A PIC based PA Sequencer

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Abstract

This paper presents a software derived sequencer for PA switching, based around the Microchip 16F84 Peripheral Interface Controller (PIC). The design is complementary to the 16F84 based PA Controller presented at last years' event [1]. In this implementation, provision is made for full independent control of both PA and preamp relays, and of the functions of tube PA's - grid, screen and ALC – to allow correct changeover in both directions - receive to transmit and transmit to receive. The design allows both normal or latching relays to be used in either the preamp or PA relay positions. Within this paper some discussions will also be made on simplified implementations – eg for triodes, or where only one set of relays is needed.

Introduction

There are many articles and presentations to be found regarding Tx/Rx Sequencers - some good references are to be found in every amateur construction manual, eg RSGB, ARRL, etc. These design s only allow use with normal relay types. Having initially intended to include the sequencing functions into the PA controller, they have now been built into this design. There are several reasons for this:

- The output drive requirements for an integrated controller sequencer in a single chip would necessitate using a chip with a much larger pin count
- Integrating the sequencer with the controller would slow down the loop sampling time of some of the controller functions – under certain combinations of conditions, the ability to detect fault conditions quickly would be impaired
- There is a functional distinction between the operational requirements of a Tube Controller and a Sequencer – there are, in fact, no duplicated routines or functions between the two designs.

Unlike the PA Controller, which is specifically designed for use with tube PA's, there is no such restriction on the Sequencer design – although the outputs are labelled for use with the functions of a tube PA, in a practical implementation they are just drive signals for switches, with defined timing delays between them – so they can be used for solid state amplifiers as well.

The added advantage of this sequencer design is its ability to drive both normal and latching type relays – many relays found on the surplus market, especially SMA relays for microwave use, are of this type – see the discussion below on Latching Relays.

Key Features and Assumptions

Key features of the Sequencer software are:

- Handles all PA/Antenna relays
- Designed for both Normal and Latching relays with <u>dual coils</u>
- Provides control of ALC, grid and screen switching
- Provides for a Bypass mode of operation
- Dual PTT inputs for driving PA and preamp changeover relays separately (necessary for Bypass mode operation).

Some assumptions about the end system have been made:

- PTT active is Earth on Transmit, floating positive on Rx.
- Where pairs of relays are used, eg on input and output of PA, that both are of the same type – ie normal or latching
- That when all relays are in their rest state there is a direct connection from the PA input to the output.
- That an external input is available to identify the state of the preamp – ie off or on (if used).
- That the PTT inputs will always assume their state changes simultaneously.
- Fixed timing delays are built into the logic – every change action is followed by a suitable delay to allow the relay to stabilize.

Latching Relays

Before discussing the Sequencer itself, it is worth looking briefly at Latching Relays.

There are different types of latching relays which may be found on the surplus market. Not only can you find changeover (SPDT, DPDT, etc) types, but you will also see transfer relays which are latching. Most of the RF relays to be found are of the dual coil type – but some care must still be taken:

- Although there are two coils, it is quite common for one end of the two coils to be joined together internally.
- The action of a latching relay is dependent upon the use of permanent magnetic material to provide the latching, and the electromagnetic effect from the active coil provides the additional impetus for movement – the sense of the applied voltage is critical for some latching relays.
- Some latching relays also have the back emf protection diodes built in – another factor which determines the polarity of the voltages that must be applied for it to operate correctly.

Fig 1 shows a representation of a latching relay – coils 1 and 2 are independent, and the armature is stable in either state – hence just a short pulse of current through the coil is enough to pull the armature into its other stable state, and change over the electrical contacts of the relay. It will remain in this state until there is a pulse through the other coil

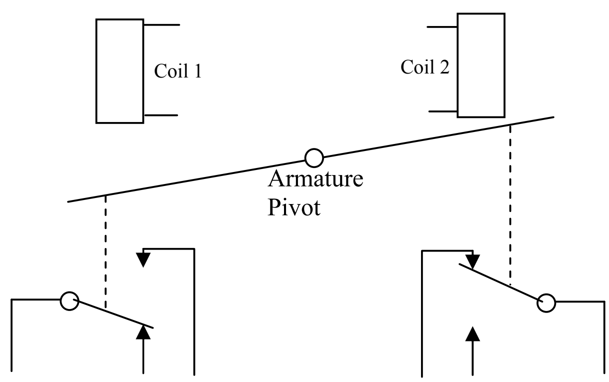

Fig 1 Symbolic representation of a Latching Relay

The combined effect of these factors is that you may be forced to adopt a common supply or common ground connection for the relay – thus different interfacing circuits are provided, so that you can cope with either requirement. Some testing of the chosen relay(s) is recommended before you commit to a particular circuit implementation!

Remember, that if you are driving multiple relays from a single set of outputs, they must all have the same driving requirements (ie common ground or supply, operating voltage etc). They do not need to be physically identical.

Operation Modes

The sequencer supports both the Bypass and Normal modes of changeover, as defined in the PA Controller article. These definitions are reproduced here for completeness:

Bypass Mode

When the PA is off, or while the heater delay is maturing, the presence of ground (0v) on the PTT line will cause the Preamp Relay output to go into Tx mode. It will not allow the PA itself to change into TX, and will not allow the drive signal to be fed into the amplifier - thus the driver stage will be connected directly to the antenna on Tx, but any preamps in use will be fully functional on receive

Normal Mode

Once the heater delay has matured, then the presence of ground (0v) on the PTT line will cause a full change over to Tx, with the drive being fed to the PA, and the PA connected directly to the antenna on Tx. On Rx the antenna will be connected directly to the driver, or via the preamp if it is switched in.

Additionally, in each of these operation modes, during Rx, the Rx Preamp may be either on or off.

The Specification

Thus, from the requirements list above, the complete controller must:

- have inputs for Bypass (preamp) and Normal (PA) PTT driving
- have an input for detecting whether the preamp (where used) is switched in
- have inputs to identify the relay types for the Preamp & PA relays
- have outputs for controlling the Preamp and PA relays – both coils
- have outputs for controlling the ALC, Grid and Screen supplies
- have pre-determined delays between switching functions

Software Description

The Sequencer software uses simple test and branch logic, to minimize the loop cycle time when there is no change of state required – typically, the loop takes approx 10 us to execute – ie, the PTT input is tested every 10us. When a need for a state change is detected, the code branches into the steps necessary to determine which change is needed, and to execute that change. Apart from the PTT condition, all other information necessary for the change is already held in the controller.

Inputs to the processor are the two PTT conditions, the type of the preamp & PA relays, and the Preamp state. Of these, the relay types are read only at processor start up (since these will not change on a regular basis). The preamp state and the PTT inputs are read in sequence around the main program loop.

Internal variables are tracked to ensure that the processor is always aware of the last state of each of the PTT inputs – this is necessary for comparison purposes in detecting a change of PTT state.
All state changes are based on the system outline diagram shown in Fig 2, below -

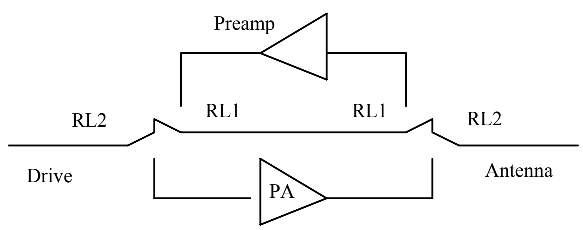

Fig 2 – System Outline Diagram

Relays marked as RL1 are associated with the Preamp switching, and RL2 are the main PA switching relays. The diagram shows both sets of relays in the rest, or normal, state.
There are three quiescent states covering all required conditions

- RL1 operated (Preamp on , receive)
- RL1 & 2 normal (Bypass Tx; Rx, Preamp off)
- RL2 operated (Normal Tx)

There are no legal states requiring RL1 and 2 to be operated simultaneously.
The software calls the appropriate changes of state by detecting the changed PTT condition, the state of the Preamp and the last known set of state conditions. From this information the required state changed is deduced and called, with the necessary change conditions correctly set up.
Each state change correctly sequences the ALC, grid, screen and relay changeovers, with delays between each action to ensure that all relay contacts have stabilized etc. 10ms delays are used after the ALC, grid and screen switches, and 50ms is allowed for the PA and Preamp relay changes. Additionally, 100ms is used as the pulse duration for latching relays. These delays are not user configurable.

Sequencer Inputs & Outputs

Tables 1 and 2 show the input and output conditions for each i/o pin of the PIC.

Port	Logical Pin	Function	State
RA	0	Preamp relay Drive from PACTL	Tx =1
	1	PA Relay drive from PACTL	Tx =1
	2	Preamp Relay type	0=normal, 1=latching
	3	PA Relay type	0=normal, 1=latching
	4	Preamp on / off	Preamp on=1

Table 1 – Sequencer Inputs

Port	Logical Pin	Function	State
RB	0	Not used	
	1	ALC Drive	On =1(ie ALC inhibited)
	2	Grid Bias drive	Tx=0
	3	Screen Grid drive	Tx=0
	4	Preamp relay drive	Tx or Pulse =0
	5	Preamp latching drive	Pulse =0
	6	PA relay drive	Tx or Pulse =0
	7	PA latching drive	Pulse =0

Table 2 – Sequencer Outputs

PIC 16F84 Physical Connections

The code is programmed into an 18 pin 16F84 PIC. In addition to the inputs and outputs listed in Tables 1 & 2 above, there are 2 oscillator connections, and three power and control connections. Table 3 lists the physical pin-out of the PIC, with the functions ascribed in this application

Pin No	Function	Comment
1	RA2	Preamp Relay Type – 1= Latching
2	RA3	PA Relay Type – 1= Latching
3	RA4	Preamp On/Off – 1= On
4	MCLR	Tie to +5V via 10k
5	V_{SS}	Processor 0V connection
6	RB0	No connection – not used
7	RB1	ALC drive – 1= active
8	RB2	Grid drive – 0=active
9	RB3	Screen grid drive – 0=active
10	RB4	Preamp relay drive/latching pulse on
11	RB5	Preamp latching pulse off
12	RB6	PA relay drive/latching pulse on
13	RB7	PA latching pulse off
14	V_{DD}	Processor +5V supply
15	Osc2	Oscillator connection
16	Osc1	Oscillator connection
17	RA0	Preamp PTT input – 1=Tx
18	RA1	PA PTT input-1=Tx

Table 3 – Physical connections for DL4MUP Sequencer PIC

Power Supply Considerations

The processor requires a regulated +5v DC supply, which should be isolated from all other supplies in the PA, including relay supplies – if the DL4MUP PA Controller is being used, the two PICs may share a common supply. Ideally, the supply should be completely separate from all other supplies in the PA, with its own transformer, or transformer winding. Care must also be taken to ensure that the ground for the PIC is not connected to the input and output (RF) grounds, and that the connections into and out of the enclosure are decoupled.

The MCLR input (pin 4) must be tied to Vdd via 10k to ensure correct start up and operation of the Sequencer when power is applied.

IMPORTANT NOTE : To preserve the integrity of the isolation provided by the optocouplers, it is important to remember that the common side of the input and output circuits MUST NOT be connected to the common side of the PIC supply. Separate input and output commons are provided via the connectors on the DL4MUP Sequencer board, and the PIC +5V and Ground connections are kept separate from these. Similarly, where a +5v supply is required on the isolated side of an input or output (eg the ALC control line, for powering the ICL7660) this is not the same +5v as is used to power the PIC – it must be a separate supply.

Oscillator Requirements

The oscillator of the PIC requires a 4MHz miniature crystal. All timing functions within the code are designed around this frequency. The recommended oscillator circuit is shown below, in Fig 3.

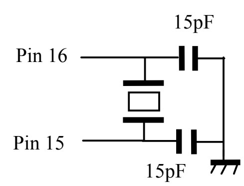

Fig 3 – Oscillator circuit for 16F84 – 4MHz crystal

Use of a 4MHz ceramic resonator, as an alternative to the crystal, will also give acceptable timing accuracy – further information on oscillator circuits can be found in the 16F84 data sheet [2]. The use of free running RC timing generation is not suitable for this application.

Screening

The Sequencer must be built into its own screened enclosure (or a combined enclosure with the PA Controller PIC). The processor clock runs at 4 MHz, and has the potential to cause EM interference by radiation from exposed circuitry and wiring. The processor clock runs continuously, and therefore is likely to cause Rx interference as a well as Tx interference if unscreened. The Rx interference will be obvious to you, but the Tx interference could be radiated with your signal, and thus could be carried for very large distances!
Preferably, filtered type 9 pin sub D connectors should be used for the input and output connections, so that the screening integrity is not violated by the connections themselves.

Dealing with Unused Inputs and Outputs

All inputs of the Sequencer must be connected – none can be left floating, even if the function assigned is not required. The two relay type inputs must be either hardwired to ground or tied to Vdd via 10k according to the type of relay used. The Preamp On/Off input can be permanently wired to ground if there is no preamp, or to Vdd (via 10k) if there is an unswitched (ie permanently in circuit) preamp. Other wise, it should be switched in sympathy with the preamp.

Where there is only a single PTT drive, the PA PTT input should be tied to Vdd through 10k, and the Preamp PTT used as the input. In this case, the Preamp On/Off input should be wired to ground.

Unused outputs can be left floating – thus if used with a triode PA, the screen grid output should be ignored, or if ALC inhibition of the rig is not required, the appropriate output pin can be ignored. All interfacing circuitry associated with such outputs can be omitted without any loss of functionality.

Implementation Options

The Sequencer PIC can be used in a number of ways:

- As a companion to the PA Controller PIC
- In the DL4MUP Sequencer board, as described below
- In a user designed installation following the guidelines given here

All options should give satisfactory results provided that the guidelines regarding Power Supplies, Screening and Interfacing are followed.

PA Controller PIC

The DL4MUP PA Controller PIC provides comprehensive controller functions for tube PA's, including:

- Heater warm up
- Normal and Bypass mode operation
- Grid, screen and air flow monitoring
- Blower control with temperature sensing
- Grid and Anode overcurrent monitoring
- PTT outputs for Preamp & PA switching

The PIC can be used in a user designed implementation – DL4MEA also has a PCB design which uses this PIC, and contains all the necessary interfacing circuitry for a fully functioning controller, including a hardware sequencer. The PIC is described in [1]

DL4MUP Sequencer Board

The DL4MUP Sequencer board provides interfacing and signal conditioning circuitry to interface the Sequencer PIC to the radio subsystem that is to be controlled. The implementation assumes that all relay drive signals will be a switched earth output, with the other side of the relay returned to a suitable rail voltage – the devices used for switching are rated to handle relay supplies up to 50V DC. All necessary isolation is provided within the circuit. The PCB is designed to fit a standard tin-plate housing, so that the unit is fully screened. Input and output connections are via 9 pin sub D type connectors. Relay type selection is via jumpers.

User Designed Installations

By using suitable adaptations of the interfacing circuit options shown in the next section, the Sequencer PIC can be adapted into any system, regardless of the sense of the relay driving voltages required. All outputs assume a logic 1 (+5v DC) for the 'on' or active state, and all inputs assume a logic 1 for the active input state. These conditions are detailed in Tables 1 & 2

Interfacing Circuits

Input Circuits

Where an input is not already isolated (eg when not being driven from the DL4MUP PA Controller PIC, or equivalent) then input isolation must be used – for the Sequencer this will apply to three of the inputs – Preamp PTT, PA PTT and Preamp on/off. PTT inputs should use a circuit similar to that in Fig 4 below

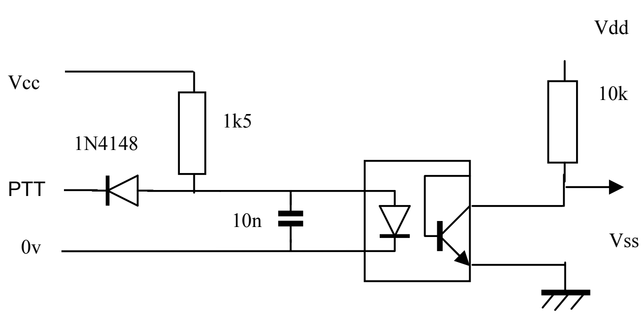

Fig 4 – Input circuit for PTT isolation

The Preamp on/off Input should be similar to Fig 5

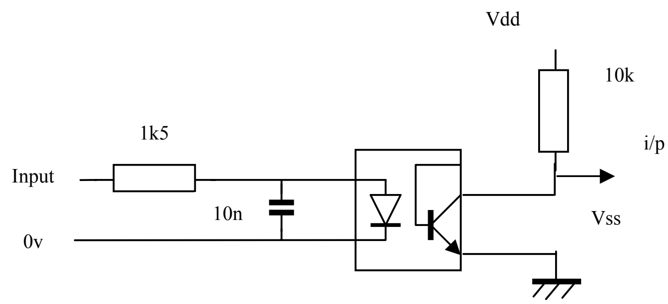

Fig 5 – Input circuit for Preamp on/off

Output Circuits

Output circuits can be arranged to provide drive for relay coils either commoned to ground or to supply. Commoning to supply is preferred, because the output circuit and components are independent of the relay voltage used – in fact relays of different voltages can be mixed. The DL4MUP Sequencer board uses commoning to supply for all relay drivers. All outputs are active low, to give the simplest interfacing circuits when using common supply for the relays. The circuit of Fig 6 is recommended for interfacing to relays. The relay supply voltage may be any voltage as required by the relay coil. One circuit of this type is required for each coil connection – thus for a PA using latching relays for both PA and Preamp functions, four such circuits would be needed. If the Grid and Screen functions are relay switched, then one circuit would be needed for each of them as well.

Note that in all the following diagrams, the reverse emf protection diodes on the relays are not shown for clarity – they must be used!

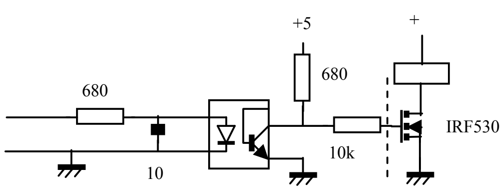

Fig 6 – Recommended output drive circuit

The exception to this is the ALC drive output, which is active high for easiest control of a negative voltage generator. Fig 7 shows the circuit for generating the negative ALC voltage using an ICL 7660, and for controlling it via the PIC output.

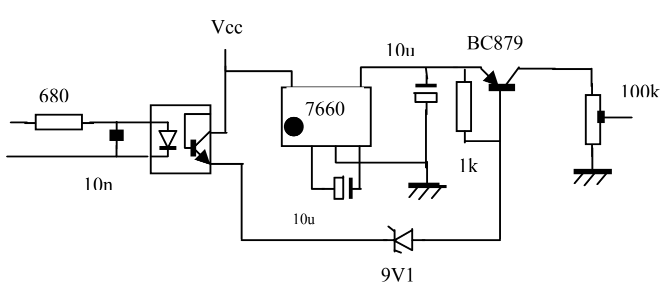

Fig 7 – ALC Control Circuit

Other Interface Circuits

For other types of relay drive, or for using negative side communing for relays etc, two other output circuits are presented here. These can be used as direct replacement for the right hand side of Fig 6 – for clarity the input circuitry into the opto coupler is not shown, since this is identical to that of Fig 6.
Fig 8 shows a non-inverting relay driver, which could be used if you want to have your relays energized in the receive position.

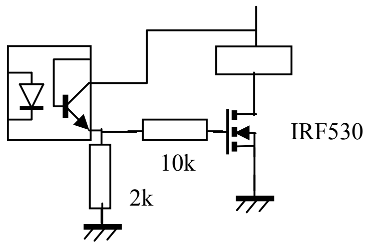

Fig 8 – Non inverting Relay Driver

Fig 9 shows an equivalent circuit (non-inverting) using a P channel FET

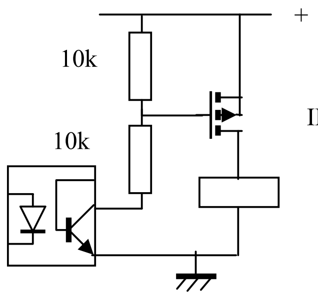

Fig 9 – Non inverting Relay Driver – P Channel

Adjustment

Whatever combination of input and output circuits you may choose for your application, there is minimal adjustment to be done. The only adjustment needed is to set the ALC output voltage so that it fully inhibits the transmit output of your radio.

This should be done with the PIC out of the circuit, but with the rest of the sequencer fully constructed and powered. Set the ALC pot to minimum, and check that the output of the ICL7660 is approx -5V (measure between pin 3 (ground) and pin 5 (-ve output)). Next temporarily connect the cathode of the 9v1 zener diode to the positive supply – this turns on the ALC output switch. Now connect the ALC output of the sequencer to the ALC input of your radio, with the ALC pot in the Sequencer set to minimum. The RF output of the radio must be connected through a power meter to a dummy load, and the mode set to FM. Set the radio to Tx, and increase the ALC preset, watching the output power on the meter. The correct setting is when there is no measurable power shown on the meter. Once set, remove the connection between the zener diode and the positive supply – the PIC can now be put into the circuit and the system powered up.

DL4MUP Sequencer PCB

The circuit diagram and PCB layout for the Sequencer is shown at the end of this article-Figs 11 & 12. It is designed to provide all functions of the sequencer, and to fit a 111 x 74 x 30 mm tinplate box. Inputs and outputs are taken through filtered, right-angled, 9 pin sub-D type sockets, and the board itself is double sided, with the top surface acting as a ground plane. Power connections also go via the sub-D type connectors. Any output functions that are not needed, for example the latching relay drives, or the screen control can just be overlooked – ie don't build that part of the circuit.

GS35 2m PA Implementation

The following section is presented to act as a demonstration of a controller/sequencer implementation which uses only part of the total functionality provided. The photograph below, Fig 10, sows the final installation. It is built into my GS35 PA for 2m to provide all control and supervisory functions, and to manage the Tx/Rx changeover. Both the Controller and Sequencer PIC's are used, with the Controller PIC providing the EHT output drive directly, and the PTT drive into the Sequencer. The PA does not make use of the blower control input or output, or the EHT Standby output of the PA Controller chip. It also only uses the PA relay switching output. The Sequencer implementation has the relay types hard wired, and does not make use of the preamp on/off switch. Since the GS35 is a triode, the screen output is not used, but grid and ALC control are. All external inputs and outputs are opto-isolated, and the two processors are powered from an independent 5v supply which is fully floating. All input and output signals are referenced to the +13.8v supply used in the low voltage stages of the PA. The Controller PIC uses a 3.27MHz crystal osc, and the Sequencer uses a 4 MHz crystal. The entire unit is hand wired on a Eurocard sized perforated board.

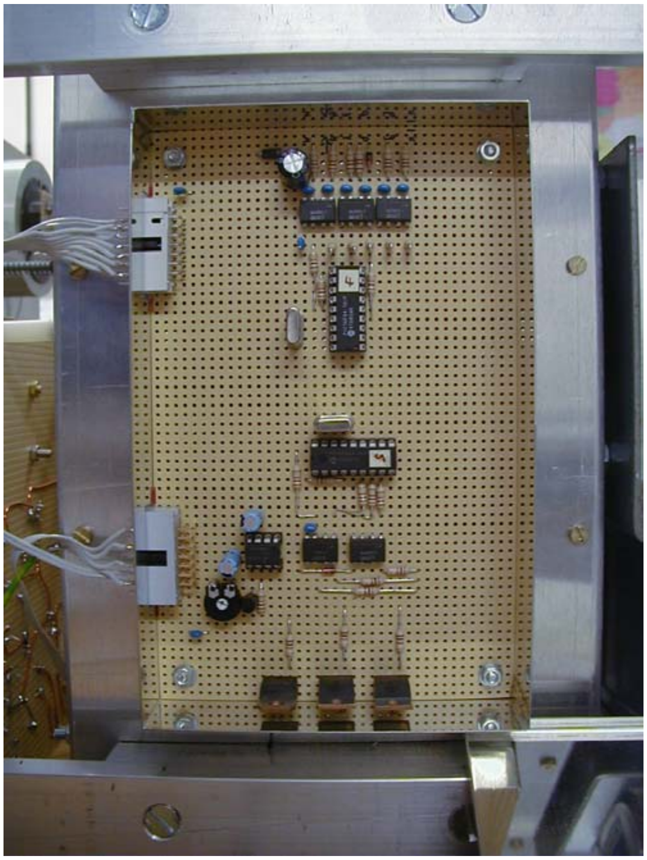

Fig 10 – PA Controller and Sequencer PIC's in GS35 PA Implementation

Conclusions

This sequencer provides the complementary functions to my PA Controller, allowing full and comprehensive control of all aspects of triode and tetrode tube PA's. Both designs can be used in many variations, depending on the needs of the user – the example of my own GS35 PA for 2m demonstrates this. The interfacing examples given above are not necessarily exhaustive, but are given for guidance – for any further clarifications of the input and output conditions, contact the author at the e-mail address below.

Chip Programming, Software and PCB information

Ready programmed 16F84 chips for both the PA Controller and the Sequencer PICs are available from the author, or for those with programming facilities, the compiled object file can be provided. The author can be contacted at dl4mup@qsl.net. Source files will not be made available.

PCB artwork, component overlays and circuit diagram for the DL4MUP Sequencer PCB are also available from the author.

References

[1] A Software based Controller for RF Tube PA's, Dave Powis, DL/G4HUP: presented: 46 Weinheimer UKW Tagung, 2001 – published 47 Weinheimer UKW Tagung, 2002!

[2] 16F84 Data Sheet

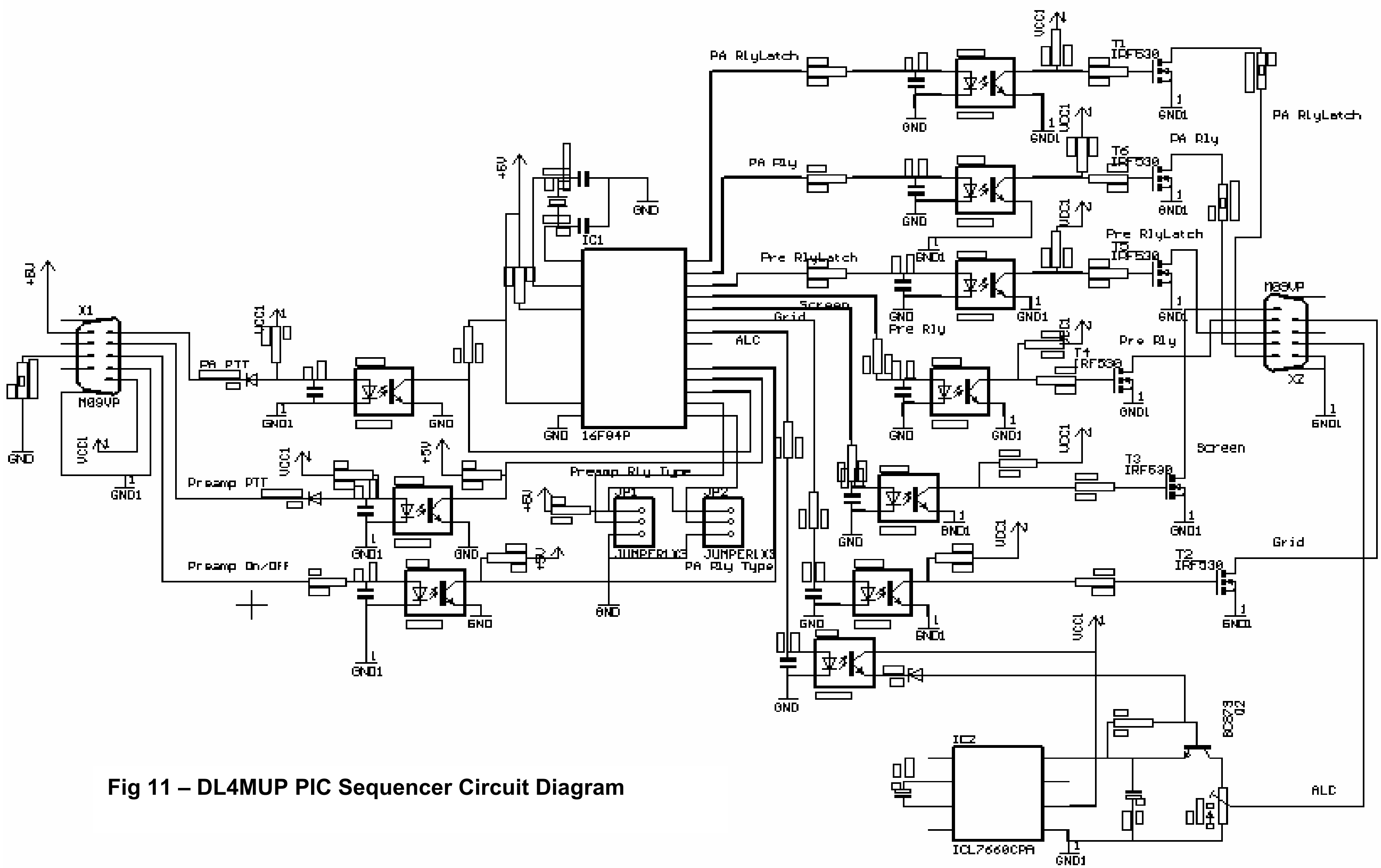

Fig 11 – DL4MUP PIC Sequencer Circuit Diagram

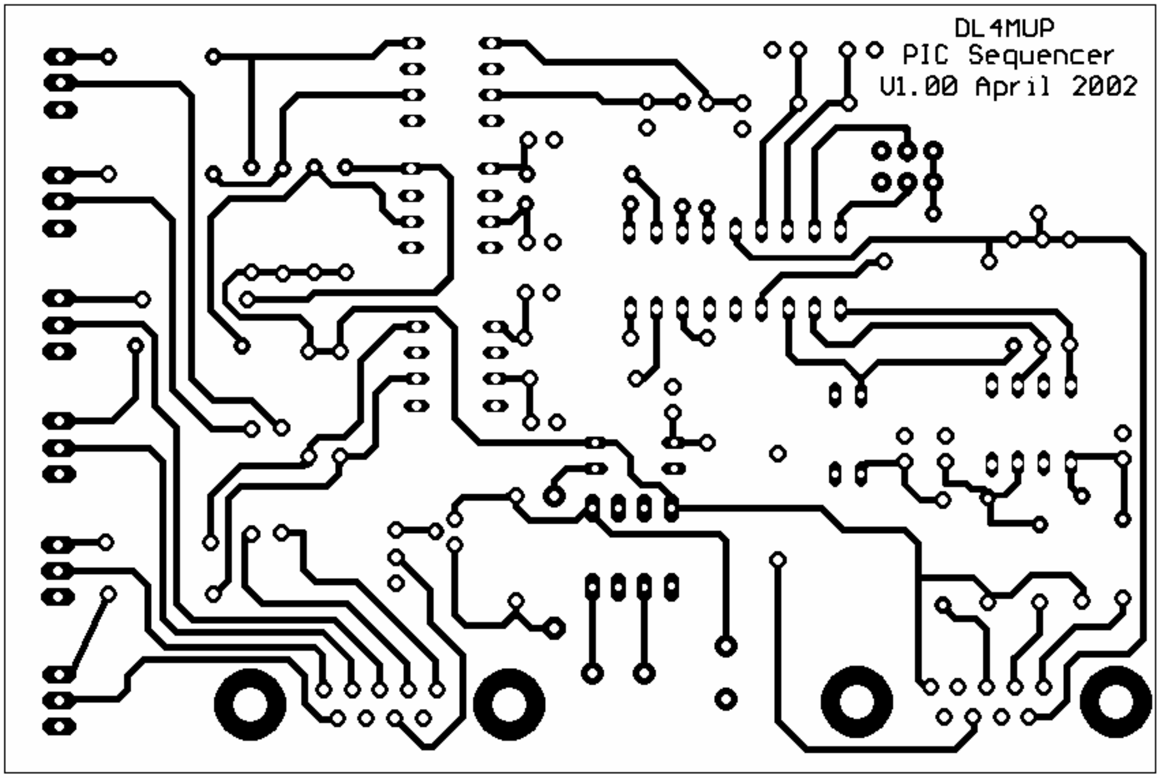

Fig 12 – DL4MUP PIC Sequencer PCB artwork

NOTE – due to the processes involved in reproducing this artwork, accurate dimensions of the final copy cannot be guaranteed by the author. Accurate copies of the artwork, and also the PCB component overlay and circuit diagram are available from the author at dl4mup@qsl.net