QUASAR PROJECT 3153 - Audio DTMF Decoder

The kit will detect DTMF tones from a telephone line or via an onboard microphone and display them on a 16 character, single line display. Up to 32 numbers can be displayed by scrolling the display left and right. There is also a serial output for sending the detected tones to a PC. The kit will not detect numbers dialled using pulse dialling.

The kit is controlled by an Atmel 89C2051 microcontroller (source code not supplied nor available.) This kit replaces the old 3056 Tone Grabber kit.

ASSEMBLY

Check the components supplied in the kit against the parts list. There are several points to note:

- Identify the BC547 transistor and the 78L05 regulator. They look the same so don't get them mixed up.
- Make sure Q1 does not poke up too high and interfere with the mounting of the LCD.
- Capacitors C3 and C5 mount inside the IC sockets. Make sure they don't poke up too high and interfere with inserting the ICs into the sockets.
- The trimpot VR1 is mounted **underneath** the PCB on the solder side (see **3153_2.jpg** photo link below)
- There a 2 wire links to be inserted on the board. These can be made from the resistor lead offcuts.

Identify the trimpot and put it aside – this will be the last component assembled. It is recommended that components be inserted and soldered in the following order.

1. All the resistors. Use a couple of the resistor lead offcuts for the two wire links.
2. Capacitors C1,2,3,5,6,7,9,10 and 11. Note that capacitors C3 and C5 fit inside the IC sockets. Make sure they are right down against the PCB before soldering.
3. The two IC sockets.
4. Crystals - solder them quickly as they can be damaged by excess heat.
5. Transistor Q1 and IC1 (the 5 volt regulator.)
6. The 16-way socket strip for the LCD. Make sure it is right down against and at right angle to the PCB before soldering.
7. The electrolytic capacitors C4 and C8 and the electret microphone.
8. The two zippy switches. Push them right in until the leads 'click' into place. The bottom of the switch should be right down against the PCB.
9. The DC jack, slide switch and transformer. The transformer can be fitted either way around.
10. Lastly, the trimpot. It is mounted on the bottom of the PCB on the solder side. The trimpot leads are exposed and can be soldered onto the PCB pads.

Do not insert any ICs or the LCD into their sockets yet.

TESTING AND SETUP

Inspect your work carefully under a bright light. The solder joints should have a 'shiny' look about them. Check that there are no solder bridges between adjacent pads. There are 2 photos of the assembled kit on our website at
http://www.quasarelectronics.com/jpg/3153_1.jpg
http://www.quasarelectronics.com/jpg/3153_2.jpg

You can now apply power. Anything between 9 and 12 volts center positive will be fine. Use a multimeter to measure the 5 volt output from the regulator IC1. The easiest place to do this is across pins 10 and 20 of the IC3 socket (+ve on pin 20). If all is well then remove power and insert the ICs and LCD into their sockets. Use the screws and nuts supplied to fix the bottom edge of the LCD to the PCB.

Apply power again. The word READY should be displayed on the right side of the LCD. **If the display is faint or all you see is black squares then adjust the trimpot until you can clearly see READY.**

To test the telephone input connect the kit to a telephone line via the two PCB pads labeled 'LINE' and move switch SW1 to the 'TEL' position. Pick up the phone and press some numbers. They should come up on the display.

To test the microphone input move switch SW1 to the 'MIC' position. Download the file '**dtmf.wav'** from **http://www.quasarelectronics.com/zip/dtmf.zip.** This contains the numbers 1-9, 0, * and #. Unzip it and play it over a speaker using Windows Sound Recorder or any other wav file playback software. With some numbers displayed on the LCD use the pushbuttons to scroll the display left and right. The kit is now ready to use.

R3 sets the gain of the internal opamp in the chip. Larger value = more gain. In some instances the gain may be too high resulting in funny characters being detected. In this case lowering the resistor value to 390K should fix it. If no characters are recognised try increasing to 560K.

OPERATION

Telephone: Connect the kit to the phone line via the two PCB pads labelled 'LINE' and move switch SW1 to the 'TEL' position. The two LINE inputs connect in parallel. That is, one telephone line connects to each of the inputs. Neither phone line needs to be cut. Just scrape off some of the insulation and connect by alligator clips.

Microphone: Move switch SW1 to the 'MIC' position and position the microphone close to the DTMF source. If the decoder fails to respond to any DTMF tones, try positioning the microphone closer to the source or increasing the volume of the tones. Note however that excessive volume may distort the signal presented to the DTMF decoder chip and cause the tones to be ignored. .

Also note you cannot pickup tones from the earpiece of a telephone handset. The signals are to weak.

As each DTMF digit is detected it is displayed on the LCD and it is also sent to the serial output as an ASCII character. The decoder can store up to 32 digits in an internal buffer. If more than 32 digits are received then only the last 32 are stored.

The display is only 16 characters wide and so is only capable of showing 16 of the possible 32 digits in the buffer. Normally it will display the last 16 digits received but at any time you can use the pushbuttons to scroll the display left or right through the buffer. A full stop (.) is used to indicate the last digit received.

The buffer can be cleared by pressing both pushbuttons at the same time. The display will clear and show the word RESET. Release both buttons to start detecting DTMF tones again – the display will show READY.

SERIAL OUTPUT AND PC CONNECTION

All data written to the LCD is also sent to the serial output, including the RESET and READY messages. Data is sent as standard ASCII characters. Eg, digit '1' is converted to 41H before being sent to the serial port. The PC connection is via the RXD and GND outputs.

The following table shows the pin connections required for both 9 and 25 pin serial ports on a PC.

	9 PIN	25 PIN
RXD	2	3
GND	5	7

The PC serial port should be configured for **9600 8N1** (9600 baud, 8 data bits, 1 stop bit, no parity). No hardware or software handshaking is required.

DTMF – HOW DOES IT WORK

DTMF was originally developed to allow sending control information (dialled numbers) across the telephone network. The telephone network has a bandwidth of approx. 300 to 3400 Hz, suitable for voice communications. Any control tones would also need to be in this range and had to work regardless of whether voice was present or not. A single tone or frequency could have been used. However, if voice was present, it would interfere with the control tones, making them useless.

To overcome this a scheme was developed whereby two tones or frequencies were combined to represent each control code or number. A total of seven tones were needed to represent the digits normally found on a telephone keypad, namely 0-9, * and #. An eighth tone was added so that some extra digits were available for use. These are commonly labelled ABCD. These eight tones were divided into two groups of four tones each, a low-frequency group and a high-frequency group. This

four-by-four array produced 16 different combinations, as shown in the following table.

Hz	1209	1336	1477	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

You may be wondering why they chose those particular frequencies. Why not simply use multiples of say 500Hz? The answer is in the harmonics generated due to nonlinear circuits in the phone system. If you look at the low-frequency group you will see that their second harmonic (multiple of two) falls between the high-frequency tones. Third harmonics and above are outside the range of the high-frequency tones and are not a problem.

A valid tone pair has to meet the following criteria:
- Only one tone per group allowed
- Start of each tone must be less than 5mS apart
- Both tones must last at least 40mS
- Each tone must be within 2% of the center frequency
- The tone levels must be within 6dB of each other

All of these features make it extremely unlikely that voice will accidently generate valid DTMF tones. This has meant that DTMF is now used for much more than just sending dialled numbers across the telephone network.

THEORY OF OPERATION

The circuit is powered via 5 volts supplied by IC1, a 78L05 voltage regulator. Diode D1 provides reverse polarity protection in case the input voltage is connected the wrong way around.

IC2 is a DTMF receiver chip, a CM8870 from California Micro Devices. It is responsible for all the processing described above. The DTMF signals are picked up by microphone M1 or direct from the telephone line via the transformer. Switch SW1 is used to select between them.

The microphone is an electret type and is biased by resistor R1. The transformer provides electrical isolation between the phone line and the kit. Capacitors C10 and C11 couple the AC signal from the phone line to the transformer whilst blocking any DC current. Both transformer windings have a nominal impedance of 600 ohms. Resistors R10 and R11 reduce the AC voltage level to the transformer to prevent signal overloading and distortion.

The DTMF signal (selected by SW1) is coupled via C1 and R2 to the inverting input (pin 1) of a differential op-amp inside IC2. The op-amp is configured for single-ended operation which means feedback from the output (pin 3) is used to set the gain. The gain is set by R3/R2 – a gain of 47 in this case. The non-inverting input (pin 1)

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is tied to a reference voltage Vref at pin 4. This approximately 2.5V (half Vcc).
Resistor R4 and capacitor C2 set the 'guard time', the length of time a tone must be present (or absent) for it to be recognized. For the values shown the guard time is set at 40mS.

Once a valid tone has been detected (after 40mS) the STD output (pin 15) goes high and the 4-bit digit data (representing 0-9 and A-F) is presented on the output pins (pins 11-14). The STD output will remain high whilst the tone is still present and will drop low 40mS after the tone stops.

IC3 is an Atmel 89C2051 microcontroller programmed with software to take the digit data from IC2 and display it on the LCD (and send it as a standard ASCII character to the serial output). It also monitors the state of the two pushbuttons and scrolls the display left or right as required.

If the DTMF tone level is too low the kit will not be able to detect them correctly. The sensitivity of the DTMF decoder can be increased by increasing the value of R3 from 470K to 560K. If the kit detects 'garbage' it may be that the sensitivity is too high. In this case decrease R3 to 390K or even 330K.

The PC serial Interface. This outputs the DTMF digit as an ASCII character. Normally RS232 uses +/- 12V signals for the data stream where +12V is logic low and –12V is logic high. Since we do not have +/- 12V available we use +5V as logic low and ground as logic high. This circuit should work in most cases but it is not guaranteed.

FUN AND GAMES WITH ALPHANUMERIC LCDs

There is a lot of information around, especially on the Internet, about these types of displays and how they work. Most of it is about the 16 character, 2 line types, which are the most common. The display used here is a 16 x 1 type and has some funny precularities of its own.

Most of the LCDs use the Hitachi 44780 controller chip and have onboard RAM to hold the display data. The controller receives the data and stores it into the RAM. An internal address counter addresses the RAM and is incremented automatically when data is stored. The amount of RAM varies depending on the size of the display. However the RAM always starts at address 00h.

For displays having 2 lines or more, the RAM address of the first character on the first line is 00h. The first character on the second line is at address 40h. The display will scroll automatically as data is written past the edge of the display. However, it won't flow over onto the second line until it reaches that address. At least you can write a full line before 'overflow'. This is not a

big problem and is handled with software in the microcontroller.
Single line displays are different. The first display character is at address 00h but the eighth is at address 40h! So, once you have written 8 characters to the display they start scrolling off the left side as new characters are written! Once again this is not a huge problem because it is handled in the microcontroller. But it did cause some problems in the development stage. The microcontroller has to keep track of where the next character is to be written and position the cursor in the LCD controller there before writing the next one.

REFERENCES
http://www.myke.com/lcd.htm Interfacing LCD's
http://www.beyondlogic.org/ Some LCD information

For technical support please contact by email at:
mailto: support@quasarelectronics.com
(Documentation: 3 May 3, 2004.)

PARTS LIST – 3153
Resistors (0.25W 5% carbon film)
2K2 red red red R5,7		2
4K7 yellow violet red R6		1
10K brown black orange..R2,8,9		3
47K yellow violet orange.R10,11		2
22K red red orange R1		1
270K red violet yellow ...R4		1
470K yellow violet yellow R3		1
10K 103 Koa trimpot VR1		1
22pF ceramic....................C6,7		2
10nF 63V MKT box poly .C10,11		2
100nF mono, 0.1" C2,3,9		3
100nF mono, 0.2" C1, 5		2
1uF 50V electrolytic C4		1
10uF 25V electrolytic C8		1
1N4004 ....D1		1
BC547 transistor Q1		1
78L05 regulator IC1		1
CM8870 DTMF decoder ..IC2		1
AT89C2051 micro IC3		1
(pre-programmed with 3153 firmware)		
LCD, 16x1 no back light		1
3.579MHz crystal..............Y1		1
11.0592MHz crystal..........Y2		1
Transformer 600R/600R line isolation		1
DC jack, 2.5mm X1		1
Electret microphone..........M1		1
Zippy tact switches S1,2		2
Slide switch.......................SW1		1
16-pin male single-in-line header		1
16-pin female single-in-line header		1
18 pin IC socket		1
20 pin IC socket		1
Plastic 10mm standoffs		4
Screw, self-tapping		4
Screw, 2.6mm		2
Nuts, 2.6mm.......		4
3153 PCB.......		1

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