MTX80 500 mW / 1W ARDF TRANSMITTER (Updated 23/4/19 for 1watt option)

This 80m ARDF transmitter was designed to be multi purpose, suitable for Classic, Sprint and FoxOring formats.
Compact and lightweight and easy to deploy.
Low component count.
Multipurpose socket for charging/syncro/tune-up.
Internal ATU for matching to a short wire antenna .

(Note: a minimum of 1 watt output is required for Official Classic competition, but the lower power will be adequate for local events)

Circuit Description

The 80m source signal is derived from a digital clock multiplier, the ICS525-01 using a 24MHz xtal.
(Note: the ICS525-02/3 has different output dividers, so is not suitable)

The ICS frequency configuration was derived from a design by **SM0KON.** This allows for a selection of a frequencies between 3510 Khz and 3610Khz at 10kHz steps by setting the high/low status of just 7 configuration pins on the IC. The other 12 configuration pins are hard wired in the PCB layout.
The 7 pins can be set high or low by cutting or grounding pads on the PCB, as shown in the table below.
Only the pins marked in yellow will require modification for a specific frequency.
For example, for 3580kHz, R0,R1,V1 and V0 will need grounding (0) with a solder bridge.
Pins highlighted and marked '1' will require a shorting bridge to be cut and removed. This is a tiny length of narrow track, so is easily done with a small modelling blade.

(Note: The column order in the table mirrors the layout on the PCB.)

ICS PIN	R0	R1	V3	V4	V2	V1	V0
DEFAULT (3610)	1	1	0	1	0	1	1
3510	1	0	1	0	1	1	1
3520	0	1	0	1	0	0	0
3530	1	1	0	1	0	0	1
3540	0	0	1	0	1	1	1
3550	1	0	0	1	0	0	0
3560	0	1	0	1	0	0	1
3570	1	1	0	1	0	1	0
3580	0	0	0	1	0	0	0
3590	1	0	0	1	0	0	1
3600	0	1	0	1	0	1	0

1 = high/open
0 = low/ground

Power Output Options
The transmitter has been tested with two battery configurations

500mW output
This was the original and simplist configuration.
4 Ni-MH cells provide a nominal 5v supply.
The PIC runs off a 3.3v regulated supply.
The ICS525 driver and the PA runs directly from the unregulated battery supply.

WARNING

1. The recommended operating voltage of the ICS chip is 3.0 to 5.5V The maximum absolute suppy voltage is stated as 7v.
2. The originally listed regulator has a 6v limiter which will may prohibit the use of 4 fresh alkaline cells. Other regulators are available with a higher voltage rating.

For 1W output

6 Ni-MH cells provide a nominal 7.5v supply.
The PIC and the ICS525 driver runs off a 5.0v regulated supply.
The PA runs directly from the unregulated battery supply.
The PCB must be modified to supply the ICS chip from the regulator .
Find the three pads next to the markings 5v & 3v3.
nb. *The marking on the PCB is not logical for this modification!*
Cut the track between the pads marked '5v', and bridge between the pads marked '3v3'.

It would seem attractive to use 2 Li-ion cells in place of the 6 Ni-MH cells to provide a similar voltage in a much smaller package.
An additional charge and discharge protection circuit is required, unless the on-board charging circuit is disabled.
However, the author has researched this option and has serious concerns the following reasons.
Most, if not all, the low cost Li-ion batteries to be found on Ebay are either fake or grossly exagerated charge capacity. For example. AA size cells (14500) are rutinely found imposably rated at over 2000mAh, but the maximum rating from reputable sources is nearer 900mAh. Also the provision of internal protection cannot be trusted.
If Li-ion cells are sourced from genuine sources the cost is greater than Ni-NH.

Charging, and value of R1

The original design was based on 4 cells, giving a nominal 5v supply. R1 was chosen, assuming a 7.5v charging voltage.
With R1 unchanged using 6 cells the charging voltage needs to be higher. 9v was used by the author.
In practice, this provides a low current charge, requiring at least 24hours to recharge tha battery pack.
If you are using a 6 cell battey pack and want a shorter charging time, then consider changing the value of R1 and/or the charging voltage.

Power Output Circuit

The original design used a pair of 2N7002s, giving 1 watt output, but these proved to be quite fragile so were replaced with a single IRLML0100.

However it was found that both MOSFET devices drew high current when the ATU was miss-tuned. No simple solution was found to solve this, so the PA device was changed to a PTZ2222A.

A pi network provides a 50 ohm match at the TP1 test point. Then a L network to match a short length of wire (see text below).
C16 and L2 provide a trap to reduce 2nd harmonic radiation.

The output matching was opimized by trial and error.
The filtering is minimal, but in the context of ARDF deployment, is considered aceptable. If this design is used or modified for any othe purpose the user should be satisfied the filtering is suffient to suppress harmonic or supruious emissions.

The ATU section of CT2 and L3 is the L-network designed to match a 6m long wire with a 6m counterpoise. A set of pre-cut antenna wire is required for the ARDF event, so the user should decide the preferred length of the wire antenna and modify the turns on the toroid (L3) to suit.
8m wire length is a popular traditional choice, but the author finds 5 or 6m lengths work well enough and is easier to deploy.
Of course, other (usually shorter lengths) can still be connected and tuned but the ATU may not be optimal.

The table below is due to **DF1FO** and shows the calculated properties of a vertical tuned against ground at 3.5MHz. The tuning capacitor (CT2) has a tuning range of 25pF to 225pF with the rear trimmers set fully meshed. CT2x may be needed for additional capacitance, to peak the output at mid range of the variable capacitor.

Antenna	Radiation resistance	Reactance.
20 m = λ/4	37,5 Ω	0 Ω
10 m	6 Ω	-j 400 Ω (110 pF)
8 m	4 Ω	-j 600 Ω (75 pF)
6 m	2 Ω	-j 800 Ω (55 pF)
4 m	1 Ω	-j 1200 Ω (35 pF)

A field check for a 6m vertical using a MFJ-269 recorded a feed reactance of 850 Ω – 900 Ω .
The higher value occured when the 6m counterpoise was randomly bundled near the base of the vertical.
~~Using a commercial ATU, the best match and lowest SWR occured when the inductor was approximatly 12-13uH, larger than anticipated by calculation.~~
(revised 27/2/2019) The prefered value for L3 is approxiately 10uH, this gives the best field strength readings for the 6m antenna. In this case CT2x needs to be about 100pF.

PCB ASSEMBLY

TRACK/BOTTOM SIDE

Firstly fix the SMD components on the bottom track side, so the PCB can lay flat on a work surface.
Most of the pads for resistors and capacitors are 1206 size, however 0805 components will just bridge the pads.

It is recommended that the PIC xtal case is grounded .

Pads for the ICS pins R0 & R1, V0 to V4 need to be cut or solder bridged according to table-1

TOP SIDE
Next fix the leaded components on the top side of the PCB.

Pin headers at J2 & J3 are not required. Using J1 only will make it simpler for others to deal with the basic configuration of the PIC . Only use headers at J2 & J3 if you intend to use the ports with your own software.

A 2 pin header is fitted for the battery input and a 50ohm output test point (TP1) (see later text)

Toroids L2 and L3 are secured with 2.5mm nylon cable ties.

The polycap capacitor will need adjusting before fixing. The lead outs should project towards the back of the capacitor. You will probably need to first remove the plastic back cover to do this.
Set both trimmer capacitors at maximum, this will help keep the ATU resonant frequency away from the PIC oscillator frequency (4.19MHz)
Use a double sided sticky foam pad to fix the polycap in place.

TESTING
When all the components are fitted the board can be tested with 5-6v applied before it is assembled into an enclosure.
Check the ICS chip is outputting the required frequency.
Attach a power meter to header T1 and check for required output. If the ATU is built, this will need to be de-tuned to get a meaningful reading (set to minimun capacitance / clockwise)

CT1 should be adjusted for accurate timing. When the PCB is placed in an enclosure the trimmer may not be easily accessible, (but only if you have used a SMD trimmer). Perhaps more importantly, the oscillators in multiple units need to on precisely the same frequency. Error in timing frequency will cause overlaps or gaps in sequential transmissions, especially if long delays are used. It is recommended that one TX unit is set up as the 'master'. Subsequent units can be adjusted to 'zero-beat' by monitoring the PIC oscillator frequency of 4.19Mhz with the master TX and another TX running.

For testing or adjusting put the TX into 'delay' mode. Set the dip-switch for a 1hr or more delay, hold the tactile button down on switch-on, release the button. The TX is now running in 'delay' mode.
Press the tactile button to key the transmitter.

ENCLOSURE
A Sistema 200ml plastic food box is used, rather than a more common ABS box, because the latter, with a screw fixed lid, does not allow for easy access to the PCB The whole unit is contained with in the waterproof box with no projecting controls, so during transportation and deployment, it is tamper proof. The PCB is mounted on 5mm stud spacers.

A short aluminium spike is bolted to the box and electrically attached to the PCB ground.
The spike allows the TX to be deployed vertically in the ground for foxOring use.
With carefull preparation, you should be able to get either a 4xAAA , 6xAAA or 4xAA battery pack into to 200mL container. The sockets for antenna, counterpoise and charging socket will all need to have a profile where the body is largely external to the enclosure, therefore, you are advised to adhere to the socket types specified in the parts-list, if you use the same enclosure as the author. Be aware, the charging socket is also connected to the port on the PIC used for TX keying. The socket may need to be protected from accidental shorting e.g. from ground moisture.

ANTENNA
The ATU has been optimized for a 6m antenna wire with a 6m counterpoise. Having a counterpoise, even if it is haphazardly distributed on the ground, increases the antenna current significantly.
The counterpoise can be simply attached to the ground spike with a crocodile clip.
The simple LED RF indicator (D5) detects the voltage at the feedpoint. Use a superbright LED for better visiblity in daylight. The LED does not have a good peak for longer wire lengths. In retrosect this system is not a good solution for tuning. It was really designed for very high impedance feeds, such as an end feed halfwave antenna. It may be better to use a simple external field strength meter for tuning.

SOFTWARE (summary)

The software is written in CCS – C
The TX identity and operating speed is set by the value of the first byte (0) in eeprom.
The end of transmission call sign is held in eeprom from byte(1)
The above settings are in eeprom because they will be infrequently changed. More likely, the transmitter identity will be permanently labelled on the TX enclosure.

The dip switch 1-3 sets the event format. e.g. 5 TXs in a 5min cycle.
The dip switch 4-8 sets the start delay (1-31 hrs in 1hr steps)
In the last 1hr of the delay, the Tx will briefly send its identity (e.g. 'MOe') at 30wpm.
Each TX will sequentially send its ident, once, at 5 sec spacing, at 30wpm, every 5mins.
This is to re-assure the planner that the TXs are all operational before the event start. If not, there might be time to fix it ! The transmission time is made very short to prevent its location being given away.

DIP SWITCH SETTINGS
EVENT FORMAT
1 2 3
0 0 0 5txs 60secs each on, 5 min cycle, **Classic format.**

1 0 0 5txs 30secs each on, 2.5 min cycle
0 1 0 5txs 12secs each on, 1 min cycle, **Sprint format.**
1 1 0 2txs 60secs each on, 2 min cycle
0 0 1 2txs 30secs each on, 1 min cycle
1 0 1 2txs 12 secs each on, 24 sec cycle.
0 1 1 foxOring, send single character indent continuously
1 1 1 foxOring, send single character indent on/off 30 secs. **UK preferred format.**

DELAY (0 - 31hrs)
4 5 6 7 8
1 2 4 8 16 hrs, additive.

CHARGING / SYNCING.
The charging socket has three functions.

1. Charge the battery.
2. Synchronize the Txs.
3. Key the transmitter (when idle).

Obtain a 6 way, daisy chain, 2.1mm power cable. These are readily and cheaply available on eBay (for guitar amplifiers!)
For charging, attach the daisy chain lead to a 7.5v dc power supply. **Do not** use a constant current or automatic power supply, there is a current limiting resistor on the PCB (R1).
For Syncing, fix a SPDT switch on a small box, connected to a short flying lead and then a 2.1mm inline power plug. (see photo)

1. Attach the switch unit to the 6 way power cable connected to each transmitter,and **close** the switch.
2. Power-up each transmitter and the green LED will flash.
3. Open the switch to start the delay period.

WARNING. Don't close the switch until the cable is removed. If the transmitters are running in delay mode, this will key all the transmitter!

Shorting the power socket or pressing the tactile button will key the transmitter for tuning the ATU, but only when the transmitter is on, but idle.

EEPROM SETTING
CHANGING THE TRANSMITTER IDENT
Short the header J1 and then switch on. The transmitter will send the current ident eg. 'MOe', except if the Dipswitch is set for foxOring, it will send a single character ident. (A to L).
You can then cycle through each ident option by pressing the tactile button, and switch off the unit when it has sent the one you want.

IDENT OPTIONS

EEPROM byte(0)	MO Indent	FoxOring Ident
0	MOe (slow CW)	A
1	MOi	B
2	MOs	C
3	MOh	D
4	MO5	E
5	MO (slow beacon)	F

6	Moe (fast CW)	G
7	MOi	H
8	MOs	I
9	MOh	J
10	MO5	K
11	MO (fast beacon)	L

CHANGING THE CALL SIGN

Short the header J3 and hold down the tactile button, then switch on the TX.

The TX will send the current callsign. Switch off if you want do not want this changed.

A new call sign is set by selecting a character using the DIP switch, saving it by pressing the tactile button and repeating this until the whole call sign is played, then switching off the TX.

A morse code dit is 'OFF, dah is 'ON' and the end-of-character is an additional 'ON' followed by **all** 'OFF'. eg. Character 'L' is di-dah-di-dit and set by OFF, ON, OFF, OFF, ON, OFF, OFF, OFF