DESIGN YOUR OWN INFRARED REMOTE

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Most of the home appliances like TV sets, stereo systems, CD/DVD players/recorders, air-conditioners, microwave ovens, multimedia computers and set-top boxes come with an IR remote control.

An infrared remote offers several advantages:

1. It is a cost-effective signaling system.

2. Unlike radio-frequency-based control devices, it is not subject to any stringent regulation and restriction.

3. It is a line-of-sight system with a range of 5 to 10 metres, hence its radiation stays confined to a single room in which it is used. It thus prevents interference between units operating in different rooms even when using identical device address and command code.

4. A relatively broad modulation frequency range is available using inexpensive ASICs and components.

5. It is generally insensitive to interference from external electrical or magnetic fields.

6. It offers relatively high energy efficiency, which enhances the battery life.

7. Infrared emitters and detectors are inexpensive and readily available.

Limitations are:

1. Line-of-sight propagation becomes a limitation when you need to control a device from another room.

2. Infrared is subject to mutual interference from multiple sources in the same room as most consumer IR transmissions use a wavelength of either 880 or 940 nm (corresponding to the two commonly available IR-emitting LED types). This limitation can be tackled by using different sub-carrier frequencies to modulate the light signals coupled with different encoding schemes to carry the data content.

3. Although largely immune to electrical or magnetic interference, the infrared signal is somewhat subject to interference from sunlight and other infrared sources as also fluorescent lights.

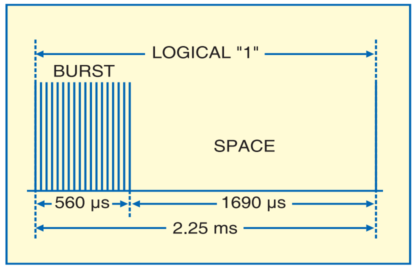


Fig. 1: Logic 1 format

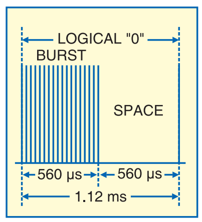


Fig. 2: Logic 0 format

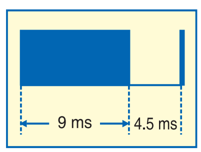


Fig. 3: Leader format

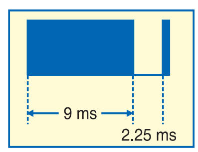


Fig. 4: Repeat format

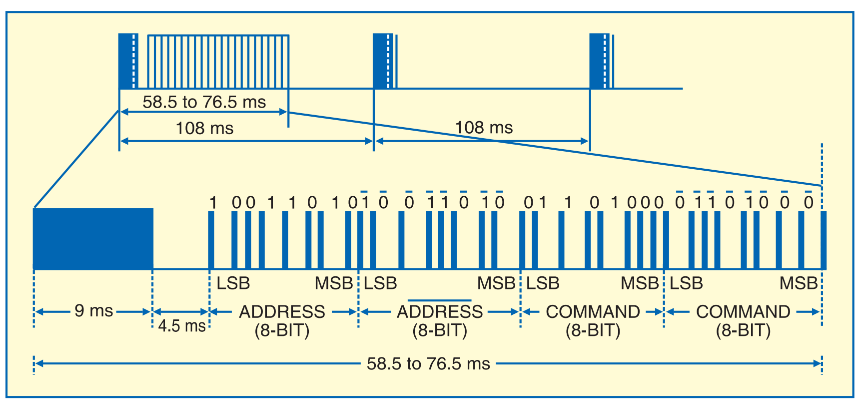


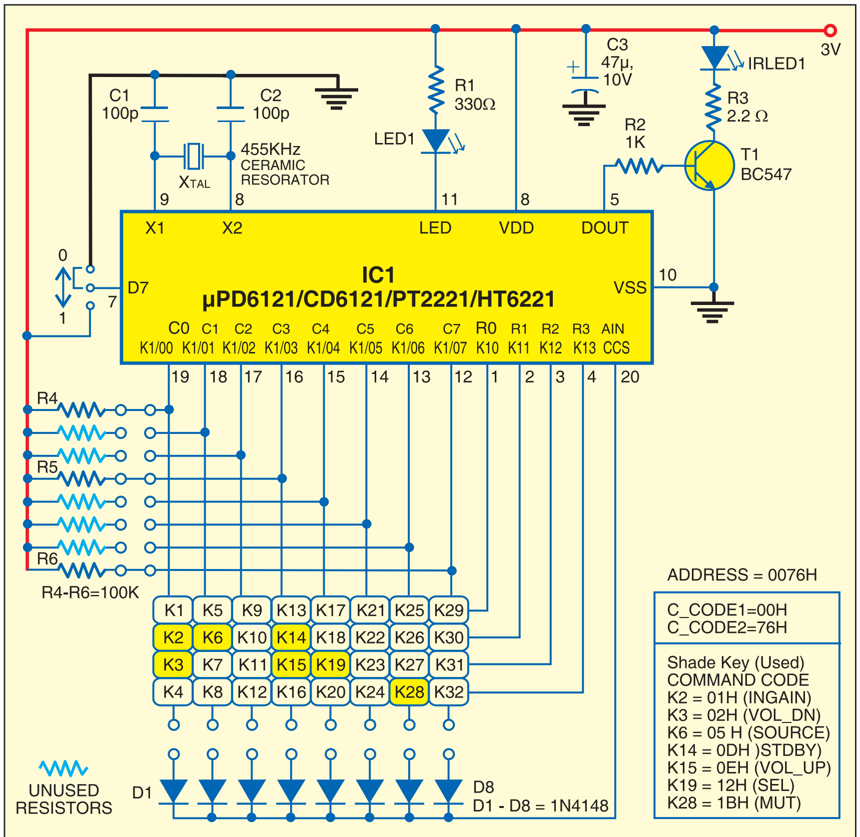
Fig. 5: Typical NEC transmission (above) and expanded view of first frame (below)

Encoding methods

Multitudes of different methods/formats/protocols for encoding the actual key/command/instruction data have evolved. Early IR command codes comprised five or six bits of information, which was adequate to encode a set of 32 or 64 key functions as simple binary values. With proliferation of the remote-controlled devices, addition of a device address or system code made it possible to operate multiple devices in the same room using the same command/instruction encoding scheme. For example, if we have five address or system bits and six command bits, we can operate 32 devices using 64 commands for each device, which may be used for identical or totally different functions in each specific device.

The NEC format features error control. It is of primary concern to prevent false operation rather than correct the wrong operation. In its most basic format, the transmitter repeats each IR data frame (explained later) some minimum number of times. The receiver compares the decoded data from two or more consecutive frames and ignores the signal if they are not identical. Sony, for example, uses such an approach in its standard IR protocol called 'SIRCS' (short for 'Sony infrared control system'). This technique is simple to implement and quite reliable.

Another popular solution is to send both the command value and its inverse. The receiver then compares the two halves of the received data and



(***Note.*** Three linked resistors for achieving address '0076H' and shaded keys for the command codes as shown in Fig. 6 were used for the 'Digital Audio Processor' project published in EFY Feb. 2005). The software for that digital audio processor has accordingly been modified and is given in this month's EFY-CD. Parts list and PCB details are given in this article.)

Fig. 6: A complete schematic of NEC remote employing 32 keys

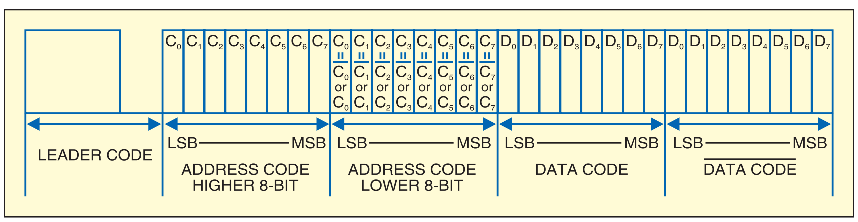


Fig. 7: Format of remote modulated output from pin 5 of encoder IC

ignores the command if they are not complement of each other. NEC uses such a format.

The third method makes use of a checksum, which generally results in a more compact frame size than sending the data and its inverse. This, however, requires a more complex receiver-decoding algorithm. This format is used by General Instruments. Some other encoding schemes include built-in redundancy to facilitate error checking without the use of any added data field.

Majority of the Asian manufacturers such as Pioneer, Onkyo, Akai, Canon, Goldstar, Hitachi, Kenwood, NEC, Teac and Yamaha use NEC format. Exceptions are Sony, Sharp, Toshiba and Philips. In this article, we shall focus on NEC and Philips RC5 formats, which are more commonly used. For both of these formats, dedicated encoder chips are available from a number of manufacturers.

NEC-format remotes

The actual data frame is sent only once in the NEC format, followed by a series of abbreviated repeat signals (9ms burst, followed by 2.25ms space terminated with 560µs burst) after every 108 ms for as long as the key remains pressed. Since the repeat frame signal consists of only a short 'blip' instead of the whole data frame, a key held down for a long period uses less energy than in many other encoding schemes.

The advantage of this approach is conservation of battery power. However, if the receiver misses the first frame for any reason, no recovery is possible as the subsequent signal pulses are devoid of any data. The key has to be released and pressed again before anything happens. Also, error detection in this approach requires use of data field and inverse data field.

Features of NEC format

1. 8-bit long addresses and 8-bit long commands are transmitted twice—however, the second (lower-order) address byte is not necessarily an exact complement of the first (higher-order) address byte, while the second command byte is a true complement of the first command byte. Thus a total of 64k (2^{16}) addresses and 256 (2^8) commands are possible. (***Note.*** The LSB of the bit pattern is transmitted first, followed by higher-order bits.)

2. Pulse-distance modulation

PARTS LIST (NEC REMOTE)

Semiconductors:	
IC1	- CD6121 remote Tx 20-pin SMT
T1	- BC548 npn transistor
IR LED1	- LD271 or equivalent IR LED
LED1	- Red LED
Resistors (all ¼-watt, ±5% carbon):	
R1	- 330-ohm
R2	- 1-kilo-ohm
R3	- 2.2-ohm, 0.5W
R4, R5, R6	- (100-kilo-ohm)
Capacitors:	
C1, C2	- 220pF ceramic disk
C3	- 47µF, 10V electrolytic
Miscellaneous:	
K2, K3, K6 K14, K15, K19, K28	- Tactile switch(10x10mm)
X_{TAL}	- 455kHz (2-pin) ceramic resonator
BAT.	- 2x1.5V=3V
	- 2-cell battery holder
	- PCB, etc

Soldering the Small SMT Parts

To solder small SMT parts such as resistors, capacitors, inductors, transistors and ICs, proceed as follows:

1. Add a small amount of flux to the area and add a small amount of the solder to one pad.
2. Pick up the component using tweezers, ensuring that the component is horizontal. Alternatively, just move the component until it is close to the final position.
3. Whilst holding the component with your tweezers, melt the solder on the pad and put the component into position.
4. Remove the iron but continue holding the component until the solder solidifies. Check to see that the component is sitting flat on the PCB. If not, re-melt the solder whilst pushing gently on top of the component with tweezers.
5. Solder the other side of the component. Re-melt the first solder joint and let it solidify.
6. Check your work under magnification. The joint should be shining and concave. If you added too much solder, wick up with a small solder wick and try again.

scheme is employed.

3. To improve noise rejection, the pulses are modulated at a carrier frequency of 38 kHz, so the IR receiver module chosen for the reception should have an optimum response frequency of 38 kHz**.** (The 38kHz modulated pulse is termed here as 'burst.')

4. Logic-'1' bit time (Fig. 1) is 2.25 ms (i.e., burst period of 560µs + space/rest period of 1690 µs).

5. Logic-'0' bit time (Fig. 2) is 1.12 ms (i.e., burst period of 560µs + space/rest period of 560 µs).

6. Leader code preceding the address field comprises 9ms burst followed by 4.5ms space during data frame as shown in Fig. 3 or a 9ms burst followed by 2.25ms space followed by 560µs burst during a repeat frame as shown in Fig. 4.

The data frame comprises leader code, address, address, command and command bits and an additional 560µs burst. The data frame length is variable between 58.5 and 76.5 ms depending upon the number of logic-0 and logic-1 bits contained in a frame and so also is the gap length between the last command bit and repetition frame. The gap is minimum 32 ms and maximum 49.5 ms (Fig. 5).

A number of manufacturers make compatible ASICs for NEC-format code transmission (µPD6121, CD6121, PT2221 and HT6221, all equivalent to each other) by employing minimal external components. These ICs allow selection of up to 65,536 device addresses (also, called custom-codes) through the use of external diodes and resistors and 32 command codes (expandable to 64 commands through SEL pin). A complete schematic employing 32 keys is shown in Fig. 6.

The shaded keys, linked resistors and bold lines indicate the components, keys, etc used for the remote of digital audio processor (published in EFY Feb. 2005). These fix the address output as '0076H,' while command codes used for the project are given in the box inside the schematic.

Determining the output code. It is necessary to configure the circuit to output code corresponding to any of the possible 65,535 addresses and any of the first 32 commands (000000b through 011111b, i.e., decimal '0' through '31') or next 32 commands (100000b through 111111, i.e., decimal '32' through '63').

Fixing the address output

(refer Fig. 7)

Higher 8-bit address. Column lines C0 through C7 (pins 19 through 12) determine the corresponding bit value. If a column line is left open (i.e., not connected to CCS pin 20 via diode), the corresponding bit is '0.' If it is connected to CCS pin 20 via diode, the corresponding bit is '1.'

Lower 8-bit address. Lower eight bits will be the complement of higher eight bits unless the corresponding line is pulled to Vcc. Else, those particular bits will have the same logic value as their higher 8-bit address counterpart.

Example. Assume that the device address is '8435H,' where '84H' is the higher 8-bit address and '35H' is the lower 8-bit address.

'84H' in binary is '0010 0001' (read it from right to left). It transpires that column lines C7 and C2 (pins 12 and 17) need to be made '1' using diodes between these two pins and CCS pin 20 (cathodes facing pin 20).

Now examine the lower 8-bit address corresponding to '35H' or '1010 1100' (read it from right to left). Compare it with the higher eight bits (0010 0001). We observe that bits C0, C4, C5 and C7 are complementary, while bits C1, C2, C3 and C6 are identical (not to be complemented). Hence pull up the pins corresponding to bits C1, C2, C3 and C6 (pins 18, 17, 16 and 13) to Vcc via 100-kilo-ohm resistors.

8-bit command (also called 'data'). With D7/SEL (pin 7) shorted to Vcc, the most significant bit (MSB) of the command is set to '0.' The command code (and its complement) is automatically generated (along with leader and address code, as already set) when a row (R0 through R3) is momentarily shorted to the respective column lines C0 through C7 using switches/keys marked K1 through K32.

The command code is '1' less than the key No., i.e., K1, when pressed, generates decimal '0,' while K32 will generate decimal '31' (11111000b, read from right to left) or '1FH.' You can similarly find out the command/data code generated by other keys. If you short D7/SEL (pin 7) to ground, add decimal '128' (80H) to the code generated otherwise.

Circuit description

Part of the circuit for generation of address and command signals has already been explained in the preceding paragraphs. IC1 can operate off a 2V-3.3V battery (two cells of 1.5V each). The carrier frequency is determined by the frequency of the crystal/ceramic resonator connected across pins 8 and 9. It is one-twelfth of the frequency of the crystal/resonator. With a 455kHz resonator, the carrier frequency is approximately 38 kHz.

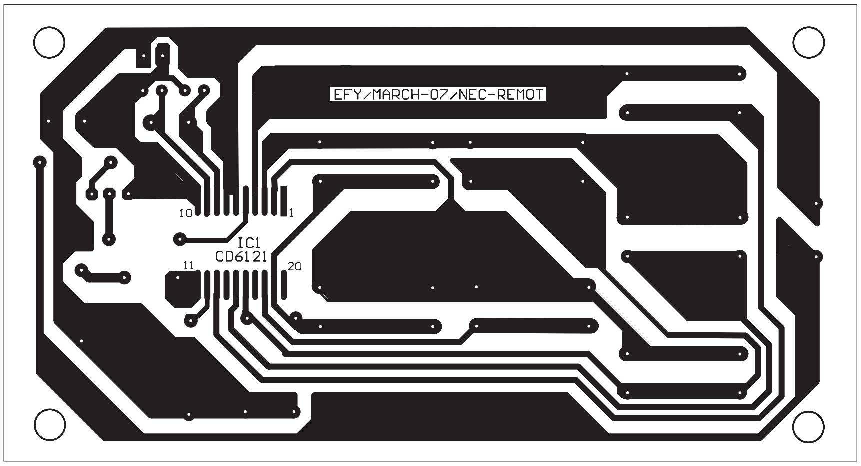


Fig. 8: Actual-size, single-side PCB layout for remote control digital audio processor

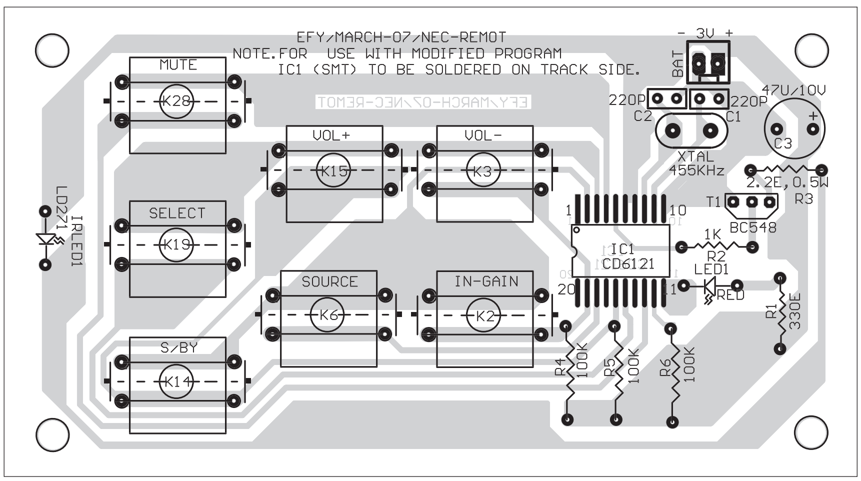


Fig. 9: Component layout of remote control PCB

CCS (pin 20) is custom-code-select (or device-address-select) input pin. Pin 11 is the lamp/LED output, which goes low when any key is pressed. The modulated output is available at DOUT pin 5, which is used for driving an IR LED for transmission of the modulated output in the form of IR signals.

An actual-size, single-side PCB layout for remote control of the digital audio processor published in EFY Feb. 2005 is shown in Fig. 8 and its component layout in Fig. 9.

Philips' RC5-format remote

The RC5 code (known as 'biphase' code) comprises 14 serial bits as follows: two start bits, one toggle bit (which changes every time a new button is pressed on the remote), five address bits as the system/device address and six command/instruction/data bits for the pressed key. This frame of 14 serial bits is repeated only once after a time interval of 88.9 ms (i.e. duration of 50 bits), while a command key on the remote remains pressed.

In the biphase modulation technique, every bit consists of two parts, which are never the same. So a bit is always a high-to-low or a low-to-high transition (or phase change), which occurs exactly in the middle of the bit-time.

In RC5 code, '1' represents a low-to-high transition and '0' represents a high-to-low transition. For all the bits, the most significant bit is transmitted first. The duration of each bit is 1.778 ms (with the change in phase occurring at 0.889 ms), and the total time of a full RC5 code, i.e., frame period, is 24.892 ms (14x1.778 ms). The space (rest period) between the end of the preceding frame and the start of the next frame equals the duration

PARTS LIST (PHILIPS RC-5 REMOTE)

Semiconductors:

IC1	- SC3010 RC5 encoder
T1	- BC548 npn transistor
IR LED1	- LD271 or equivalent

Resistors (all ¼-watt, ±5% carbon):

R1	- 1-kilo-ohm
R2	- 2.2-ohm, 0.5W
R3	- 1-kilo-ohm

Capacitors:

C1	- 47µF, 10V electrolytic

Miscellaneous:

X_{TAL}	- 455kHz ceramic resonator
	- 2-pin male/female connector for battery
	- Two-cell (pencil) holder
	- 3-pin SIP connector (M) with shorting link
	- 25×10mm tactile switches (N/O type)
	- PCB

TABLE I
Systems and Their Address Numbers (5-bit)

System address (in decimal)	Equipment
0	TV set 1
1	TV set 2
2	Videotext
3	Expansion for TV 1 and 2
4	Laser video player
5	Video recorder 1 (VCR 1)
6	Video recorder 2 (VCR 2)
7	Reserved
8	SAT 1
9	Expansion for VCR 1 or 2
10	SAT 2
11	Reserved
12	CD video
13	Reserved
14	CD photo
15	Reserved
16	Audio preamplifier 1
17	Receiver/tuner
18	Tape/cassete recorder
19	Audio preamplifier2
20	CD
21	Audio rack
22	Audio SAT receiver
23	DCC recorder
24	Reserved
25	Reserved
26	Writable CD
26-31	Reserved

TABLE II
Commands and Functions (6-bit)

Command (in decimal)	Description of function
0-9	Numeric keys 0-9
12	Standby
13	Mute
14	Presets
16	Volume up
17	Volume down
18	Brightness +
19	Brightness –
20	Colour saturation +
21	Colour saturation –
22	Bass up
23	Bass down
24	Treble +
25	Treble –
26	Balance right
27	Balance left
48	Pause
50	Fast reverse
52	Fast forward –
53	Play
54	Stop
55	Record
63	System select
71	Dim local display
77	Linear function (+)
78	Linear function (–)
80	Step up
81	Step down
82	Menu on
83	Menu off
84	Display A/V sys status
85	Step left
86	Step right
87	Acknowledge
88	Pip on/off
89	Pip shift
90	Pip main swap
91	Strobe on/off
92	Multi strobe
93	Main frozen
94	3/9 multi scan
95	Pip select
96	Mosaic multi pip
97	Picture DNR
98	Main stored
99	Pip strobe
100	Recall main picture
101	Pip freeze
102	Pip step up
103	Pip step down
118	Sub mode
119	Options bus mode
123	Connect
124	Disconnect

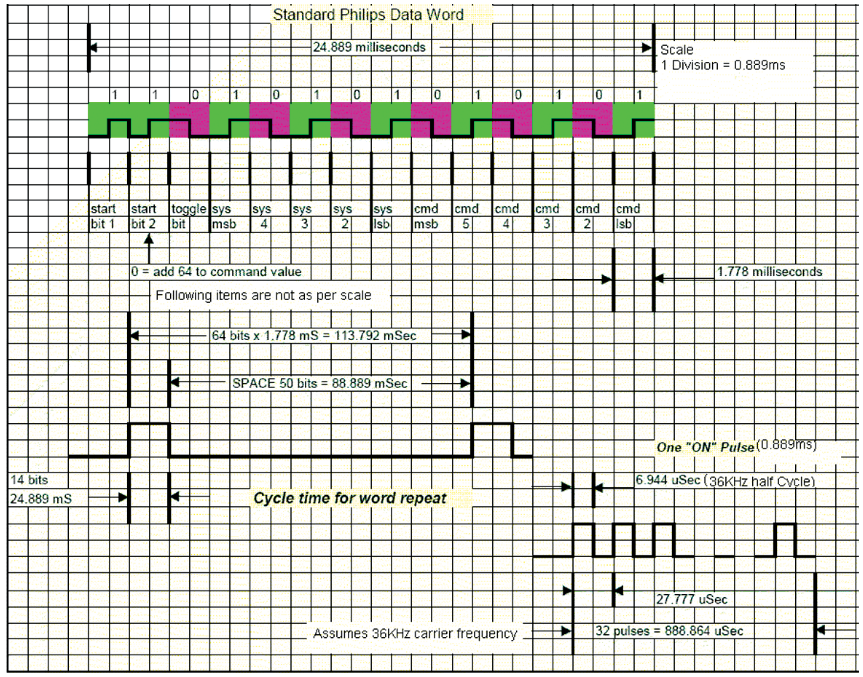


Fig. 10: The time relationship and typical bit pattern conforming to standard Philips RC5 protocol

TABLE III
Pin Signals/Functions of IC SC3010

Pin no.	Symbol	I/O	Description	Note
1	K17	IP	Key-sense input pin	
2	SMS	I	System-mode-selection input pin	
3-6	C0-C3	IP	Key-sense input pins	
7	MD_{OUT}	O	Generated output data pin modulated with 1/12 oscillator frequency at a 25 per cent duty factor	IP = Input with p-channel pull-up transistor
8	D_{OUT}	O	Generated output data pin	
9-13	KO7-KO3	OD	Scan driver pins	OD = Output with open drain n-channel transistor
14	V_{SS}	Power	Negative power supply	
15-17	KO2-KO0	OD	Scan driver pins	
18	OSC	I	Oscillator input pin	
19	T2	I	Test pin 2	
20	T1	I	Test pin 1	
21-27	KI0-KI6	IP	Key-sense input pins	
28	V_{DD}	Power	Positve power supply	

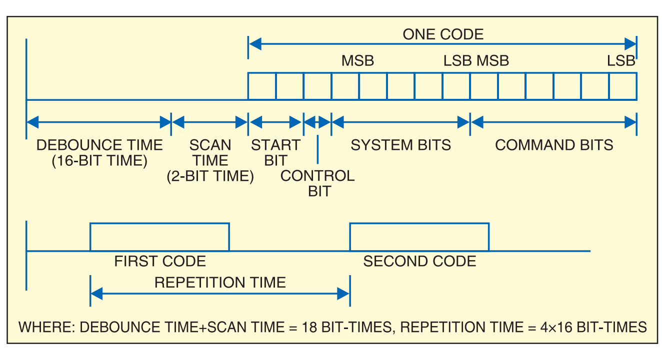


Fig. 11: Data output format

of 50 bits or 88.9 ms. Repetition period is equal to frame period plus space period, which thus equals 113.792 ms.

The time relationship and typical bit patterns are shown

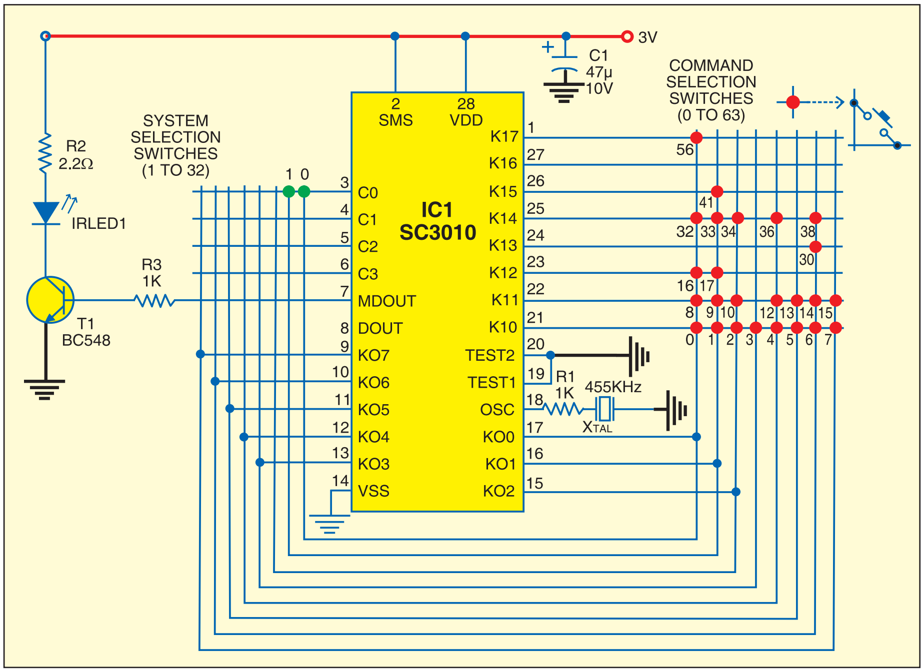


Fig. 12: Circuit of RC-5 encoder for selecting 1 of 32 system and 64 commands

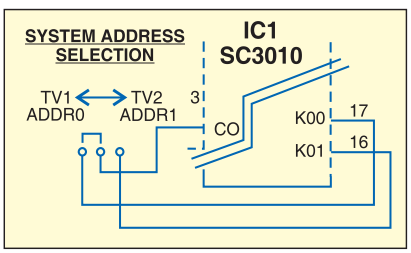


Fig. 13: Selection of TV1 or TV2 using shorting link

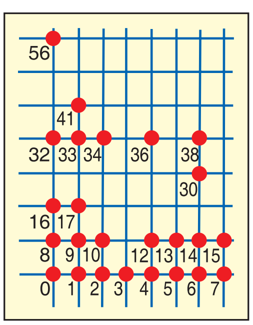


Fig. 14: Command switches used for RTC-interfaced multiple device control

in Fig. 10. For neatness, only the envelope is shown, while the carrier frequency of 36 kHz with 50% duty cycle is separately shown in the right-hand corner at the bottom. There are 24 pulses of 36 kHz during the 'on' period (0.889 ms) of any bit.

In the market, you can easily find RC5-compatible chips from a number of manufacturers (SAA3010 from Philips, SC3010 from Silan Semiconductors, PT2210 from Princeton Technology, SL3010 from System Logic Semiconductor, etc).

TABLE IV
Remote Command Codes

Button	Command	Function (as used)
0-9	0-9	Number keys
'—'	10	10+
'Sfx'	36	20+
Mute	13	Delete task
AC	34	Clear the prog. memory
PWR	12	Change the password
Timer	38	Change the time
Search	30	Change the existing tasks
CH+	32	See the next task
CH-	33	See the previous task
RCL	15	Toggle the LCD backlight
PP	14	Enter a new task
Store	41	Toggle the child lock
Volume+	16	Increase the value
Volume–	17	Decrease the value
TV/AV	56	Confirmation

With five bits used for system/address selection, you may select/address 32 different systems. System addresses have been standardised for identifying specific equipment types (refer Table I). With next six bits used for key commands/data, it is possible to have a set of 64 different commands for each of the 32 systems. There is also a possibility of using up to 128 commands. This is achieved by assigning the second start bit a value of '0' (rather than '1'). Thus when the second bit is '0,' '64' is added to the command value defined by six command bits.

Typical command values (in decimal) are shown in Table II. Most of the available RC5 encoder chips can be used for 64 commands only as both start bits are preprogrammed to a value of '1.'

As soon as the encoder IC senses depression of a key, key debounce time (=16-bit duration =28.448 ms) starts. This is followed by scan time (=2-bit duration=3.556 ms) and then the actual code consisting of 14 bits starts. On completion of the first code frame of 14 bits, there is a gap of 88.889 ms and then the 14-bit code repeats. The data output format is shown in Fig. 11.

Most of the RC5 encoder chips as mentioned above are available in 28-pin surface-mount packages. Pin signals/functions are shown in Table III.

Circuit description

Fig. 12 shows the circuit of RC-5 encoder for selecting one of 32 system addresses (using shorting link, rather than a tactile switch). For system selection, scan-driver pins 17, 16, 15, 13, 12, 11, 10 and 9 for scan lines KO0 through KO7, respectively) need to be connected to key-sense inputs C0 through C3 (terminating at pins 3 through 6), respectively (only one at a time).

Fig. 13 shows a shorting-link arrangement enabling selection of either TV1 (system address '0') or TV2 (system address '1'). The system address (decimal), as shown in Table II, equals the address represented by each dot in the circuit.

Similarly, for command selection, scan-driver pins 17, 16, 15, 13, 12, 11, 10 and 9 for scan lines KO0 through KO7, respectively, need to be momentarily connected to key-sense input pins 21 through 27 and 1 representing sense

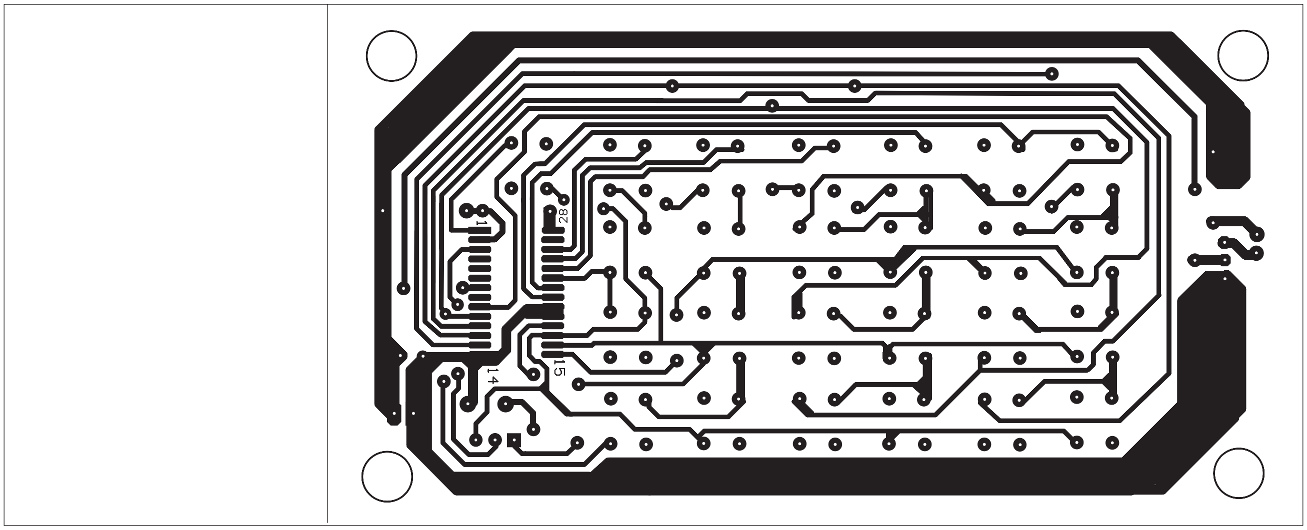


Fig. 15: PCB layout of RC5 remote for RTC-interfaced microcontroller for multiple device control

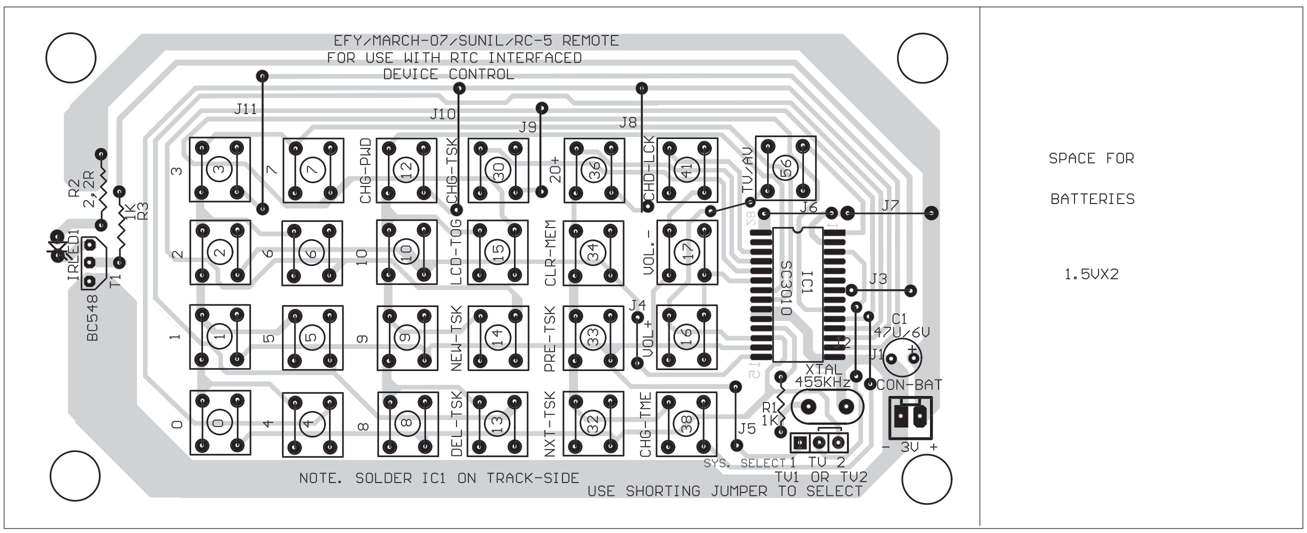


Fig. 16: Component layout for the PCB shown in Fig. 15

lines KI0 through KI7, respectively, one at a time (for one system). Command numbers '0' through '63' (decimal) for any specific system (selected as described above) can be selected by pressing respective push-switches marked '0' through '63' (i.e., command number + 1).

Once a system is selected and a command key is momentarily pressed, 14 bits of the code word modulates a 38kHz carrier generated within IC SC3010 and the modulated output is available at pin 7 (labeled as 'MD-OUT'). The output signal MDOUT transmits the generated information modulated by one-twelfth of the oscillator frequency with a 50% duty cycle. This output is used to drive IR LED1 via transistor T1. A single OSC input pin 18 is used for connecting the 455kHz resonator via a 1-kilo-ohm resistor, while the other end of the resonator is grounded.

System-mode-select (input pin 2) is to be held low (connected to ground) when the encoder is used for combined system operation, whereas for a single-system selection pin 2 is to be connected to Vcc. Fig. 12 shows selection of the single-system mode.

The device will immediately reset under the following conditions:

1. A key is released during the debounce time.

2. A key is released between two codes.

3. During matrix scanning:

1. A key is released while one of the driver outputs is in the low ohmic state (logic 0).

2. A key is released before that key has been detected.

3. There is no wired connection in the C-KO matrix when pin 2 is high.

(*Note*. Although 36kHz carrier frequency has been mentioned in the RC-5 format, but for that you have to use a 432kHz resonator. Since the 432kHz resonator is not commonly available, we have used a 455kHz resonator to get a carrier frequency of 38 kHz as in the case of the NEC remote.)

Example. Let us design an IR remote for the 'RTC-interfaced Multiple Device Control' project published in Sept. 2006 issue of EFY, which requires a Philips' RC5-code compatible remote controller for programming the RTC chip DS12887 used in that project. Command switches used for RTC-interfaced multiple-device control are separately shown in Fig. 14 (***Note.*** Three additional command switches for functions Volume+ (code 16), Volume— (code 17) and TV/AV (code 56) have been added to enhance its application for some other projects, which may be published in EFY in due course). The actual command No. (decimal) is the same as the switch/key number. The first 22 command numbers are the same as used by author as per Table IV of the project. You can easily correlate command numbers (decimal) of Table IV to switch numbers shown by red dots in Figs. 12 and 14. That makes designing the circuit really easy.

For system selection, simply short pin 17 to pin 3 as the author has configured the project to recognise TV1 system commands only. An additional provision can be made for selection of TV2 system as well.

The system-selection arrangement is shown in Fig. 13, which makes use of a shorting link to select either TV1 or TV2 system. The identical system-selection arrangement is also shown by using switches marked '1' (address '0' for TV1) and 2 (address '1' for TV2), as per Table I. These two switch dots are shown in different colour in Fig. 12. (Note that the system address is equal to the switch No.–1.)

The PCB designed for the example project shows the command code as well as the function in the screen overlay.

Caution. IC1 is a surface-mount device and it is to be mounted on the track-side itself after proper alignment of pins. For soldering the surface-mount IC, strictly follow the instructions in the box. This caution applies to the previous PCB of NEC remote as well.

The PCB for the example remote is shown in Fig. 15 and its component layout in Fig. 16. Ready-made PCBs for both the projects are available with Kits'n'Spares. ●