Lite Com II FRS (P520 FRS)
Technical Description

1 Overview

LiteComII is a complete Active Hearing Protection Headset with built in medium range Communication Radio working in the US FRS (Family Radio Service) band. It has an External I/O port that allows connection to:

- Most types of Land Mobile Radios.
- Entertainment sources like portable CD's, Walkman etc.
- GSM and other Analog or digital cellular phones

The user interface is based on five levels with varying capability:

Voice message.	This level is used in normal operation. It gives brief info and feedback to allow unambiguous operation with your hands only.
LCD, Operation	This level gives the user more information at the expense of taking the unit off to see the LCD.
LCD, Configuration	This level enables the user to configure a number of Set-up parameters without a PC.
PC, Set-up.	Using a level 2 password, this level gives total control of all Set-up parameters.
PC, Service	Using a level 3 password, this level allows total control of all Set-up parameters and all adjustment points.

The mechanical parts are in line with other high end Peltor products.

1.1 Development phase

The electronics was developed by ONE (O-Network Engineering AB) for Peltor. The development project was based on the P520 LPD radio for Europe

2 Documentation

The documentation is created by Peltor and ONE (O-Network Engineering AB). The documentation builds on the P520 LPD version. Documentation CD (pdf format):
"LiteComII documentation. Up to Revision 1.1 2000-04-20"

You need the Acrobat Reader 4.0 or later to read them.

The most documentation specific to the FRS version are the circuit diagram and layout etc for the Rf board. The software is identical except for the RF channel data.

2.1 Revision History

Date	H/W Rev	S/W Rev	ECN	Notes

There are no revisions yet.

The details of the various revisions can be found in the documents and ECN's.

2.2 Support documents

On the P520 LPD CD there are a large number of support documents:

- Datasheets for all major components in the directory "Component Data"
- Regulatory documents in the directory "Approval"
- Application related information in the directory "Support"

Most of these are valid also for the FRS version.

2.3 LiteComII Utility Software

These can be found in the directory "LiteComII Utilities"

2.4 Block Diagram

The principle of the set can be seen in the Block Diagram P520FRSB_SCS.PDF. This can be found in the directories R1.0 and R1.1.
The block diagram is detailed down to the major parts and signal names. To fully understand the design it is recommended that a hierarchical view is employed:

1. This document is the top level
2. The block diagram is the second level
3. The circuit diagram is the most detailed technical level.
4. The BOM (Bill Of Material) is the most detailed parts level.

The design is based on a number of highly integrated IC's that perform the principal functions.

Function	Major parts
• DC/DC Converter	U203 MAX1706
• CPU	U1 TMP87CH21
• EEPROM	U3 24C02/24C16
• Voice message storage	U2 ISD1210
• LCD	Custom LCD with 1:3 multiplexing.
• Baseband processing	U13 AKM2344
• VOX	U4 LMV321
• Synthesizer	U1 TB31202FN and U2 VCO1
• Receiver IF	U3 MC3371D
• Speaker Amplifier	U201,202 MC34119 (2pcs)
• Ambient channel gain and AGC	U9,12 LMV358 (2pcs) Q4
• Ambient channel volume control	U5,8 X9315W (2pcs)
• External VOX	-
• Half Duplex RS232	-
• DC Sink	-

The support functions are then realized by a set of discrete components around these IC's. These are listed in the Block Diagram when they are important for the understanding. Otherwise refer to the circuit diagrams.

2.5 Software

The software is documented by a number of documents in the directory "Software". The most important items are:

- RS232 Commands 107_doc.pdf
- Voice_doc.pdf

2.6 Circuit Diagrams

The fully detailed circuit diagrams are:

- Base Band Board P520C11_SCS.PDF (2 pages)
- RF Board PFRSR11a_SCS.PDF (2 pages)

They can be found in the directory R1.1

2.7 Assembly drawings.

The assembly drawings are:

- P980221 (1 page) Wiring Instruction
- P980223 (3 pages) Assemble Drawing

They can be found in the directory "Assembly"

3 Hardware - Software Relationship

An important feature of the LiteComII is the heavy use of software controlled switches and electronic potentiometers. These are used to:

- Adjust the unit in production. Examples are Max Modulation, Squelch set-up level etc.
- Select operational modes. An example is the switching of the audio signals between Receive and Transmit.
- Set the level of most functions. Examples are both the Ambient Volume, Transceiver (Mix) volume and Balance.

There are very few normal "mechanical" adjustments of the type found in most sets:

- TCXO frequency is set by the trimmer in X2
- The Tx Lo power is set by R11.
- The The Tx Hi Power is set by R8
- The discriminator is tuned by L23.

4 Software

In normal operation the unit has several two start-up modes, 1 and 2. In start-up mode 1 it then has several sub-modes handled by several tasks managed by the Real Time Operating System. These tasks and submodes are numbered in a hierarchical way from 1. to 1.10:

1. **Normal operation**. This is the mode you enter when you switch the unit on. In this mode the unit has a number of different software tasks running, each of them responsible for a defined part of the operation.
   - 1.1. **ON task**. Verify battery voltage and set the unit ON. This task is also responsible for the voice messages, beeps, battery monitoring, battery indicator, low battery warning and low battery shutdown.
   - 1.2. **Store default in EEPROM**. This task is skipped if the correct signature is found in the EEPROM.
   - 1.3. **Initialisation.** During this phase all hardware and software is initialized using the data stored in the EEPROM.
   - 1.4. **Transceiver** task. This task is responsible for the handling of the 433 MHz transceiver. An important part of this is the switching and sequencing of the Rx to Tx and Tx to Rx in a way that minimizes RF transients.
     There are four possible modes in this task:

1.4.1. **Transceiver off**. In this mode all Rx and Tx functions including the Synthesizer are off. This mode is entered if the MIX=0 or periodically during Power Save, i.e. BATT>0.
1.4.2. **Mute**. This is the most common mode, i.e. the Tx is disabled, the Rx is active and the Rx AF channel is muted.
1.4.3. **RX**. This is the same as Mute but with the Rx AF channel is open. This is entered when Squelch=0 or the signal level is high enough to open the squelch.
1.4.4. **TX**. Rx is off and the Tx is on. This mode is entered when the Boom-Mic level is high enough to open the Squelch or the PTT is pressed.

1.5. **Ambient Channel** task. This task is responsible for the ambient channel R&L. The main job is to set the VOL and BAL.
1.5.1. **On**. The default mode, i.e. with the ambient channel active and VOL>0.
1.5.2. **Off**. Entered if VOL=0.

1.6. **External PTT** task. This task is responsible for the handling of a communication radio or GSM attached to the EXT Jack. When the EXT PTT is activated it blocks the Transceiver, attenuates the Ambient Channel, activates the DC Sink and sets the RS232 pin low.
Note 1: If the RSTX is ON then the RS232 pin is used for serial communication instead.
Note 2: If the EXT Vox is enabled, the state of that will be ORd with the PYTT_AUX. If the EXT_Vox is released after PTT_AUX a 2s turn-off delay will be added.
1.6.1. **Inactive.** This is the normal state.
1.6.2. **Momentary**. This is entered when the PTT AUX key is pressed and remains until released.
1.6.3. **Locked**. This state is entered when the PTT AUX key is double clicked. It is then maintained until the PTT or PTT AUX key is pressed.

1.7. External Audio task
1.7.1. **EXT Vox disabled**. In this mode the task does nothing but EXT-Af-in is still sent to the R&L speakers and the Boom-Mic output is fed to the EXT-Af-out.
1.7.2. **EXT Vox enabled**. In this mode the task monitors the Ext Vox.
1.7.2.1. **EXT Vox true**. See 1.6 above.
1.7.2.2. **EXT Vox false**. Ditto.

1.8. **Power saving task**.
1.8.1. **Disabled**, i.e. BAT=0. In this mode the task does nothing.
1.8.2. **Active** , i.e. BAT>0. In this mode the task has a 250ms cycle with a short "Normal Operation" phase and a longer "Sleep" phase. The BAT setting defines the sleep ratio with a maximum of about 80% with BAT=5. Any activity on the VOX, Squelch or PTT will force the unit into normal operation. After a period of inactivity the set will progressively inverse the sleep ratio up to the level set by BAT.
1.8.2.1. **Normal operation**. This is active 100% - Sleep% of the time. Any activity will be detected and will inhibit sleep.
1.8.2.2. **Sleep**. During this phase all functions are shut off to save power. As the Ambient function can not be power saved also the AF power amplifier will be constantly on if VOL>0.

1.9. **PC Communication mode** . This task is responsible for handling the PC Communication. Refer to the RS232 Commands 107 file for a detailed listing of all commands available.
1.9.1. **RS232 Tx disabled**. In this mode the set will never send any RS232 data. The reason is that the RS232 output is also used to control a external GSM.
1.9.2. **RS232 Transmit enabled**. In this mode the RS232 Tx is activated.
1.9.2.1. **Level 1**, No password entered. The unit will not react to any commands except PW.
1.9.2.2. **Level 2** password entered. The unit will process most commands. The exception are all commands related to the adjustment in production and the Id string.
1.9.2.3. **Level 3** password entered. All commands are available.

1.10. **Shut down**. This task is responsible for orderly shut down.

2. **Configure mode**. This mode can only be entered by switching the unit ON with the M-key pressed before the ON key is pressed and released after the ON key is released. In this mode you

can adjust the set-up of a number of functions. Refer to the Software versions file for detailed information.

Note:

1. The CPU has a built-in Transmit timer (in software) that limits the maximum transmit time. The timer can be set to different time-outs and can also be disabled.
2. The RTOS (Real Time Operating System) has a 1ms cycle time and has maintains a large number of simultaneous tasks that do the actual job. A small part of the job is actually done inside the timer interrupt.
3. There are a number of signals from the CPU that controls the power to the various blocks: RX_ON, /IF_ON, /PLL_ON, /TX_ON, /AMB_ON, /AF_PA_ON.
   The AK2344 (U13) has power control through the serial control bus.
   The following blocks have intrinsically low power consumption so there is no need for explicit power control:
   U3 24C02/24C16, U5, U8 X9315W, U2 ISD1210.
   These signals are then controlled by the various tasks n a way that balances power consumption against switch on/off clicks and noise.
4. The PC Communication (RS232) is done by a software UART.
5. There is an independent Watchdog that will reset the CPU if a software error occurs. This ensures that no long term unwanted transmission can occur.
6. The present code size is close to 32kByte.

5 Detailed Circuit Description

The circuit is described in detail on the electronic level.

5.1 K134A Base Band Board

This board contains all the CPU and most of the BaseBand Functions, the LCD and the keys.
Note that this board is identical to the K100A Base Band Board used by the P520 LPD with the exception of the software.

5.1.1 CPU

The CPU U1 is a Toshiba 8-bit CPU with a basic part name TMP87CH21DF. This has built in ROM and RAM. It also has a built in LCD controller, many I/O Ports, a 8-input ADC and other peripherals. Refer to the CPU datasheet. for more details. The CPU is an OTP version TMP87PP21DF is used initially wit h a change to the mask version TMP87CM21DF planned for the future.

The set-up and other parameters are stored in the EEPROM U3.

Q1 is used to switch on the ADC reference when making an ADC Conversion.

The LCD is connected to 3 Commons and 14 Segments in a 1:3 multiplex arrangement.

The keypad is connected directly to the port pins.

5.1.2 Transceiver Baseband processing

The core of this function is a complex IC AK2344 that performs all the critical BaseBand processing of the Transceiver Audio. The CPU controls the IC through serial interface. The IC is based on switched capacitor technology based on a 3.6864MHz clock X3. Note that there are many functions in the AK2344 that are presently not used.

The most important functions in the Tx mode are:

- Boom Microphone — This is a dynamic noise-cancelling microphone.
- AMP6 — Boom Mic amplifier (30dB).
- AMP1 — Buffer amp
- HPF — High pass filter 300Hz
- P/E — Pre-emphasis (on)
- Limit — Modulation limiter. This is very important and limits the maximum modulation.
- LPF — 3KHz low pass filter

The most important functions in Rx and Mute mode are:

- D/E — De-emphasis (on)
- HPF — High pass filter 300Hz
- LPF — Low pass filter 3KHz
- VR4 — Used for MIX and BAL setting in Rx mode.
- VR6 — Ditto
- VR7 — Ditto
- AMP7 — Used as HP filter for Rx-Noise (Squelch). This is the basis of the Squelch. The function is based on the fact that the high frequency (out of band) noise is inversely proportional to the signal level.
- RXRECT — Used as Rx-Noise rectifier. The output of the rectifier is digitized by the ADC in the CPU. After applying suitable level limits, hysteres and delays in software the squelch is formed.

Refer to the AK2344 Datasheet for detailed information. There is a very useful block diagram that should be read together with the info above.

The output of AMP6 is used to feed the Ext-Af-out and the VOX.

The VOX is based on an active rectifier with gain formed around U4 and D1. The input is bandpass filtered around 700Hz by the network around R69.

5.1.3 Ambient Sound Function

This function has two identical channels Left and Right. The function of the Left channel is:

- +4V switch Q4 controls the supply voltage.
- Left ambient electret microphone. Bias is through R25 - R28 with C40 as a ripple filter.
- Frequency response tailoring around R39, R42.
- Main amplifier U9 pins 1-3.
- AGC amplifier U9 pins 5-7.
- AGC rectifier D3-4.
- Attack and release filter C67, R47, C66.
- Gain control element Q3 (Shunt)
- Volume control U5.

The design of the Right hand channel is identical. Refer to the circuit diagram for the corresponding part designators.

5.1.4 Voice function

The voice messages are stored in a non-volatile EEPROM based storage IC U2 ISD1210 (in the future upgraded to ISD1410).
The IC is controlled by the CPU through a parallel bus.

Recording is primarily done through a low impedance source feeding the Ext-Af-out pin in the EXT Jack. Secondarily it can be done using the Boom Microphone. The commands necessary are found in the "RS232 Commands 107" file.

Play back for test is done using commands as above. Playback in actual use is handled by the CPU. The messages are placed in default positions, using the 80 segments available, based on a table loaded into the EEPROM U3 by the CPU. If a set of messages with different lengths are recorded the table will dynamically be modified accordingly by the CPU. Note that the messages must be recorded sequentially starting from Segment 0 and up.

Refer to the ISD1210 Datasheet for detailed information.

D7,8 form an anti-click circuit that reduces the power switching clicks from the voice circuit to an acceptable level.

5.1.5 Beep function

The beeps are generated by the PWM output of the CPU (pin 10) and mixed into L-pa and R-pa by R97, R38, R92.
The beep frequency and timing is set in software. Amplitude can be controlled in a crude way by the duty cycle.

5.1.6 Audio mixing

The Left and Right channel audio L-pa and R-pa are formed by resistive mixing in R38, R88, R89, R94, and R87, R90, R92, R95 respectively. The sources are the Left and Right Ambient Channels, the Left and Right Transceiver Rx audio, the Beep (CPU PWM -DAC), Transceiver Tx audio, the Voice.

Note that the Ext-Af-in is mixed into L-pa and R-pa in the same way on the RF Board.

5.2 K133A RF Board

This board contains all RF parts, the DC/DC Converter, the speaker amplifiers, the Ext Vox RS232 Tx, DC sink and the pads for connection to speakers, microphones, batteries etc.

5.2.1 TCXO

This is a Temperature Compensated Xtal Oscillator. The oscillator a SC cut fundamental xtal of 20.95000MHz. The xtal can be tuned by the built-in trimmer capacitor.

Q9 controls the power. The supply voltage is filtered by Q10 to ensure low noise. This also feed the PLL.

The output is used as the reference for the PLL Synthesizer and as the second Lo.

5.2.2 PLL Synthesizer

This is an low power PLL Synthesizer based on U1 Toshiba TB31202FN..
The frequency is the Tx frequency in Tx (exciter) mode and the Rx frequency minus 21.4MHz in the Rx mode.

The data is loaded into the TB31202FN through a serial data bus from the CPU. The data bus is separate from all other buses to ensure that there is no unnecessary traffic on it that could cause phase noise.

The PLL_lock signal is fed to the CPU and allows the CPU to adopt to the frequency step timing and to stop the Tx from transmitting if the PLL does not lock.

The VCO is a shielded module attached to the RF Board.

Q7 is a buffer that isolates the VCO and Tx/Rx from the PLL divider.

D3 is a diode switch that directs the main PLL signal to the Tx or Rx based on the power control signals RX_ON and /TX_ON.

The VCO is directly modulated by the band and amplitude limited Boom Mic signal VCO_Mod. This signal has also pre-emphasis to improve the S/N ratio.

5.2.3 Tx, T/R switch and antenna matching.

The Tx is a straight forward tuned amplifier with an output into 50 Ohm of about 26dBm. With an antenna gain of -4 to -5dB this yields an ERP of 21dBm, i.e. well within the limit.

Q5 is the driver amplifier. L13 is the matching network to Q1, the PA. C20, L11, C17 is a Pi filter matching network between the low impedance of the PA and the 50Ohm of the T/R switch and LP filter. L9 is the feed choke.

L8, D2, C11, L2, D1 is the T/R switch. The control signal is TX supply voltage switched by Q3.

The LP filter C9,8,4,2 and L6,5,3 is designed to attenuate the odd and even harmonics to below the regulatory limit.

5.2.4 Rx

The Rx is a conventional double superheterodyne type with a classic discriminator type decoder and de-emphasis to improve the S/N ratio. There is also a RSSI output with a dynamic range of more than 60dB. This is used for the squelch at high signal levels while the HP filtered rectified noise is used at low level.

The first IF is 21.4MHz and the second is 450KHz.

5.2.4.1 LNA and 1st Mixer

The signal from the antenna passes first through the LP filter and T/R switch described above.

The signal then passes through the 464MHz BP filter C12, C14, L10, C6. The filter is designed to attenuate the out-of band signals, especially the mirror frequencies around 422MHz.

The matching network C18 feed the signal into the LNA (Low-Noise Amplifier) Q2 . The output of the LNA is fed through the matching network L15, C26 into the 464MHz SAW filter SAW1. This adds further selectivity to improve the mirror frequency attenuation and reject out of band signals.

The output of SAW1 is then fed through the matching network L18, C30 into the RF port of the first mixer Q6.

The 1st LO is fed through the matching NETWORK C35 into the LO port of Mixer Q6.

The IF port of the Mixer Q6 is matched to the xtal filter impedance by the tuned network L19 , C41.

XF1 a 2-pole xtal filter adding the front-end selectivity needed.

Q8 is the first IF amplifier.

5.2.4.2 2d Mixer and IF

The second mixer and IF use the Motorola MC3371D. Q11 controls the power.

The 2d-mixer RF port is fed from the TCXO thru a buffer ampifier in the PLL IC TB3102FN.

The mixer output is filtered by CF1 and then amplified by the IF amplifier part of MC3371D. This sets the close-in sensitivity of the Rx.

The output of the IF amplifier is fed into the limiter part of MC3371D.

L23, R30 form the discriminator tank circuit (90 Deg phase shift).

5.2.4.3 Headphone Amplifier

The L-pa and R-pa signals are fed into the L&R speaker amplifiers U201,202. These have a power control signal /AF_PA_ON that shuts them down when not needed.

The network from pin 5 to pin 4 and ground of each of them sets the frequency response to match the headset mechanics and speakers.

5.2.5 External I/O

The EXT Jack has several signals that makes it possible to connect different types of equipment. There are also several software functions and set-ups that define the details of this. Refer to the RS232 Commands 107 file, the Software versions file and the user manual.

5.2.5.1 External Audio I/O function

Pin 1 of the EXT Jack is an Audio output with an amplified Boom Mic signal. The level matches a typical electret microphone.
The output is AC/DC coupled, i.e. there is a DC path to ground only if Q201 "DC Sink" is conducting. This is controlled by the PTT_AUX key and the EXT_Vox through the CPU and the /PLL_ON and RX_ON signals. Refer to the software sectionfor a detailed description. Note that these signals are used in a different way from what you could expect from their name. This is just a way to save CPU pins.
It is important to know that the PTT_AUX key is momentary unless double clicked, when it will lock. When it is locked the software will emit a short double beep every 30 seconds.

Pin 3 of the EXT Jack is an Audio input that will be mixed directly into the speakers. The sensitivity is suitable for normal headphone outputs from all sorts of communication and music equipment.
To the input the EXT Vox is connected. When this is enabled in the configuration set-up it will disable the transceiver (if the Tx is active it will delay this until finished) and attenuate the Ambient Channel.

This Ext-Af-out and the PTT_AUX key are typically used to interface an external GSM or LMR where it will activate the transmit function in the same way as an external Mic with PTT.

5.2.5.2 Serial Data I/O and set-up/programming.

The software UART in the CPU uses half-duplex and a 1-pin interface, EXT Jack pin 4, where transmit and receive data coexist.
The same pin is also used as a signalling pin to control the "Off-hook" of a GSM phone.

To solve the conflicts between these usage's the unit always starts with the RS232 transmit disabled. The pin will then be controlled by PTT_AUX and EXT_VOX., refer to the software section for a detailed description.

5.2.6 DC/DC Converter

The DC/DC Converter MAX1706 is a step-up design, from 3V to 4.3V followed by a low noise and low drop linear regulator, from 4.3V to 4V. The voltage margin across the linear regulator is maintained at 0.3V by the DC/DC converter.

The battery voltage is also monitored by the LB comparator in MAX1706. The negative input of the comparator is fed from the built-in 1.25V micropower reference. The positive input is fed from the divider R217,216. The LBO pin will then be low if the battery voltage is lower than 1.75V. The LBO signal can then be fed to the CPU Reset and/or the IF_ON signal to force a shut-down if the battery is too low. This feature is presently not used.
Note that this would be an emergency action as the software will do an orderly shut-down at 1.95V.

The DC/DC converter is also used as the power switch for ON/OFF control together with the CPU.

6 Adjustments

The adjustments and set-up procedure

6.1 Manual adjustments.

There are only three manual adjustments

6.1.1 TCXO

Set the unit in transmit on CH1.
Adjust the TCXO trimmer to 462,562,500±100 Hz transmit frequency.

6.1.2 Tx

Set the unit in transmit on CH1 in Lo power.
Set R11 for a conducted Tx output of 13±2dBm
Set the unit in Hi power mode
Set R8 for a conducted Tx output of 21±2dBm

6.1.3 Rx

Set the unit to Squelch=0 on a channel=1.
Connect a signal generator set to channel 1, -110dBm, 1.5KHz deviation to the antenna input.
Adjust L23 for minimum distortion.
Repeat until stable.
Verify that the sensitivity is at least -120dBM with CCITT filter.

6.2 Software adjustments

These adjustments are done using the RS232 commands from a PC.

6.2.1 Max modulation

Put the unit in Transmit on channel=1.
Inject a 1KHz signal of 75mV rms. into the Boom Mic input.
Set the modulation to 5-6KHz using the VR 4 and VR 5 commands.

6.2.2 Squelch

Connect a signal generator set to channel 5, -90dBm, 1.5KHz deviation to the antenna input.
Use the LitComII programming software to adjust the squelch.

7 Fault Finding

The following tests are important to get the unit into a testable state:

1. Switch ON
   - 1.1. Check that the battery voltage is around +3V between SP14 and SP15.
   - 1.2. Press the ON key and keep it down. Verify that the +4.3V and +4V supply are correct.
   - 1.3. Switch the unit ON. To do this the CPU detects the /SET_ON signal, verifies that the battery voltage is higher than 1.95V by the ADC (CPU pin 33, 39 and 41) and then sets the IS_ON signal.
2. LCD. All LCD segments should be visible when switching on until the ON key is released.
3. Synthesizer
   - 3.1. Check that the supply voltage on Q10/e is around 3.8V.
   - 3.2. Check that the TCXO output on X2/2 is correct.
   - 3.3. Check the VCO output on C36. Should be around -10dBm at 441.1625MHz.
   - 3.4. Check the 2d Lo output on U1/9. Should be 20.950MHz.
   - 3.5. Switch to Channel 14 and push PTT and check C36. Should now be 467.7125MHz
   - 3.6. Check the PLL_lock signal, should be high except during switching.

Note:

- All tests are done in default condition without any keys pressed unless otherwise noted.

When these basic parts are operating normally, it will be possible to use normal fault finding to cover all the other parts.