CK603 - 4 Relay Telephone Switcher

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

Ouputs	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 avaliable' 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

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electrolytic capacitors is marked by a 'stripe' whereas the PCB overlay indicates the hole for the positive lead.

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.
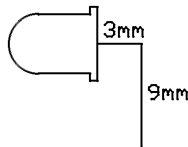
Fit the front and rear panels to the PCB. Be sure that the LED leads are inserted into their matching holes on the PCB. While holding the panels in place slowly position the PCB into the base of the plastic case, making sure that the front and rear panels slide into the slots provided. Secure the PCB 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.

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 accidently 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 you user 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.

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!

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

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.ElectronicKits.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	R5	1
1K brown black red	R18,22	2
2K2 red red red	R6	1
8K2 gray red red	R21	1
10K brown black orange	R8,17,19,20	4
22K red red orange	R7	1
47K yellow violet orange	R1,2	2
56K green blue orange	R11	1
68K green violet orange	R12	1
180K brown gray yellow	R16	1
220K red red yellow	R9,10,13	3
270K red violet yellow	R14	1
3M3 orange orange green	R15	1

Capacitors

27pF ceramic	C12,13	2
10nF 103 63V box poly	C5,6	2
100nF 104 monobloc	C7,8,11	3
120nF box poly	C3	1
1uF 105 63V/100V poly	C15	1
330nF 250V poly	C4	1
1uF 63V electrolytic	C1	1
4.7uF 63V electrolytic	C2	1
10uF 25V electrolytic	C10,14	2
100uF 25V electrolytic	C9	1

Semiconductors

1N4004 diode	D1,2,3	3
1N4148	D4	1
WO2	B1,2,3	3
Diode bridge		
MJE340 NPN transistor	Q1	1
MPSA42 NPN transistor	Q2	1

Semiconductors (cont.)

LCA110 opto-isolator	IC1	1
4N25 optocoupler	IC2	1
CM8870	IC3	1
DTMF receiver		
AT89C2051-24PC	IC4	1
ATMEL microcontroller		
24C01A	IC5	1
128x8 serial EEPROM		
MAX666	IC7	1
LED, 5mm Green	L1	1

Miscellaneous

Crystal, 3.5795MHz	Y1	1
Crystal, 12.000MHz	Y2	1
Metal Oxide Varistor	MOV	1
Socket, RJ-11	X1	1
Pluggable header	X2	1
12 way, Dinkle 2EHDRC-12P		
DC jack, 2.5mm, PCB mtg.	X3	1
Pluggable socket	for X2	4
3 way, Dinkle 2ESDV-03P		
Relay, SPDT	RL1,2,3,4	4
Goodsky RWH-SH-112D		
TACT pushbutton switch	S1	1
LED clip, 5mm black	for L1	1
IC socket, 20 pin	for IC4	1
IC socket, 18 pin	for IC3	1
IC socket, 16 pin	for IC6	1
IC socket, 8 pin	for IC5,7	2
IC socket, 6 pin	for IC1,2	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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C2
4.7uF 63V

R1
47K

Q2
MPSA42

Q1
MJE340

V+ V+

RL1

R22
1K

V+

X1

MOV
150LA10

B1
WO4

AC   3

AC   4

R2
47K

R4
100

R5
820

C3
120nF

IC6
ULN-2003A

I1 O1 D+ 16
I2 O2   15
I3 O3   14
I4 O4   13
I5 O5   12
I6 O6   11
I7 O7   10
GND

RL2

X2

NO
C
NC
NO
C
NC
NO
C
NC
NO
C
NC

TELEPHONE
LINE

C1
1uF 63V

R3
56 1W

C15
1uF 100V

TELEPHONE LINE
IMPEDANCE
MATCHING NETWORK
(CHANGE TO SUIT)

RL3

V+

RL4

+5

R6
2K2

IC1
LCA110

4   1

6   2

SWITCH HOOK ON/OFF

R7
22K

+5

R8
10K

PASSWORD RESET

C4
330nF 250V

D1
1N4004

IC2
4N25

1   6
5
2   4

RING DETECT

S1

C11
100nF

+5

+5 C7
100nF

+5
C8
100nF

R9
220K

C5
10nF 100V

IC3
MT8870CE

IN+ VDD
IN- ST/GT
GS
VREF EST

OSC1

R14
270K

TONE 17
R4   9
R3   8
R2   3
R1   2

IC4
AT89CX051

P1.5 VCC 20
P3.5
P3.4 P3.2 6 RING
P3.1
P3.0 P3.7 11 SWHK
P1.0
P1.1 P1.7 19 SCL
P1.2 P1.6 18 SDA
P1.3
P1.4 P3.3 7 LOOP

XTAL1 RST
XTAL2 GND

+5 +5 +5

R19 R20
10K 10K

IC5
24C01A

VCC A0
WP   A1
SCL A2
SDA GND

R10
220K

C6
10nF 100V

Y1
3.579MHz

OSC2
INH
PWDN
VSS

Q1
Q2
Q3
Q4
STD

D0
D1
D2
D3
DAV

R11 R12 R13
56K 68K 220K

Y2

C12 C13
27pF 27pF

12MHz

C14
10/16

+5

D4
1N4148

R21
8K2

R15
3M3

V+

IC7
MAX666

LBI SENSE
VOUT

+5

R17
10K

B2
WO4

AC   3
AC   4

R16
180K

VIN
VSET
SHDN
GND

LBO

LOOP DETECT

C10
10/16

X3

B3
WO4

AC   3
AC   4

D2   D3
1N4004   1N4004

R18
1K

L1
POWER ON

12VDC
INPUT

C9
100/25

E B C

MPSA42
TOP VIEW

C
COIL
NO   NC

MJE340
FRONT VIEW

ECB

RELAY (RWH-SH-112D)
TOP VIEW

Title
TELEPHONE SWITCHER MK2

Size Number
A3   K140

Revision
1

Date: 7-DEC 2002
File: K140/1

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Drawn By: FC