1. Introduction

The RLC220 is an intelligent microprocessor based radio modem (or communications controller) that allows the transmission of serial data over business radio. The RLC220 can be used with a wide range of radio transceivers including PMR (non-trunked), emergency services (both AM and FM) and telemetry band equipment.

RLC220 provides data transmission on the radio channel at 1200 or 2400 bits per second using Fast Frequency Shift Keying (FFSK) and other special data rates can be supplied to order.

At 1200bps modulation is compatible with the DTI recommended MPT1317 FFSK signalling tones of 1200 and 1800Hz, and at 2400bps the tones used are 1200 and 2400Hz FFSK. All modulation schemes are recognised in the European Telecommunication Standard ETS-300.113.

The RLC220 modem hardware provides:

- one RS232 level serial port with full modem signals (TXD, RXD, RTS. CTS, DSR, DCD, DTR and Buffer Status) for connection of computer/terminal equipment

- a second serial port with TXD & RXD only, which is jumper selectable to RS232, TTL and inverted TTL.

- analogue interface to radio transceiver with transmit audio, receive audio, press-to-talk and external busy signal

RLC220 can be used in a wide range of applications with the transmission protocol(s) selected to suit the application, these include:

- Virtual Circuit based (or "connection orientated") protocols such as X.25 or AX.25

- Datagram based systems such as Thorcom's RAW-mode and TEXT-mode protocols

- MPT1379 compatible protocols for use on Speech Dominant and Data Dominant PMR radio channels in the UK

- MAP27 trunked radio transceivers for use on MPT1327/1343 radio networks

- Telemetry, telecommand or telecontrol systems with "real time" reporting of measurements or readings from systems

The facilities available from the modem, its on-air protocol(s) and user interface (or user presentation) are firmware specific. To ensure that you select the most appropriate protocols and firmware for your application we recommend that you consult Technical Sales Dept at Thorcom Systems regarding your application.

2. Installation

Two versions of the RLC220 are available: the standard cased unit (RLC220) for stand alone operation and a circuit board version (RLC220-UB) for OEM use by systems builders.

2.1 Stand alone cased RLC220

The RLC220 is supplied in a heavy gauge Aluminium extruded case which is anodised black. The radio port and serial port connectors are on the rear panel and the status indicator lights (LEDs) are on the front panel.

The equipment may be operated in any orientation, and over the temperature range -20 to +70 Celsius. Power to the unit is provided via the radio connector and should be between 10.0 to 16.0 Volts (13.8V nominal) DC, negative ground. Incorrect orientation of the power connection (ie. reverse polarity) or connection of an excessive supply voltage (over +16V) may cause damage to the unit, in these circumstances failure is not covered by warranty.

RLC220 can be mounted on a flat surface, for example in the boot/trunk of a car, using four mounting lugs which slot into the grooves in the side of the case. These lugs then provide four 5mm holes for anchoring the unit. Mounting brackets are product reference code RLC2XX-ML.

2.2 OEM circuit board version

The OEM circuit board version of RLC220 is known as RLC220-UB (unboxed), and provides four fixing points which may be used to mount the PCB on a flat surface.

The fixing points are 3.3mm diameter holes designed to be used with M3.0 screws. The holes are centred on a square 4.5 inches by 3.65 inches (114.3mm by 92.7mm).

The four holes are connected to signal/power ground on the PCB.

NB. When handling the board ESD (Electro Static Discharge) precautions should be observed. All semiconductors on the board are of CMOS construction and can be damaged by electro static discharge. Appropriate handling methods should be used including ESD protected work area, wrist straps etc. The PCB should be kept in its "static safe" packaging until needed, and returned to its packaging for shipment etc.

2.3 General information

Sections 3 and 4 cover interfacing the RLC220 to computer equipment via the serial port connector and radio equipment through the radio port connector. High quality D-type connectors should be used (preferably the "tin and dimple" type) with metal covers to provide good grounding and maximum screening of signal leads.

Good screening will reduce the chance of possible radio interference to/from the RLC220 and provide best overall performance.

3. Interfacing to Data Equipment

This section describes the interface between RLC220 and the RS232 device.

3.1 Definition of RS232 pin connections

SK1 on the rear panel is the RS232 serial port socket, this port is wired as a Data Communications Equipment (DCE), and provides the majority of the signals found on a modem.

Signal levels on this port conform to EIA-RS232C and V.24, the voltage amplitude is greater than ±8V. An industry standard DB25S (25 way D-type female) connector is employed on the equipment with the following pin assignments:

Pin	Name	Description
1	PG	Protective/Frame Ground - connected to signal ground
2	TXD	Transmit Data (input)
3	RXD	Received Data (output)
4	RTS	Request To Send (input)
5	CTS	Clear To Send (output)
6	DSR	Data Set Ready (output)
7	GND	Signal Ground
8	DCD	Data Carrier Detect (output)
20	DTR	Data Terminal Ready (input) - see note 2
25	BUF	Buffer in use/free (output) - see note 1

Notes:

1. Non-standard RS232 assignment. Pin 25 is normally defined as "Busy Out", in the RLC220 it follows the front panel BUF light giving an indication of when one or more packets remain in the output buffer for transmission to the remote device.

   This pin is only available when the second serial port is being used at TTL/Inverted TTL levels.

2. Hardware or out of band flow control is implemented on the CTS & RTS pins and not DTR. DTR is used to indicate that the terminal equipment (the attached device) is ready to receive AX.25 connections or to force connections to be cleared.

3.2 Connecting the serial device

In order to properly connect the serial device to the RLC220 you need to know if it is a DCE or a DTE, the type of flow control, speed and parity.

The minimum connections required are pin 2 (Transmit Data), pin 3 (Receive Data) and pin 7 (Ground). The RLC220 is a DCE, this means that the Transmit Data pin (2) is an input. RS232 pin designations are named with respect to the DTE; the RLC220 as a DCE transmits data on behalf of the attached DTE (so it has a Transmit Data input, correspondingly the RLC220's Receive Data pin (3) is an output).

The serial port's pins have the following functions:

1. PG Earth pin to protect equipment by connecting the chassis of the equipment(s) together.

2. TXD Input on which the attached device sends data.

3. RXD Output which the RLC220 uses to send data to the attached device.

4. RTS Input which the attached device uses to stop the RLC220 from sending data when the device's input buffer is full (flow control).

5. CTS Output which the RLC220 uses to stop the attached device from sending data to the RLC220 when it's internal buffers are full (flow control).

6. DSR Data Set Ready. Indicates that the RLC220 has power applied and the cable connection is made. Permanently asserted by the RLC220.

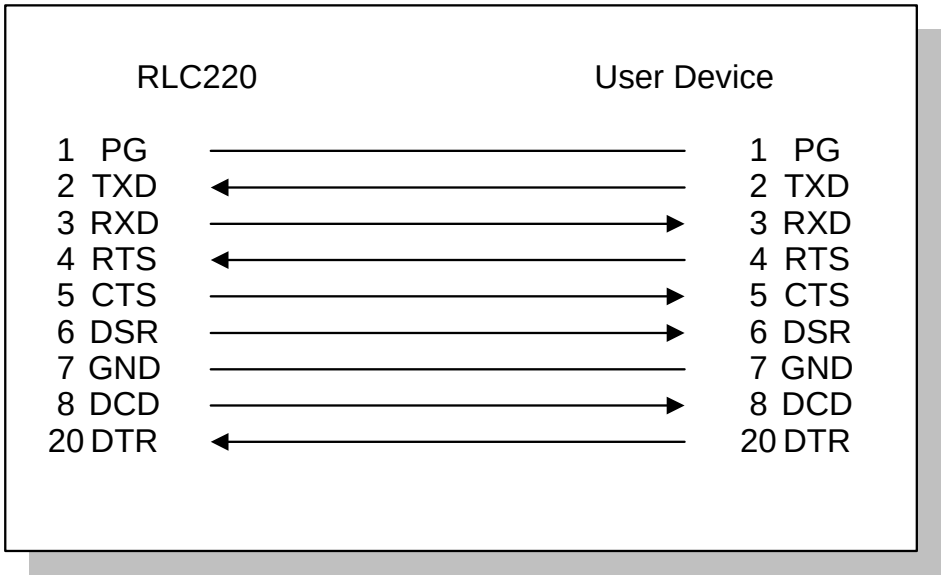
7. GND Signal ground.

8. DCD Data Carrier Detect. This signal is an output and is asserted by the RLC220 while a connection is present (indicated by the 'CON' light on the front panel). DCD is used to indicate to the connected device that a data link is present, the device needs to be able to send data without DCD asserted to be able to communicate with the RLC220's command interpreter.

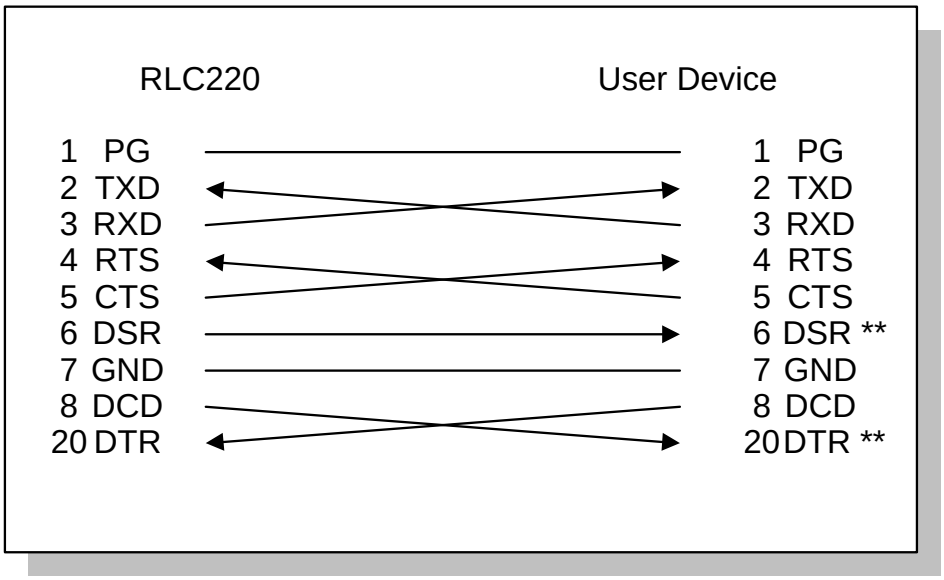
20. DTR Data Terminal Ready. This signal is an input to the RLC220 which the attached device uses to indicate it's readiness to accept data connections, and to force data connections to be cleared. (See DTRCONNECT, DTRCLEAR, DTRANSWER commands).

25. BUF Buffer Status. Indicates the status of the RLC220's transmit buffer.

Wire a DTE to the RLC220 as follows:



You may find that a sub-set of this arrangement is sufficient. Many systems will work correctly with just TXD (2), RXD (3) and GND (7) connected, but for this you will need to use XON/XOFF software flow control.



Wire a DCE to the RLC220 as follows:

** will depend on your system's handling of DSR, DCD and DTR. A simple cross-over cable using pins 2, 3 and 7 only may be sufficient.

Note:
For full binary transfers of data (where all 256 byte values are valid) hardware

flow control (the use of the CTS and RTS pins) is required, since the flow control characters XON and XOFF cannot be used as they may occur in user data. This applies primarily to AX.25 Transparent Mode and Raw-mode protocols.

4. Interfacing to Radio Equipment

Interfacing the RLC220 to the radio equipment to be used involves wiring for transmit and receive audio, power supply and transmitter on (PTT) line, as a minimum, depending on the application you may also need to use the Squelch/transmitter inhibit input.

4.1 Radio port connector assignments

The radio port/power input connector is a 9 way D-type male connector on the rear panel which carries the following signals:

Pin	Name	Description
1	GND	Power supply ground and AF ground
2	TXD	Secondary transmit data serial
3	RXD	Secondary receive data serial
4	RXAF	Receiver AF (input from receiver)
5	+12V	Positive supply input
6	-	Not Connected
7	PTT	Press To Transmit (output to transmitter)
8	TXAF	Transmitter AF (output to transmitter)
9	SQ	Squelch input (transmit inhibit)

The pins have the following functions and uses:

1. GND — This pin is the negative power supply connection and reference point for the PTT (transmitter on) line and earth for the transmit and receive audio.

2. TXD — Secondary transmit data serial, wired as a DCE.
This port is jumper selectable between RS232, TTL, and inverted TTL. Please refer to jumper settings at the back of this manual.

3. RXD — Secondary receive data serial, wired as a DCE.
This port is jumper selectable between RS232, TTL, and inverted TTL. Please refer to jumper settings at the back of this manual.

4. RXAF — This pin is the input for the audio from the receiver. Audio should be supplied to the RLC220 on this pin from the loudspeaker output or other point on the receiver.

5. +12V — This is the positive power supply input. A source of +12V nominal (10.0-16.0 Volts) should be applied to this pin to operate the equipment.

7.	PTT	Press To Talk. This output should be connected to the transmitter in order to turn the transmitter on. The RLC220 takes this pin low when it wishes to transmit data via the radio link.
8.	TXAF	This output pin provides the audio from the modem for transmission. The output level is adjustable to suite the transmitter in use (see below).
9.	SQ	Squelch/busy input (transmitter inhibit). This input pin, when taken low, causes the RLC220 not to transmit on the radio channel by causing the channel to be 'busy'. Taking this pin low brings on the DCD indicator and the CSMA algorithm then will not allow the unit to transmit.

4.2 Audio connections and modulation - general information

The key to reliable transmission and reception of data is in getting the correct amplitude signal to the receiver modem chip with minimum distortion and use the correct amount of deviation on the transmitter.

The FFSK modem in the RLC220 employs 1200Hz and 1800Hz tones when operating at 1200 bits per second (as per DTI specification MPT1317), and employs 1200 and 2400Hz tones when operating at 2400 bits per second. FFSK tones are phase continuous, resulting in a form of audio MSK (minimum shift keying) the data taking up the bandwidth between 900Hz and 2100Hz at 1200bps and between 600Hz and 3000Hz at 2400bps.

The RLC220 can be used with CTCSS sub-tone systems and selective calling systems if suitable interconnections are provided.

We recommend that 70% of the radio system's peak deviation (voice mode) is used for data transmissions, therefore on 12.5KHz channel spaced systems, with 2.5KHz peak deviation for voice, 1.75KHz should be used for data. Similarly for 25KHz channel spaced systems, with 5KHz peak deviation for voice, 3.5KHz deviation should be used for data. Keeping the deviation lower than the peak level guarantees that the FFSK tones are not limited or distorted by the IF filters in the receiver or clipped by the audio stages in the transmitter.

When implementing a system (especially if several different makes of radio equipment are employed) it should be decided whether the audio is going to be sent "flat to air" or through the transmitter pre-emphasis/receiver de-emphasis circuitry. Sending the audio "flat to air" generally results in better performance because the problems of group delay etc. in the audio filtering circuitry are avoided. Sending "flat to air" involves connecting the transmit audio from the RLC220 to the "Set deviation pot" or varicap modulator, and taking the receive audio from the discriminator or suitable point before de-emphasis. The ease with which this can be done depends on the type(s) of radio(s) in use, and may not be appropriate for all makes of radio equipment.

All radios on a system should use flat or pre-emphasised audio so that the amplitude of the received audio remains equal for both tones.

Notes for UK users of business/PMR radio

Any modification to a type approved radio transceiver, for example connections to PCBs/wiring etc. inside the equipment, drilling holes in the case or changing components within the equipment may invalidate the type approval of the unit.

Only type approved radio equipment can be used by licensed business radio users. In order to stay within type approval requirements connections must be made via existing 'facilities' or expansion connections already present on the radio equipment, or a DTI/RA approved modification must be fitted by an

authorised radio dealer. Document RA207 gives further details on type approval and modifications to approved equipment by dealers.

Thorcom Systems Ltd. can advise on what steps are necessary to ensure that a particular piece of equipment will be operated inside the appropriate regulations. In addition Thorcom Systems Ltd. can supply suitable radio equipment for use with the RLC220 radio modem.

4.3 Connection to radio equipment

The following section details the individual connections to the radio and modem equipment:

4.3.1 Power connection

The power to operate the RLC220 is supplied through the radio connector, and is covered in more detail in the installation section.

4.3.2 Receiver audio connection

The RLC220 should be connected to a point on the receiver that is able to provide between 25mV and 5V RMS audio signal with low distortion. Input impedance of the RLC220 is 47K ohms, this prevents the RLC220 from loading high impedance parts of the receiver (eg. discriminator output). Because of the high input impedance screened cable should be used to prevent pick-up of stray signals, mains hum etc. It is good practice to take audio from a point which is at a fixed level and independent of the volume control so that the radio operator cannot accidently disable receive audio while the unit is operating.

PMR/business type radios often have a suitable point where an a selective calling or CTCSS sub-tone board is fitted, facilities connector, or alternatively the "hot" side of volume control is usually a suitable. The loudspeaker output can be used if no other connection point is available. A dummy load resistor (typically 8 ohms) may be needed if the loudspeaker is disconnected in order for the audio amplifier to function correctly.

The connection point for the received audio must normally be muted under no signal conditions, ie. squelch closed, and the squelch should be adjusted to mute the receiver (the DCD LED should be off).

A radio communications test set or transmitter connected to another RLC220 should be arranged to transmit the test tone(s) using a calibration method (see below) at the appropriate deviation level and the input level control, VR1, adjusted to provide 250mV RMS (700mV peak-to-peak) at TP1 when observed with an oscilloscope. See Appendix III for location of TP1.

VR1 provides adjustment over the range from no signal to ten times (10x) gain, this allows for signals over the range of 25mV (RMS) to over 5V RMS to be catered for easily. With the FFSK modem employed it is important to set the correct input level for the optimum BER (bit error rate).

Refer to the Software Reference Manual - Section 2.3 for calibration commands used to cause the RLC220 on the transmitting radio combination to transmit a continous tone. The receiver should be checked to see that the tones are of

equal amplitude and not distorted. The DCD LED on the front panel should be illuminated during the continous tone.

4.3.3 Transmitter audio connection

The audio from the RLC220 is 600 ohm source impedance and adjustable over the range 0-4V RMS in two ranges (0-200mV and 0-4V). The coarse setting is selectable by the the modem firmware and the fine adjustment is provided by VR2.

The audio should be connected to a suitable input point on the radio equipment, for example the 'facilities' connector or if the radio has provision for a selective calling/CTCSS sub-tone board there should be a suitable input point.

Connection can be made directly to the microphone input of the radio equipment, but the output from the RLC220 may be too high, leading to distortion. If distortion occurs when connection via the microphone is used then a high value series resistor (typically 100K ohms) should be connected in series with the transmitter audio.

The transmitter should be observed with a deviation meter and set to 70% of system deviation when using the firmwares calibration function used to cause the RLC220 to send continuous tones. See the Software Reference Manual for more information on the calibration routines.

Note that the transmitter watch-dog timer is usually enabled, this means that transmissions are limited to around 40 seconds, after which time the system will revert to receive.

4.3.4 PTT connection

The PTT (Press To Talk/Transmit) output is used by the RLC220 to put the transmitter "on air". This output goes low (short to ground) to enable the transmitter and can be connected to the PTT line on most radio equipment.

The PTT output can sink up to 100mA and is "open collector" but should not have more than 30V DC across it when un-keyed. For higher voltages or switching lines other than to ground a 12V DC relay should be used, the coil being connected between the PTT pin and the +VE supply to the RLC220.

4.3.5 Squelch input (transmitter inhibit)

The Squelch/busy input is used to inhibit the transmitter when there is non-data activity on the channel. Normally on a data only radio system the RLC220's FFSK modem can detect activity due to transmissions from other packet controllers (the

DCD light on the front panel indicates reception of the data carrier from other packet controllers).

The squelch input is useful if shared voice/data systems are being implemented. When an operator is speaking the channel is busy, so data transmissions should not occur. The squelch input, when taken low (shorted to ground) by the radio, inhibits transmissions and causes the DCD LED to light. The squelch input is normally high, at around +5 Volts and is approximately 10K ohms impedance. Most applications do not require the use of the squelch input, so it can be left floating (not connected).

On some radios the squelch input is inverted, so by changing JP3 the correct functionality can be provided. Please see Appendix I detailing jumper configuration. The squelch input can be used with selective calling or tone access systems, for example CTCSS, to hide data transmissions from the voice operator.

4.4 Loopback

In some firmware options the modem has the ability to do a self-test of its audio stages. The yellow TM (test mode) LED on the front panel is illuminated, and the usual transmit and receive pins on the D-type radio and power connector are disabled. Note also that because loopback is intended for diagnostic purposes, during normal packet transmission and calibration modes, the PTT line to the radio is not asserted.

4.5 Status indicators

RLC220 has seven front panel status indicators (see diagram in section 2.4), these are low current 3mm LEDs and have the following functions (reading left to right):

PWR	Power	Indicates that power is supplied to the unit.
CON	Connected	In certain protocol modes indicates that a virtual circuit (link) exists between this unit and another device. In TEXT and RAW protocol modes CON flashes briefly indicating that a packet is being sent to the attached computer/terminal from the modem.
BUF	Buffer	In certain protocol modes indicates that this RLC has data in its transmit buffer to send across the link, or data which has been sent but is, as yet, unacknowledged. In TEXT and RAW protocol modes the BUF light comes on during the reception of a frame/packet from the attached computer/terminal.
DCD	Carrier Detect	The DCD indicator shows that the RLC220 is receiving data on the radio channel or that the unit is being held "busy" by the external DCD/Squelch input. The DCD input is used to control transmission of the unit through the CSMA algorithm.
PTT	Press To Talk	Indicates that the RLC220 has asserted the "transmitter on" line to the attached equipment and is sending data.
ERR	Error	Indicates an error condition. In normal operation RLC220 will light the ERR LED when HDLC frames are received that have an invalid CRC (checksum). This LED may also flash when in an idle state.
TM	Test Mode	Indicates that RLC220 is in analogue loop back test

mode. In this mode transmit modulation is connected to the receiver and external receive modulation is ignored. The PTT output from RLC220 is disabled but packet operation continues normally. This mode allows "self connections" and is used at power up as part of power-on diagnostics.

5. Trouble shooting & Maintenance

This section covers finding simple problems in a packet radio system and correcting them.

5.1 RLC220 fails to operate

Before returning an RLC220 because of a suspected fault, please check the following:

1. When power is applied to the unit check that the Red power-on light illuminates. If it does not check the power wiring and check that +10 to +16 volts are reaching the unit.

2. If the power-on light is working check the serial port connection to the terminal equipment, try a different lead, try a different terminal to isolate the problem.

3. Turn the power off and then wait a few seconds and turn the power back on.

If you cannot get a sign-on message out of the modem unit, check which protocol mode you have selected as default. In some firmware options you will not get a sign-on banner. Please check the software reference manual for information about any sign-on banner.

If the unit fails to operate still check the installation and cabling sections of the manual again before returning the unit.

RLC220 fails to communicate with attached terminal/computer

1. Check the RS232 cable from the RLC220 to the terminal device.

2. Check that the same baud rate, word length and parity options are set up at both ends of the link.

   If some characters appear correct and some appear garbled then check the parity and word length are the same.

3. Check that the flow control conventions are the same at both ends.

RLC220 fails to receive packets

1. Check the audio connections from the receiver

2. Check the audio level from the receiver, with the receiver's squelch control open the background noise should make the DCD light come on, then with the receiver's squelch closed DCD should be off

3. Check that a suitably modulated data signal is arriving at TP1 test point on the board.

4. Check that both (or all) modems are set to the same radio baud rate selected.

5. Check that loopback is not enabled - the Yellow "TM" LED should be off.

RLC220 fails to transmit packets

1. Check the audio connections to the transmitter

2. Check the PTT connection to the transmitter

3. Check that DCD is off (for normal half-duplex operating)

5.2 Maintenance

No periodic maintenance of the RLC220 is required.

In order to change the configuration jumper links or adjust input/output levels the RLC220 case must be opened. Use the following procedure for opening the case:

1. Remove connections from the rear of the unit (serial port and radio port)

2. Undo the four corner self-tap Posidrive screws on the rear panel

3. Slide the PCB with rear panel attached out of the casing.

Refer to the diagram in Appendix III for the layout of the PCB and location of adjustments and jumpers.

5.3 Returns for factory maintenance/repair

In the unlikely event that RLC220 needs to be returned for repair, please ensure that you have the serial number and date of purchase available and then telephone (+44) 01905 756700 for a Return Authorization Number, as items can only be returned to the manufacturer by prior arrangement.

Returned units must be sent well packed, by fully paid post with the Return Authorization Number clearly marked on the outside of the packing.

6. Specification and Related products

This section gives the technical specification of RLC220 packet radio modem and a brief overview of related products.

6.1 Specification of RLC220

CPU:	Zilog Z80181 Smart Access Controller, high integration Z180 CPU core, serial controller, parallel I/O, DMA, memory controller, timer/counter, running at 6.144MHz clock speed.
Memory:	32K or 128K CMOS static RAM, 32K/64K/128K/256K EPROM (firmware), and 2K Non-Volatile RAM
Radio port:	9 way D-type male connector with the following signals: Transmit audio output: 0-4 V pk-pk into 600 ohms. Receive audio input: 50mV-4V pk-pk, input impedance >47K ohms. Press to talk (PTT) signal, low to operate transmitter, I_{max} = 100mA.
Radio modulation:	1200bps or 2400bps Fast Frequency Shift Keying (FFSK) software selectable (other special modulation to order).
	1200bps: 1200/1800Hz tones (MPT1317) (ETS-300.113 MM12)
	2400bps: 1200/2400Hz tones. (ETS-300.113 MM24)
Serial port primary:	RS232/RS423 and V.24 compatible DCE (modem) supporting TXD, RXD, RTS, CTS, DSR, DCD, DTR and buffer status. Flow control XON/XOFF or CTS/RTS software selectable (depends on firmware option installed).
Serial port secondary:	RS232/TTL/Inverted TTL, DCE (modem) supporting TXD and RXD only.
Serial port speeds:	600, 1200, 2400, 4800, 9600, 19200 or 38400 baud software selectable.
Status indicators:	Seven low power LEDs: Power on, PTT on, DCD on, Connected, Buffer status, Test mode, Error in frame.
Power supply:	10.0-16.0 Volts DC (13.8V nominal) at <110mA

Dimensions:	170mm (L) x 110mm (W) x 32mm (H) - cased unit. 160mm (L) x 100mm (W) x 26mm (H) Eurocard OEM PCB
Environmental:	Temperature: -20 to +60 celsius Humidity: 0 to 90% non-condensing

Appendix I - RLC220 PCB Jumper/Adjustment Configuration

The following jumpers are used to set up and configure the RLC220. Settings marked default are the positions of the jumpers as the product is supplied. Jumper position directions assume the RLC220 is orientated component side up with the 9 and 25 way D-type connectors on the left.

JP1. Eprom size

This jumper is used to set the EPROM size used to hold the operating firmware.

Open	27C256 32K EPROM (default)
Closed	27C512 64K EPROM and larger

JP2. PTT watchdog

This jumper is used to over-ride the hardware watchdog timer that limits the period for which the PTT line is asserted. This jumper is directly equivalent to J12 on RLC200. The watchdog limits the PTT active time to approximately 45 seconds.

Open	TX watchdog timer enabled (default)
Closed	TX watchdog disabled

JP3. Squelch Input (Normal/Inverted)

This jumper gives the ability to invert the busy/mute so that we have compatibility with some radio transceivers which have the mute signal different to that commonly used.

North	Normal squelch operation
South	Inverted squelch operation

Appendix II - LED expansion connector assignments

SK3 is the LED expansion, this is a 8 pin right angled Molex connector (0.1" pitch, KK series) to which an external LED status board can be connected. The LED board will contain the appropriate components to operate external LEDs.

Pin	Name
1	+12V
2	Test Mode (TM)
3	Error (ERR)
4	Press To Talk (PTT)
5	Data Carrier Detect (DCD)
6	Connect Status (CON)
7	Buffer Status (BUF)
8	GND

The signals on these pins are at logic CMOS levels and are negative-true, ie. a logic level 0 indicates the active state and +5V indicates the inactive state.