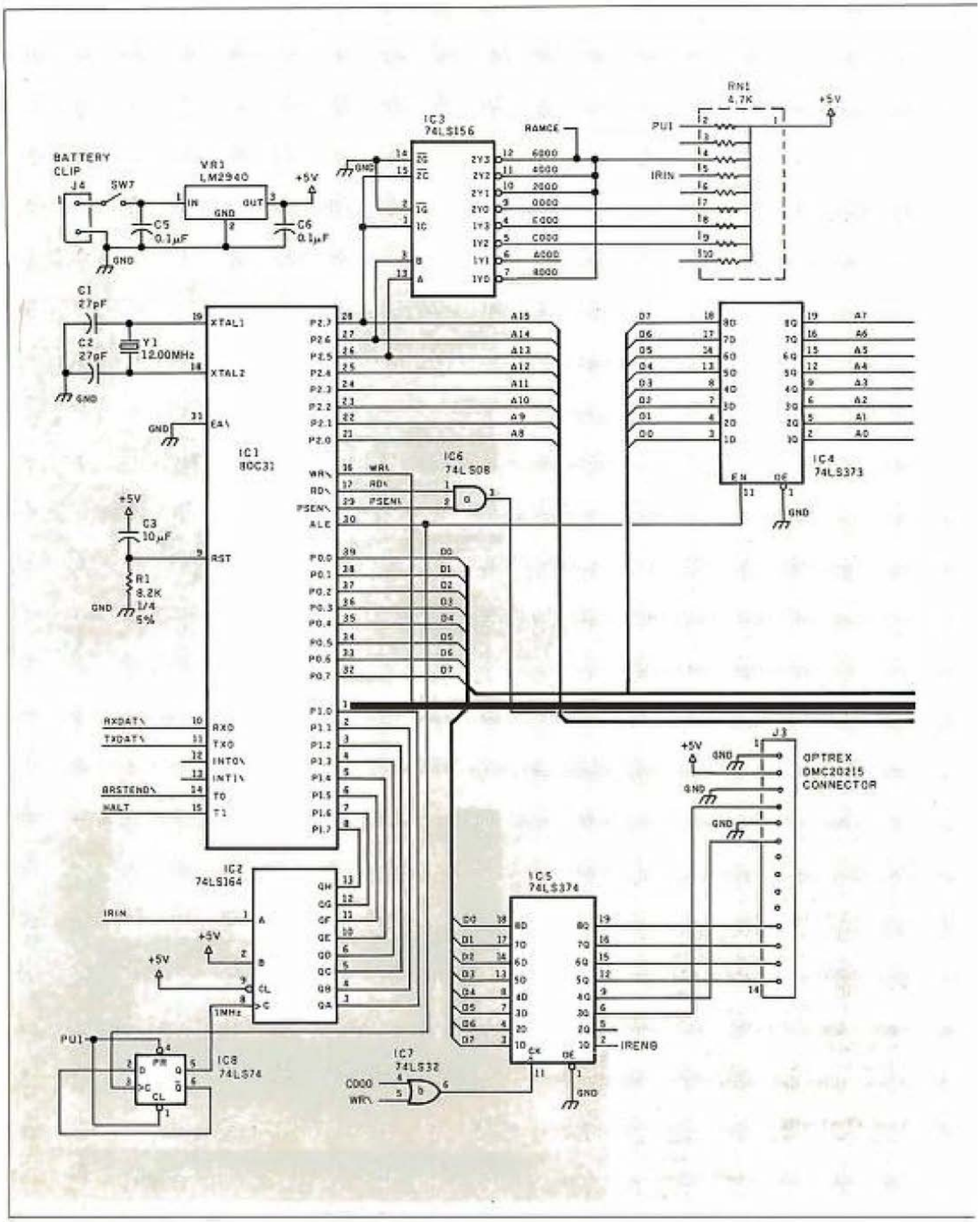
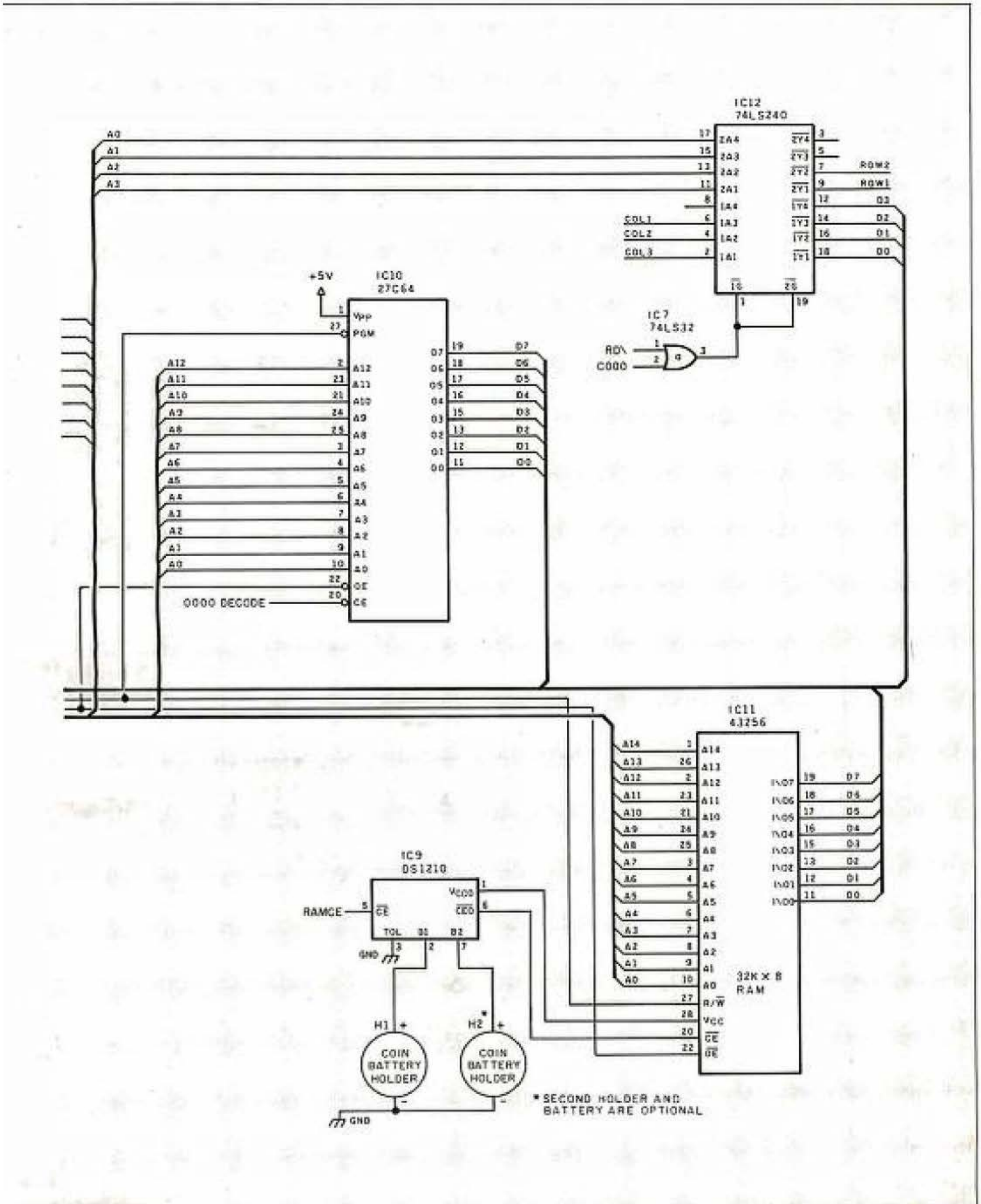



**Figure 1:** *Master Controller schematic diagram.*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