

DIY KIT 140. Telephone Switcher MK2

This device connects to the telephone line and can be used to remotely control up to 4 relay outputs using a DTMF (tone dialing) telephone. A number of user settings are available to improve the useability and security of the device. The kit comes complete with a small plastic case with silk-screened front and rear panels.

The unit is controlled by an Atmel 89C2051 microcontroller. Source code is **not** available. This kit replaces our previous K86 kit which was discontinued due to the Motorola 68HC705K1 chip becoming obsolete.

FEATURES

Outputs	Relays x 4
Contact rating	See text
Operating voltage	12VDC (nominal)
Operating current	30mA with no relays operated 120mA with all relays operated
Connections	1. 2.5mm DC power jack 2. RJ-11 for telephone line 3. 4 x 3-way pluggable screw terminals for relay contacts
Case size	13cm (W) x 10cm (D) x 3cm (H) (6.1" x 4" x 1.3")
User Settings (see text)	1. Password 2. Tamper 3. Rings to answer 4. Auto hangup time 5. Lockout

CIRCUIT DESCRIPTION

We will not review the operation of how telephone lines work or the detailed operation of the various ICs used. See the 'References' section for Web links where you can get this information.

The brains of the switcher is the Atmel AT89C2051 microcontroller, IC4. Incoming ring is detected via C4, R7 and the opto-coupler IC2 and connected to pin 6 of the microcontroller. This pin also has the 'Password Reset' switch connected to it (more on this later).

The incoming call is answered by connecting the circuit based around Q1 and Q2 (an electronic holding coil) to the line via IC1, a bi-directional opto-isolator. This circuit has a low DC resistance but a high AC impedance which is required by telephone circuits when the line is looped. The RC network consisting of R4, R5 and C3 is used to provide impedance matching to the telephone line. The metal oxide varistor protects the switcher from telephone line transients. The configuration and values used here are optimized for the Australian telephone system but they should work in all other phone systems. They may be changed to suit other telephone systems if it is desired to get official approval of this device.

DTMF detection and decoding is provided by IC3. This chip, an 8870, is a complete DTMF receiver

which is able to detect and decode all 16 DTMF tone pairs into a 4-bit code. When a valid DTMF digit is detected the 4-bit code is placed on pins 11-14 and a 'data available' output, pin 15, is set to a logic high.

The output relays, RL1-4, are controlled via the relay driver IC6. One output from the relay driver (pin 14) is used to output a 800Hz software generated tone into the telephone line via the impedance matching network. This tone is used to signal the user when commands have been completed or of any command errors.

User settings are stored in IC5, a 24C01 EEPROM. The microcontroller 'talks' to this device using a 2-wire I2C bus via pins 18 and 19.

IC7 provides two functions – a regulated 5V power supply output and detecting when the phone line is 'looped' (in use). This chip is a Maxim MAX666 low power programmable voltage regulator with on-chip low-battery detection, mainly intended for use in battery powered equipment. The regulator output voltage is set via the 'VSET' input (pin 6). By tying this pin to ground the output is fixed at 5 volts. We have used the low-battery input to monitor the state of the phone line.

An idle (not in use) phone line normally has about 50VDC across its pair of wires. This voltage drops to less than 20V when the line is in use. The MAX666 Low Battery Input (LBI, pin 3) is one side of a simple voltage comparator which compares this input to an internal 1.30V reference voltage. When the voltage at the LBI input falls below the reference voltage then the Low Battery Output (LBO, pin 7) will go high.

The phone line is connected to the comparator input via the diode bridge B2 and resistors R15 and R16. The diode bridge makes sure that the voltage polarity connected to LBI is the same regardless of which way around the phone wires are connected. The resistors form a voltage divider which is used to set the 'low battery' threshold at LBI. For the values used the LBO output will go high when the phone line voltage drops below 25 volts, indicating that the line is in use (looped).

PCB ASSEMBLY

First check the components supplied in the kit against the component listing. Identify all the components. It is generally best to solder the lowest height components first: the resistors, diodes & IC sockets. Leave the connectors and relays until last.

Note that two components, resistor R14 and capacitor C11, are mounted inside the IC sockets for IC3 and IC4 respectively. This is no problem – just fit these components before the IC sockets.

Make sure to get the diodes and electrolytic capacitors the correct way around. Match up the bar on the diodes with the bar on the overlay. The negative lead of electrolytic capacitors is marked by a 'stripe' whereas the PCB overlay indicates the hole for the positive lead.

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When fitting the MJE340 transistor, Q1, check the PCB overlay first. The thick 'line' on the PCB indicates the **back** of the transistor which may have a metal surface. If not then use the markings on the transistor – they indicate the **front** of the transistor.

Make sure the power jack is facing straight out, not skew. We have made the front panel hole 0.320" which will tolerate some shewness.

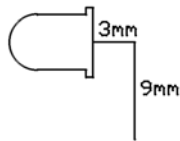
When mounting the connectors make sure they are sitting right down on the PCB before soldering.

Do not insert any ICs yet!

We are now going to fit the assembled PCB into the plastic case. Before that check all your work carefully. Look for unsoldered joints and any solder bridges or splashes that may be shorting out adjacent pins.

Now comes assembly of the front panel. Start by inserting the LED clip into the hole, pushing it in from the front. Now insert the LED into the clip **from the rear**. The LED should "click" into place.

Turn the LED in the clip so that the long lead is to the right (as viewed from the front). **This is very important so make sure it is right.** Now bend the leads down at right angles, about 3mm from the LED body, as shown below. Use a pair of long nose pliers to hold the leads while bending. Cut the leads off to a length of about 9mm from the bend.



Fit the front and rear panels to the PCB. Be sure that the LED leads are inserted into their matching holes on the PCB. While holding the panels in place slowly position the PCB into the base of the plastic case, making sure that the front and rear panels slide into the slots provided. Secure the PCB to the case using the self-tapping screws then solder the LED leads **from the top of the PCB**.

Do not fit the plastic case lid just yet. Proceed to the next section 'PRE-TESTING'. Now fit the plastic case lid and secure it in place.

For 2 photos of the completed kit see

http://www.kitsrus.com/jpg/k140_1.jpg

http://www.kitsrus.com/jpg/k140_2.jpg

PRE-TESTING

Insert IC7 (MAX666) and connect a 9-12V power supply to the DC input jack. Use a multimeter to check the 5V supply. Easiest place to measure this is across pins 20 (+) and 10 (-) of the IC4 socket. If all is well then remove power and insert the rest of the ICs into their sockets. Check that the IC legs are actually inserted into the socket and not accidentally bent up underneath the IC body (quite a common fault).

USING THE KIT FOR THE FIRST TIME

Before you can use the kit for the first time the various user settings must be set to their 'default' values. To do this, **press AND hold the 'Password Reset' button while powering up the kit. Hold the button down for a further 2 seconds before releasing it.** This procedure is also used if you forget the password.

The **default** value for each setting is:

Password 0000
Tamper 3
Rings to answer 3
Auto hangup 30 seconds
Lockout Disabled

Each of these settings can be changed by the user to suit.

FINAL TEST AND OPERATION

Connect the kit to the phone line using a suitable cable. Note that the kit uses the two inner pins on the RJ-11 plug. Some cables do not – check before using.

Turn on the power. If using the kit for the first time follow the procedure described previously to set the user settings to their default values. The kit is now ready for incoming calls.

Dial the phone number to which the kit is connected. After 3 rings it will answer with 4 short beeps. Type in the password (0000) followed by the '#' key. If the password is correct the kit will respond with 4 short beeps. It is now waiting for a command.

COMMANDS

A command is a string of characters starting with * or # and ending with a #.

Entering a * at any time after the first character aborts and starts again.

1. *<1-4># - operate one of the four relays 1,2,3 or 4.
2. #<1-4># - release one of the four relays 1,2,3 or 4.
3. *5# - set password
4. *6# - set tamper setting
5. *7# - set number of rings to answer
6. *8# - set auto hangup time
7. *9# - set lockout time
8. *0# - forced disconnect
9. #0# - release ALL relays

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Commands 3-7 require additional data. After the command is entered the unit will issue a single, short beep as a prompt for the data. Enter the required data followed by # to finish. A description of the data to be entered is given in the section "USER SETTINGS".

WHAT DO THE BEEPS MEAN?

The beeps are used to acknowledge commands, prompt for more data or indicate errors.

- **4 short beeps** - valid command entered.
- **2 short beeps** - command aborted by user
- **1 short beep** - more data required
- **1 long beep** - command error
- **3 long beeps** - disconnecting (hanging up)

A "forced disconnect" command will cause 3 long beeps to be sent back to the user before the switcher hangs up.

USER SETTINGS

These are stored in non-volatile memory (EEPROM) and are not affected by loss of power.

None of these settings are defined initially - they have to be 'set' to their default values before you can use the kit (see "USING THE KIT FOR THE FIRST TIME").

Password (4 - 8 digits)

From 4 to 8 digits long using any number from 0 to 9.

Tamper setting (0 - 9)

The number of attempts allowed at entering a valid password. A value of 0 disables this feature (unlimited).

If the tamper setting is exceeded then the unit will automatically disconnect and go into 'lockout' if enabled (see Lockout time).

Number of rings to answer (0 - 9)

Number of incoming rings required before the unit will automatically answer the call. A value of 0 disables this feature (does not automatically answer).

Valid ring is defined as having an "off" time of more than 1 second between each burst of ring. So the American single ring, and the European double ring are both seen as a single ring.

If the caller hangs up BEFORE the number of rings to answer have been received then the unit will wait 10 seconds before 'resetting' itself to wait for the next call.

Note: If this feature is disabled then no answer beeps will be sent to line when the call is answered. The password can still be entered - there is just no prompt for it. However once a valid password is entered the kit will respond as normal.

When this feature is disabled the unit expects the the call to be answered 'externally', eg. by an answering machine. Everything else works as normal, including entering a valid password. The only difference is that it does not automatically answer the incoming call.

Auto hangup time (00 - 99 seconds)

This is the length of time that the unit will wait for a VALID command. If this time is exceeded then the unit will automatically disconnect itself (hang up) from the call. A valid command includes entering a correct password at the start. A value of 0 disables this feature (no auto hangup).

Note: Do not set this value too short – the user will need time to enter their commands!

Disabling auto hangup means that the only way the kit will hang up the call is via a 'force disconnect' command (*0#). If the kit fails to accept the password then the line will be held looped 'forever'. Use with caution!

Lockout time (00 - 99 minutes)

This only comes into effect when the tamper setting has been exceeded on the PREVIOUS call.

This is the length of time that the unit will wait AFTER disconnecting (hanging up) before it will answer the next call. A value of 00 disables this feature (no lockout).

For example, suppose the tamper setting is 3 and the lockout time is set to 10. The unit receives a call and answers it. If a valid password is NOT entered in 3 attempts the unit will disconnect (hangup) and then wait for 10 minutes before it will answer any further calls. In other words, further calls a 'locked out' for 10 minutes.

This security feature helps prevent multiple attempts at 'hacking' into the unit by introducing a delay time between calls being answered.

WHAT IF I FORGET MY PASSWORD?

In this case you will need to follow the procedure in "USING THE KIT FOR THE FIRST TIME". This will reset the password to 0000. However it will also reset all the user settings to their default values. You will have to re-enter them as required.

IT DOESN'T WORK – WHAT DO I DO?

1. Check that all components are in their correct place and the correct way around. Check for unsoldered joints and solder bridges or splashes.
2. Is the 5V supply OK?
3. Any IC legs bent up under the IC body?
4. Is the phone line cable using the two inner pins on the RJ-11 plug?

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REFERENCES

Understanding Telephone Electronics, by J. Fike & G. Friend, published by Sams (ISBN 0-672-27018-8)

The newsgroup **sci.electronics.basics** frequently discusses telephone related questions.

Visit **www.atmel.com** for a datasheet on the 89C2051 microcontroller and 24C01 EEPROM.

MAX666 datasheet from Maxim
<http://pdfserv.maxim-ic.com/arpdf/MAX663-MAX666.pdf>

LCA110 datasheet from CP Clare
[www.clare.com/home/pdfs.nsf/www/Lca110.pdf/\\$file/Lca110.pdf](http://www.clare.com/home/pdfs.nsf/www/Lca110.pdf/$file/Lca110.pdf)

CM8870 datasheet from California Micro Devices
www.calmicro.com/products/data/pdf/cm8870.pdf

DTMF Decoder, in Silicon Chip, 5/91, p30.
 DTMF Decoder, in Electronics Now, 11/93, p53.
 Build a DTMF Decoder/Logger, in Popular Electronics, 9/95, p37.

For information about all DIY Kits see our web page at <http://www.kitsrus.com>

Send us email at peterhk@kitsrus.com

The kit was designed and developed by Frank Crivelli at Ozitronics. For technical questions email him at frank@ozitronics.com

PARTS LIST

Resistors (0.25W carbon film unless specified)

56R 1W green blue black .. R3	1
100R brown black brown .. R4	1
820R gray red brown	1
1K brown black red	2
2K2 red red red	1
8K2 gray red red	1
10K brown black orange ... R8,17,19,20	4
22K red red orange	1
47K yellow violet orange .. R1,2	2
56K green blue orange	1
68K blue grey orange	1
180K brown gray yellow ... R16	1
220K red red yellow	3
270K red violet yellow	1
3M3 orange orange green .. R15	1

Capacitors

27pF ceramic	2
10nF 103 63V box poly	2
100nF 104 monobloc	3
120nF box poly	1
1uF 105 63V/100V poly	1
330nF 250V poly	1
1uF 63V electrolytic	1
4.7uF 63V electrolytic	1
10uF 25V electrolytic	2
100uF 25V electrolytic	1

Semiconductors

1N4004 diode	3
1N4148	1
WO2	3
Diode bridge	
MJE340 NPN transistor	1
MPSA42 NPN transistor	1

Semiconductors (cont.)

LCA110 opto-isolator	1
4N25 optocoupler	1
CM8870	1
DTMF receiver	
AT89C2051-24PC	1
ATMEL microcontroller	
24C01A	1
128x8 serial EEPROM	
ULN2003A	1
MAX666	1
LED, 5mm Green	1
Miscellaneous	
Crystal, 3.5795MHz	1
Crystal, 12.000MHz	1
Metal Oxide Varistor	1
Socket, RJ-11	1
Pluggable header	1
12 way, Dinkle 2EHDR-12P	
DC jack, 2.5mm, PCB mtg	1
Pluggable socket	4
3 way, Dinkle 2ESDV-03P	
Relay, SPDT	4
Goodsky RWH-SH-112D	
TACT pushbutton switch	1
LED clip, 5mm black	1
IC socket, 20 pin	1
IC socket, 18 pin	1
IC socket, 16 pin	1
IC socket, 8 pin	2
IC socket, 6 pin	2
Self tapping screws for fixing PCB to case	4
Plastic case, 130(W) x 100(D) x 30(H)mm	1
PCB, K140	1
Set of front & rear panels	1

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