

**Copyright © 2008, Wimborne Publishing Ltd**  
**(Sequoia House, 398a Ringwood Road, Ferndown, Dorset BH22 9AU, UK)**  
**and TechBites Interactive Inc.,**  
**(PO Box 857, Madison, Alabama 35758, USA)**

**All rights reserved.**

**The materials and works contained within EPE Online — which are made available by Wimborne Publishing Ltd and TechBites Interactive Inc — are copyrighted.**

TechBites Interactive Inc and Wimborne Publishing Ltd have used their best efforts in preparing these materials and works. However, TechBites Interactive Inc and Wimborne Publishing Ltd make no warranties of any kind, expressed or implied, with regard to the documentation or data contained herein, and specifically disclaim, without limitation, any implied warranties of merchantability and fitness for a particular purpose.

Because of possible variances in the quality and condition of materials and workmanship used by readers, EPE Online, its publishers and agents disclaim any responsibility for the safe and proper functioning of reader-constructed projects based on or from information published in these materials and works.

In no event shall TechBites Interactive Inc or Wimborne Publishing Ltd be responsible or liable for any loss of profit or any other commercial damages, including but not limited to special, incidental, consequential, or any other damages in connection with or arising out of furnishing, performance, or use of these materials and works.

#### READERS' TECHNICAL ENQUIRIES

We are unable to offer any advice on the use, purchase, repair or modification of commercial equipment or the incorporation or modification of designs published in the magazine. We regret that we cannot provide data or answer queries on articles or projects that are more than five years' old. We are not able to answer technical queries on the phone.

#### PROJECTS AND CIRCUITS

All reasonable precautions are taken to ensure that the advice and data given to readers is reliable. We cannot, however, guarantee it and we cannot accept legal responsibility for it. A number of projects and circuits published in EPE employ voltages that can be lethal. You should not build, test, modify or renovate any item of mains-powered equipment unless you fully understand the safety aspects involved and you use an RCD adaptor.

#### COMPONENT SUPPLIES

We do not supply electronic components or kits for building the projects featured; these can be supplied by advertisers in our publication Practical Everyday Electronics. Our web site is located at [www.epemag.com](http://www.epemag.com)

**We advise readers to check that all parts are still available before commencing any project.**



To order your copy for only \$18.95 for 12 issues go to [www.epemag.com](http://www.epemag.com)

# PIC MAGICK MUSICK

JOHN BECKER



*Conjure music from thin air at the mere untouching gesture of a finger-tip.*

Having enchanted and puzzled his intimate audience with close-up magic, the lone magician raised his hands and made a grand sweeping gesture of departure, punctuated by the downwards glissando of an ethereal harp, conjured as though from thin air.

Later in conversation with the author, the hotel's magical entertainer showed off the splendid capabilities of his Yamaha keyboard. A superb (and probably very expensive) piece of equipment, it seemed an ideal instrument through which to further spell-bind an audience.

Then, with a less dramatic gesture, he passed his hand over a small hole in the top of the keyboard – again the descending scales of a harp were heard. On being questioned, though, all the magician would say was “there’s a magic beam”!

INTRIGUED by the foregoing wizardry, the author continued to puzzle for several days about what had actually been meant by the magician’s cryptic reply. He did not have an assistant. Was the triggering done by a laser beam being intercepted? Infra-red? Ultrasonics? Quite naturally, thoughts turned to how a similar effect plus individual note playing could be achieved as a hobbyist electronics project.

This, then, was the inspiration for PIC Magick Musick, and the following discussion tells how it is achieved (without, we hope, triggering the wrath of the Magic Circle)!

## HOW TO PERFORM MAGIC?

At first, optical techniques in the form of laser or infra-red diodes and detectors seemed attractive.

It soon became apparent, however, that whilst these could be used to readily trigger a preset series of consecutive notes, it would be extremely difficult to use them if individual notes were to be triggered according to the height at which the optical beam was intercepted.

Theoretically, it is possible to measure the time lag between a light beam being

emitted and its reflected return from a passing hand. Regrettably, though, the speed of light is too Einsteinian-fast for its delayed reflection to be timed by the electronic components typically available to the average hobbyist.

The speed of light is generally taken to be 300,000 kilometres per second (186,000 miles per second). To time its transition across one metre, therefore, would require a detector and timing circuit that could respond in at least  $1/300,000,000$  of a second.

The response time would need to be even greater if distances varying by only a centimetre or two were to be differentiated. No, such cosmic speeds are beyond hobbyist monitoring!

Optically measuring distance can also be done by sensing the amount of light reflected when a beam of known intensity is emitted. This, though, would require the

target to have a known and constant reflectivity. Hands, by their very human nature, have widely differing reflective qualities. The target’s angle to the source would also be critical so that none of the beam’s intensity became reflected away from the detector. This rules out a waving hand as the target.

What about interferometry, measuring the phase difference between emitted and reflected light beams? Huh! Who’s going to pack that amount of equipment into a box portable enough for gigging stage work? Not even the National Physical Laboratory, that’s for sure!

Ultrasonics, then – what about that? Ah, now we’re getting somewhere reasonable. Sound travels at a mere 332 metres per second, roughly. It’s far more easy to measure short distances using ultrasonic transmitters and receivers. It has been proved in *EPE* several times, using pulsing timing techniques in the author’s *Ultrasonic Tape Measure* (Nov ’98), for instance, and phase differences in the rain sensing circuit of his *EPE Met Office* (Dec ’95/Jan ’96).



Magick Musick can drive almost any sound output, large or small.

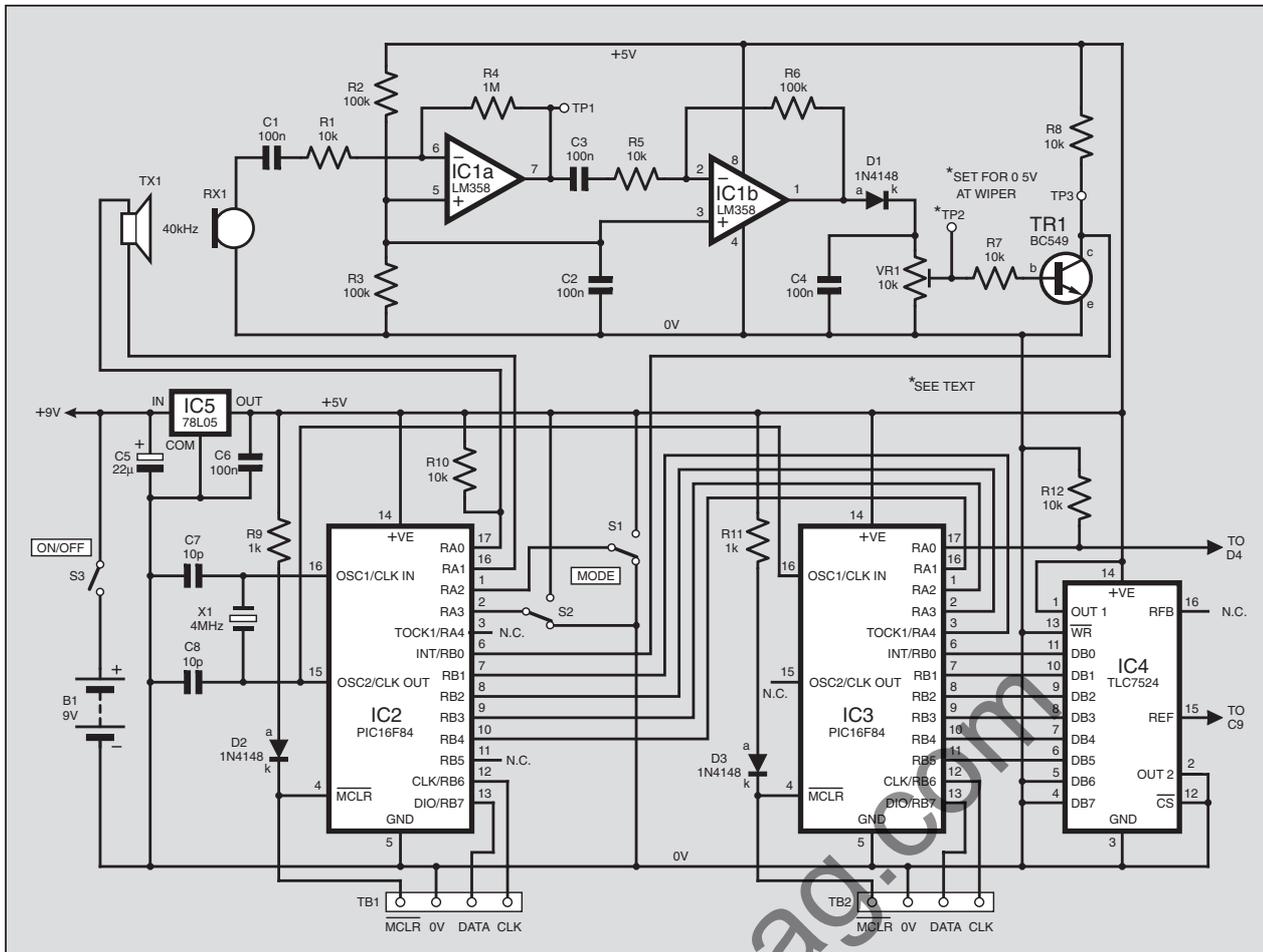


Fig.1. Circuit diagram for the ultrasonic transducers and dual-PIC controllers.

## ULTRASONIC ECHOES

In pulse timing techniques, allowance has to be made for the fact that the mutual proximity of transmitting and receiving transducers causes a “ringing” in the latter during transmission. Even so, with careful hardware or software design it is possible to “mask-out” the ringing and detect only the echo pulses. Distances as close as a few centimetres can be readily measured using this method.

This is the technique used in PIC Magick Musick. A 40kHz ultrasonic transmitter constantly emits six square wave pulses approximately every 140 milliseconds, about seven batches per second (7Hz). After each batch, and following the conclusion of a “masking” period, the return of an echo signal is timed using a synchronised counter. The count value is then related to a look-up table which allocates a particular note frequency to be generated.

For each new note value allocated, an envelope shaper is triggered, which causes the note to be emitted by a loudspeaker or headphones, or sent to a normal domestic amplifier. It starts at full required signal strength and progressively decays in amplitude until it finally ceases. If the next pulse detects a distance significantly different to the previous one, another note is similarly played.

The circuit is designed so that the detection range starts about 20 centimetres above the transmitter and extends for about a further half metre. There are 15

trigger “zones” within that range allowing two octaves to be covered in eight steps per octave (just the “white” notes on a keyboard – there are no sharps or flats), from C to C” (131Hz to 523Hz). Approximately two centimetres separate each note.

By inserting a hand or other object into the transmission beam at different heights, different notes can be triggered. Triggering occurs not only vertically above the sensors, but also within a “cone of sensitivity”. This means that adjacent notes can be triggered even though the hand remains at the same height.

Triggering can occur as rapidly as the transmission pulses are generated, even though the envelope shaper has not allowed the previous note to die away fully. Only single notes can be played, however. It is not possible to create chords.

## MODE VARIETY

Variety is added to the unit in various ways. The preceding description is for the principal mode, in which all 15 notes can be triggered. A secondary mode allows just four notes per octave (seven across two octaves) in musical order 1, 3, 5, 8 – e.g. C, E, G, C’ (the notes that would make up a major chord on a polyphonic instrument).

Two other modes can be switched in as alternatives. In the first of these, there are four repeating preset sequences of notes which are triggered by a single pass of the hand anywhere within the detector’s range. The first generates a descending 15-note scale. The next hand-pass causes the same 15 notes, but in ascending note order.

Next, a descending 7-note scale (C’, G’, E’, C’, G, E, C) is triggered. At the fourth triggering the same seven notes are repeated in ascending order. The cycle then repeats.

The other option plays notes determined by values held in the PIC’s data EEPROM (up to 64 notes). There is a pre-loaded sequence created by the author. Readers having PIC programming facilities, such as offered by EPE PIC Toolkits Mk2 and Mk3 (TK3), can create their own sequences as text files and program them into the data EEPROM using the Send Message facility (which leaves the main program itself untouched).

## CIRCUIT DESCRIPTION

The circuit diagram for the PIC Magick Musick ultrasonic processing and control system is shown in Fig.1.

The first point of interest is that two PIC microcontrollers are used, IC2 and IC3. They operate synchronously at 4MHz as set by crystal X1, which is in circuit with IC2.

Early attempts to use a single PIC to control the ultrasonic signal and generate musical notes simultaneously proved to be unsuccessful. It was decided, therefore, that with PICs being so inexpensive, two would be used. IC2 controls the ultrasonic transmission pulses and performs the timing of their reflected return. It repeatedly transfers the echo delay values to the second PIC, IC3. This generates the required notes in response to the timing values received from IC2.

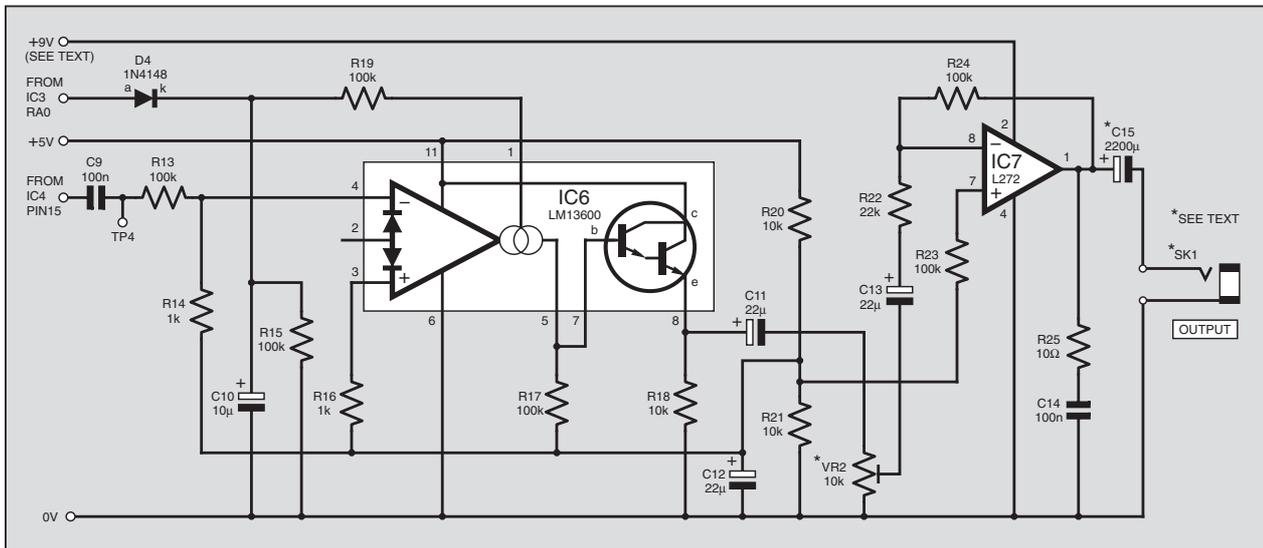


Fig.2. Envelope shaper and audio output stages.

Pins RA0 and RA1 of IC2 output brief push-pull 40kHz pulses to transmitter TX1. Echoes are detected by receiver RX1 and amplified by the serial network comprising op.amps IC1a and IC1b.

The op.amps are biased to a half-rail voltage (2.5V) by the potential divider consisting of resistors R2 and R3. Amplified pulses are output from IC1b pin 1 and are half-wave rectified by diode D1. Capacitor C4 charges to a d.c. level set by the positive-going amplitude of the rectified signals, superimposed on the 2.5V bias.

Preset potentiometer VR1 has two functions: it sets the trigger level to which transistor TR1 responds, buffered by resistor R7, and provides a discharge path for capacitor C4. The voltage at the wiper of VR1 is set to about 0.5V, just below TR1's turn-on level of about 0.6V.

In the absence of an echo pulse, TR1 stays in a turned-off condition, with its collector (c) at +5V. On receipt of pulses above its trigger level, TR1 is turned on and its collector voltage falls to a saturation level close to 0V, as governed by load resistor R8.

### MASKED COUNT

Controller IC2, having transmitted each ultrasonic pulse sequence, waits for the brief "masking time" referred to earlier, and then starts a counting sequence. On detecting a negative-going echo pulse from TR1, it stops the count and analyses its value.

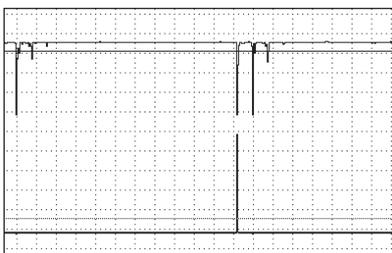


Fig.3. The lower trace shows the ultrasonic transmission pulse. The upper trace shows the "ringing" pulse received during transmission, followed by the required echo pulse, and then by a later, unrequired, minor echo.

If the count is greater than a software-set value, the pulse is considered to have arrived too late. This prevents the unit from being triggered, for example, by echoes from the ceiling above it.

If the count is in range, it is allocated to one of 15 sub-ranges, as a value between 1 and 15. This is output as a 4-bit binary code from pins RB1-RB4 to the second PIC, IC3, which receives them via its pins RA1-RA4.

### FREQUENCY GENERATION

The software for IC3 causes Port B to constantly increment through 63 steps, roll over to zero and step upwards again. The rate at which it increments is set by 15 sub-routines, each of which has a different rate of increment. The binary code received from IC2 determines which sub-routine is in current use. As soon as the code changes, so does the sub-routine. The rate at which the counter increments determines the audio tone that is ultimately heard.

The output from Port B is fed as a 6-bit value to the 8-bit digital-to-analogue converter (DAC) IC4, Texas Instruments type TLC7524, whose bits 6 and 7 are held permanently low. It is configured in the mode most suited to this application in which a binary input value causes an equivalent d.c. voltage (as opposed to current) to appear at its REF (reference) pin. In this mode the DAC has its two "normal" outputs (OUT1 and OUT2) connected to +5V and 0V, respectively (the device's data sheet, which describes the modes of operation, is downloadable free from [www.ti.com](http://www.ti.com)).

Because the input digital value is constantly counting upwards and then rolling over and so on, the output from DAC IC4 is a rising sawtooth (ramp) waveform. Its frequency is that of the musical note required, lying between 131Hz and 523Hz (musical notes C to C"). The waveform is

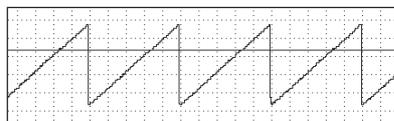


Fig.4. Sawtooth waveform created via DAC IC4.

fed via capacitor C9 and resistor R13 to pin 4 of transconductance amplifier IC6 (see Fig.2).

The reason for using a counter in 6-bit mode is to speed the frequency at which it rolls over (see the later discussion on PIC frequency generation). It also intentionally limits the range of the DAC's output voltage to about 1V peak-to-peak.

### ENVELOPE SHAPING

Transconductance amplifier IC6 is a dual device (of a similar type discussed in *Circuit Surgery* Dec '01) of which only one half is used. It is an extremely versatile device that can be used in many signal control applications. Its data sheet and applications notes are well worth studying and using (obtainable via [www.nsc.com](http://www.nsc.com)).

In this application it is used as a voltage controlled amplifier (VCA) that is under pulsed control as an envelope shaper (a term much favoured in the "golden" music project days of the 1970s and early '80s). It is controlled by the logic level output from IC3 pin RA0.

On receipt of a value that is greater than zero and different to the previous value received, IC3 briefly sets its pin RA0 high and then returns it low until the next different note value is received from IC2.

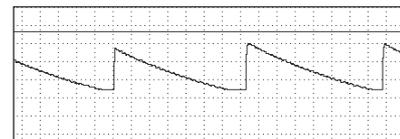


Fig.5. The envelope shaping pulses at capacitor C10.

The output from RA0 is fed via diode D4 (Fig.2) to capacitor C10. The capacitor charges rapidly, and then its voltage ebbs away via resistor R15 (and R19 – more in a moment) once the pulse from RA0 has ended.

The voltage across C10 is also a ramp, rapidly charging to a peak close to 4.3V (+5V – 0.7V voltage drop across D4), and then decaying exponentially in typical capacitor discharge fashion to close to zero volts.

VCA IC6 allows a signal to pass from its input at pin 4 to its intermediate output at



workshop equipment). Do not insert them until the correctness of your 5V power supply has been established. Once this has been done and assembly completed, you are ready for a bit of magic of your own.

The transducers TX1 and RX1 were mounted on 24s.w.g. enamelled wire 'stalks' so that they were close to the holes drilled in the lid of the case.

## SOFTWARE

Both PICs (IC2 and IC3) are identically programmed. *It does not matter which of your two PICs is put into which IC2/IC3 socket.* The correct transmission or music generation routines are automatically selected depending on the logic level connection made to pin RA0. With IC2, the connection is to the +5V rail via resistor R10. For IC3 it is to the 0V line via resistor R12.

If programming your own PICs using *Toolkits Mk2* or *TK3*, also send file *MagicM04.MSG* to the data EEPROM via the Send Message option. (It only needs to go to PIC IC2.)

## SOFTWARE SOURCES

The software for PIC Magick Music is available on 3.5 inch PC-compatible disk from the *EPE* Editorial office, for which a nominal handling charge is made. It is available for free download from the *EPE* ftp site. More details are given on the *EPE PCB Service* page.

The easiest way into the ftp site, however, is via our UK web site at [www.epemag.wimborne.co.uk](http://www.epemag.wimborne.co.uk). From the entry screen click on **FTP Site (Downloads)** at the top, drill down through folders PUB and PICS and open folder *MagicMusic*.

There are three main software files, the source code (ASM written in TASM), and code for sending to the PIC in two formats: OBJ (TASM) and HEX (MPASM). PIC configuration details for TASM users are given at the top of the ASM file. They are automatically embedded in the HEX file.

There are also four example "notes" files for the data EEPROM, *MagicMxx.MSG* (where xx = 01, 02, 03 and 04).

Readers with *Toolkit Mk2* or *TK3* programmers can program the PICs while in

circuit via pin-headers TB1 (IC2) and TB2 (IC3). Components R9, R11, D2 and D3 prevent programming voltages from distressing the +5V supply line.

## TESTING

For initial testing, place the assembled p.c.b. on a flat surface facing the ceiling and switch on the power. Adjust preset VR1 so that a voltage of about 0.5V appears at its wiper (and at the base of transistor TR1). Set VR2 to maximum volume position (fully clockwise). Plug in a loudspeaker or headphones.

With the switches set to normal "hand-control" mode (both Off), slowly move your hand in from the side to about half a metre above the ultrasonic transducers. *Let there be music* – and hopefully there will be as a note is triggered by a returning echo!

Moving your hand up and down above the transducers, different notes should be played. You should find that there are minimum and maximum hand distances beyond which the notes will not be triggered (see earlier). Experimenting, you should also find that there is a "cone of sensitivity" around the transducers that causes notes to be triggered when it is entered.

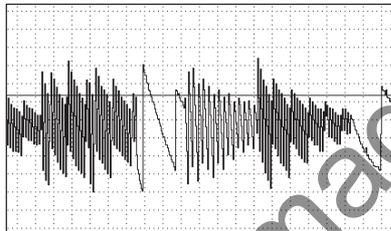


Fig.8. Finger-triggered note sequence.

If you don't achieve immediate success, slightly readjust preset VR1. If the presence of the ceiling is causing triggering (as would be indicated by lifting the board up and down above the bench), reduce VR1's wiper voltage fractionally.

If the triggering range is too small, or non-existent, increase VR1's wiper voltage a bit – but regard 0.55V as being the practical maximum, otherwise you could be setting it too close to TR1's trigger threshold.



Interior layout arrangement. The transducers are mounted on "stalks", see text.

# COMPONENTS

## Resistors

R1, R5, R7, R8, R10, R12, R18, R20, R21 10k (9 off)  
R2, R3, R6, R13, R15, R17, R19, R23, R24 100k (9 off)  
R4 1M  
R9, R11, R14, R16 1k (4 off)  
R22 22k  
R25 10Ω  
All 0.25W 5% carbon film or better

See  
**SHOP**  
**TALK**  
page

## Potentiometers

VR1 10k sub-min preset, round  
VR2 10k sub-min preset, round, or 10k log rotary, panel mounting (see text).

## Capacitors

C1 to C4, C6, C9, C14 100n ceramic, 5mm pitch (7 off)  
C5, C11 to C13 22μ radial elect, 16V (4 off)  
C7, C8 10p ceramic, 5mm pitch (2 off)  
C10 10μ radial elect. 16V  
C15 2200μ radial elect, 16V (see text)

## Semiconductors

D1 to D4 1N4148 signal diode (4 off)  
TR1 BC549 or similar gen. purpose npn transistor  
IC1 LM358 dual op.amp  
IC2, IC3 PIC16F84-4P microcontroller (2 off, identically pre-programmed, see text)  
IC4 TLC7524 8-bit digital-to-analogue converter  
IC5 78L05 +5V 100mA voltage regulator  
IC6 LM13600 or LM13700 dual transconductance amplifier  
IC7 L272 dual power op.amp

## Miscellaneous

RX1, TX1 40kHz ultrasonic transducer matched pair (transmitter plus receiver)  
S1, S2 s.p.d.t. min. toggle switch (2 off)  
S3 s.p.s.t. or s.p.d.t. min. toggle switch  
SK1 3.5mm jack socket  
X1 4MHz crystal

Printed circuit board, available from the *EPE PCB Service*, code 332; 8-pin d.i.l. socket; 14-pin d.i.l. socket; 16-pin d.i.l. socket; 18-pin d.i.l. socket (2 off); 1mm 4-way pin-headers, 0.1in pitch (2 off) (see text); plastic case to suit, 150mm x 80mm x 50mm; 9V battery and clip (see text); enchantable audience (many); connecting wire; solder, etc.

Approx. Cost  
Guidance Only  
excluding case & batt.

**£35**

## THEME TUNES

Users of *EPE PIC Toolkits Mk2* and *TK3* will find that writing theme tunes for downloading into PIC IC2's data EEPROM is as easy as writing program code – perhaps easier!

Using your preferred text editor, one way is to write a sequence of 64 numbers whose values lie between 0 and 15, as illustrated in file *MagicM02.MSG*. Save them as a *Toolkit* Message file (extension .MSG). Then send the file contents to PIC IC3 via *Toolkit's* Send Message option. Job done! Next time you trigger PIC Magick Musick when switch S1 and S2 are both in the On position, your programmed notes will be generated.

A second melody writing technique is to use alphabet letters relating to the notes required, as illustrated in file *MagicM01.MSG*. Lower case a-f are the notes for octave 1, upper case A-F for octave 2, and upper case H for top C (C<sup>''</sup>). A further example is in *MagicM03.MSG*.

But, you may ask, what numbers should I use? Ah, that's where your talents as a composer come into play! The options are shown in Table 1.

Column 1 shows the value to be written into your MSG text file. Column 2 shows the letter that could be entered instead. Column 3 shows the name that is given to the resulting note when its frequency equals that in column 4. Column 5 shows the approximate frequency that should be expected from PIC Magick Musick.

**Table 1. PIC music program note values, musical names, ideal (calculated) and prototype-generated frequencies (the latter may vary slightly between units).**

Value	Alpha	Note	Ideal Hz	Prototype Hz
0	–	–	none (pause)	
1	c	C	130-813	129.9
2	d	D	146-832	146.9
3	e	E	164-814	163.9
4	f	F	174-615	175.0
5	g	G	195-998	194.5
6	a	A	220-000	222.1
7	b	B	246-941	246.7
8	C	C'	261-625	263.3
9	D	D'	293-664	292.9
10	E	E'	329-627	330.1
11	F	F'	349-229	352.4
12	G	G'	391-995	397.1
13	A	A'	440-000	442.0
14	B	B'	493-883	498.4
15	H	C''	523-251	532.4

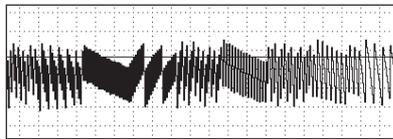


Fig.9. Part of the downwards 15-notes scale.

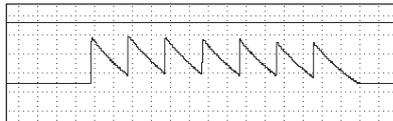


Fig.10. Envelope shaping waveform when 7-note scale is played.

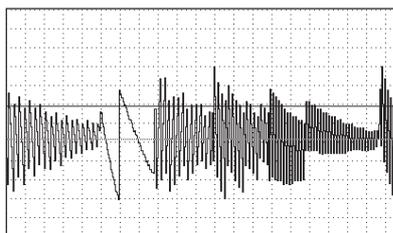


Fig.11. Ascending 7-note scale.

Another option is to use a random melody, created by loading any 64 characters of a text file. This is how the theme pre-installed (*MagicM04.MSG*) into the PICs is created. It consists of the first 64 characters of the first line in this article (*Having enchanted...*).

The software automatically ANDs the ASCII values of the characters with 15, so that they trigger one of the 15 notes available. Spaces, punctuation etc. may all be left in. Any resulting zero value simply creates a pause.

Once triggered, the scales and melody run their full course before another hand movement or switch setting comes into effect.

## FREQUENCY PRECISION

As the author has discussed in previous PIC controlled music generating designs, such as *PIC-olo* (Aug '97) and the *PIC Musical Sundial* (Jun '99), it is impossible to actually program a PIC to generate truly accurate musical notes. A compromise has to be accepted.

Software-generated frequencies depend on the time between a register value being taken high and low. For instance, if bit 0 of a Port register is taken high, held there for half a second, and then taken low for half a second, and the cycle constantly repeated, the resulting output at Port register pin 0 is a 1Hz square wave.

It will be obvious that with a PIC's oscillator running at a high rate, timing of the pause lengths between the cycle phases of a slow frequency square wave can be very accurately adjusted, because there are many PIC program cycles that take place during them. Frequency adjustment can be made minutely just by increasing or decreasing the count values between each phase by just one cycle.

In the case of a PIC running at an effective rate of 1MHz (i.e. its crystal clock is running at 4MHz), the precise value of a nominal 1Hz output frequency can be adjusted by a mere one millionth of a second, the duration of just one command.

Look at the other extreme, though. Again suppose the PIC's effective rate is 1MHz and we want to output a frequency via PORTB pin 0 (RB0). The fastest output frequency generating routine is:

```
HERE: INCF PORTB,F
      GOTO HERE
```

Two commands are involved, between them taking 2μs, thus to complete a full square wave cycle takes 4μs, an output frequency rate of 250kHz.

This rate cannot be increased without changing the basic clock rate. It can, however, be slowed by the addition of one command, NOP for example. There are now six commands to the square wave cycle, and an output rate of approximately 167kHz. Adding another NOP reduces the rate to 125kHz.

There are no intermediate frequencies that can be generated between either of the above frequency pairs with a 4MHz crystal controlled clock.

## LOOPED DELAYS

Although the required output frequencies for a PIC music-generating design are much slower than these examples, a similar principle prevents truly accurate music frequencies being developed.

A simplified example of frequency generation as it is done in PIC Magick Musick is shown in Listing 1.

Listing 1a provides a look-up table in which the PORTA value causes a jump to the correct note generating routine, one of which is shown in Listing 1b.

Here the routine is for note G, which has an approximate frequency of 195Hz. LOOPB is loaded with a delay value of 21, and then is decremented to zero. After two additional delaying commands, a jump is made to the OUTIT routine in which PORTB is incremented, and a jump made back to label TONE.



### LISTING 1a

```

ROUTE: movf VALUE,W ; VALUE holds code received via
      PORTA
      andlw 15 ; it's limited to 15
      addwf PCL,F ; added to the Program Counter, to
                  cause a value related jump:
      goto BVL ; 0 not used
      goto CL ; 1
      goto DL ; 2
      goto EL ; 3
      goto FL ; 4
      goto GL ; 5
      goto AL ; 6
      goto BL ; 7
      ; etc

```

### LISTING 1b

```

TONE: goto ROUTE ; do required table jump
GL: movlw 21 ; set loop val for note 5, G 195Hz
     movwf LOOPB
GLa: decfsz LOOPB,F ; decrement loop until zero
     goto GLa
     nop ; timing adjustment
     nop ; timing adjustment
     goto OUTIT ; go and increment PORTB output
                  value
                  ; other note generators here
OUTIT: incfsz PORTB,F ; is PORTB value zero?
       goto TONE ; no
       (yes, so get PORTA value routine here)
       goto TONE

```

Even though it is known that the PORTA value has not been changed at this time, the seemingly unnecessary jump again to the look-up table helps to keep the frequency generation even.

When PORTB rolls over to zero, PORTA is read for its current value. If the value is the same as the previous sample, note G routine is again repeated. If a new value is found, the table automatically routes to the appropriate delay routine.

Each note's delay routine has a different LOOPB value, and varying quantities of NOP commands. These help to "tune" the frequency as close as possible to that ideally required.

In the note G example shown, the actual frequency required is 195.998Hz. The prototype produced a frequency of 194.5Hz (measured on PICGEN of July '00). Deleting one NOP to raise the frequency generated 196.9Hz. Adding one more NOP to slow it, resulted in 192.2Hz.

As illustrated earlier, the higher the required frequency, so it becomes increasingly difficult to tune software to produce it. Where the decision has been marginal, the author has generally erred for a frequency fractionally higher than the ideal.

### WAVEFORM SHAPE

It may at first sight seem that the note loops have a low value compared to the frequency expected when using a 4MHz crystal clock. Had just PORTB pin 0 been



the frequency output source, generating a square wave, much higher loop counts could have been used, allowing much tighter control of the actual frequency being output.

However, the aim with PIC Magick Music was to generate a non-square waveform. Experiments were tried using sine and triangle generating algorithms, but a sawtooth was felt to produce a more interesting sound.

Its generation, though, takes 64 clock cycle steps at PORTB (used as the 6-bit counter referred to earlier), bringing the

note delay loop rates down by the same amount. Originally, 256 PORTB steps were tried, but the frequency results were too low to be acceptable.

Using 256 steps (8-bit) also produced a waveform amplitude greater than required to suitably drive the power amp via the envelope shaper. The 6-bit value basically results in a DAC output swing of about 1V peak-to-peak.

### WIZARD FUN!

Whilst music "purists" may wonder if some notes have a frequency that might not be fully welcomed in a concert hall, remember that PIC Magick Musick is an inexpensive *fun* design. Had greater tuning accuracy really been desired, considerably more complex techniques would have been needed – at much greater cost.

When PIC Magick Musick was demonstrated at EPE HQ, the author was delighted by the positive response it received. It is, he has to say proudly, a super little design which can generate lots of fun for anyone using or hearing it. You've just got time before the festivities to build one, and maybe even program it with an appropriate jingle.

Magick Season's Greetings from a would-be PIC Wizard!

The waveform "screen dumps" were created via the author's PIC Dual-Channel Virtual Scope of Oct '00. □

## Radio Bygones

The leading magazine  
for vintage radio  
enthusiasts

WHETHER your interest is in domestic radio and TV or in amateur radio, in military, aeronautical or marine communications, in radar and radio navigation, in instruments, in broadcasting, in audio and recording, or in professional radio systems fixed or mobile, RADIO BYGONES is the magazine for you.

ARTICLES on restoration and repair, history, circuit techniques, personalities, reminiscences and just plain nostalgia – you'll find them all. Plus features on museums and private collections and a full-colour photo-feature in every issue.

IT'S MOSTLY about valves, of course, but 'solid-state' – whether of the coherer and spark-gap variety or early transistors – also has a place.

FROM THE DAYS of Maxwell, Hertz, Lodge and Marconi to what was the state-of-the-art just a few short years ago . . .

THERE IS ALSO a selection of free readers' For Sale and Wanted advertisements in every issue.

### Radio Bygones covers it all!

THE MAGAZINE is published six times a year, and is only available by postal subscription. It is not available at newsagents.

We accept Visa, Mastercard, Amex, Diners Club and Switch. Minimum card order £5.

To TAKE OUT a subscription, or to order a sample copy, please contact:

RADIO BYGONES, Wimborne Publishing Ltd.,

408 Wimborne Road East, Ferndown, Dorset BH22 9ND.

Tel: 01202 873872. Fax 01202 874562.

Web sites: [www.radiobygones.co.uk](http://www.radiobygones.co.uk)

[www.radiobygones.com](http://www.radiobygones.com)

Now Also  
Available To  
**BUY ONLINE**  
[www.radiobygones.com](http://www.radiobygones.com)  
Log on, pay by credit card  
and download the magazine  
to your PC  
ONLY **\$9.99** (US dollars)  
**FOR 6 ISSUES**  
A free issue is  
available