ADCON TELEMETRY

A733 RTU

Technical Reference (Type Approval)

SMART WIRELESS SOLUTIONS

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Release 1.0, December 14, 1999

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1. Introduction

1.1. About the A733

The A733 Remote Telemetry Unit (RTU) is a portable low-power, medium-range telemetry device capable of sampling up to 12 analog and 8 digital inputs (of which 4 are counter types); in addition, it can control up to 4 outputs. A 3-volt CMOS serial interface is also built-in, allowing for configuration, data download, or expansion (e.g. various bus implementations). The unit is based on a powerful 8-bit Flash RISC microcontroller, which can also be programmed in the field (for software upgrades).

The units incorporates an A431 radio module operating in the 430 to 470 MHz range, making it adaptable to most radio communication regulations in the world. The output power is 0.5 W, while the modulation is narrow band FM (12.5, 20 or 25 kHz channel spacing).

Due to its construction, as well as to the software controlling it, the power consumption is extremely low (average 1 mA—without sensors). The unit operates from a built-in NiCd 6.2 Volt rechargeable battery, which is charged using either a solar panel or an external power supply adapter. A special configuration may be implemented where no internal battery is used, rather the power is obtained exclusively over an external connector.

The A733 is a ruggedized unit, complying with the IP65 environmental protection class (NEMA 4). It can be easily installed and it integrates perfectly with an Adcon A730 network.

This manual describes the technical details of the A733, both hardware and software. It is organized in several parts, as follows:

- Hardware: includes the schematics as well as a description of the main board and interface boards of the A733
- The A431 radio module: includes the schematics and description of the radio module
- Software: a short description of the software with the most important commands that can be used to control the unit over the serial interface

This manual is intended for the radio approval authorities and laboratories.

2. Hardware

2.1. Overview

Most of the electronics (including the A431 radio module) are situated on the main board (for the A431 description, see "The A431 Radio Module" on page 25). The main board (Figure 1) contains the radio unit, a low-speed modem interface, a microcontroller and a power management subsystem. For the analog inputs and the digital inputs/outputs, two identical interface boards (A733CA) holding the 7-pin Binder connectors are used. The serial line and the power are provided on a 5-pin Binder connector, while the antenna is fed through a 50 Ω BNC connector.

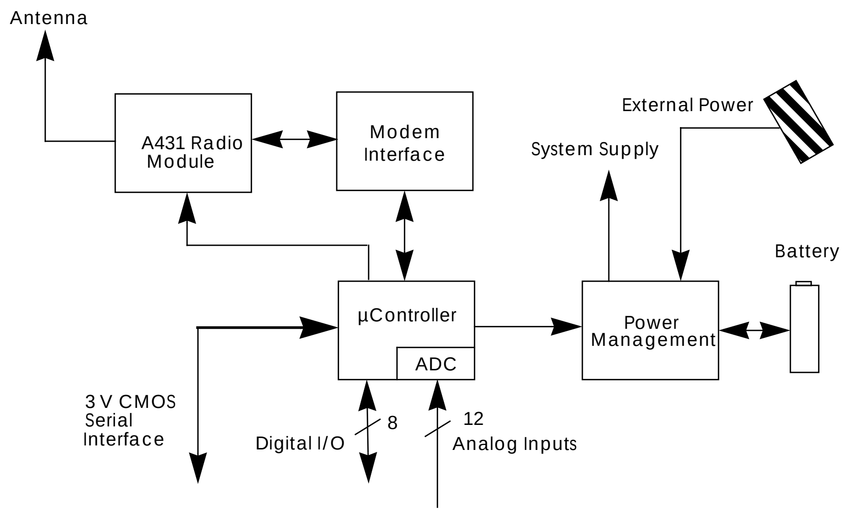


Figure 1. A733 Block Diagram.

For further details, consult the schematic diagram in Figure 2.

2.1.1. The Modem Interface

The modem operates with two tones: 1 kHz (representing the "1" bits) and 2 kHz (representing the "0" bits). A bit cell is represented by a complete time period (*1/f*), thus the raw throughput varies between 1 and 2 kbps (average 1.5 kbps). The modem functions are essentially implemented in software. However, a signal conditioning is performed on both receive and transmit paths.

On receive, the buffered analog data signal from the radio unit is applied to a 3 kHz low pass filter (U6). The filter output is further fed both to a Schmidt trigger (U5:A) and a 100 Hz low-pass filter (U5:B), the output of the latter being used as a reference for the slicer (the Schmidt trigger). The TTL data, **RXDO**, is obtained at the output of the slicer (i.e. on TP1). The microcontroller overtakes the decoding operation (see also "Modulation Technique Used" on page 57).

On transmit, a two-poles low-pass filter (U11) is used: its role is to "smooth" the square signal **TXDI** generated by the microcontroller. Before entering the filter, a microprocessor-controlled, variable-gain amplifier built with U12/U13 is used to set the modulation level for different bandwidths (12.5, 20 or 25 kHz). The selected value is stored in the microcontroller's EEPROM during the aligning procedure.

2.1.2. The Microcontroller and the Power Management Sections

The operation of the whole unit is under the control of U9, an Atmel ATMega 103 microcontroller. It is a powerful chip exhibiting a very low power consumption. Its main functions are:

- Controls the radio unit
- Implements the modem functionality
- Assembles the radio frames and waits for requests from a remote
- Performs the sampling of the sensor inputs and the A/D conversion
- Stores the values in a local FIFO; manages the FIFO
- Implements the pulse counter function
- Manages the real-time clock
- Assures the power management
- Implements a serial Command Line Interface (CLI)

The chip operates at its maximum speed, in this case 4 MHz (the "L" version), and uses a crystal (X2) for the on-board clock generator. The real time clock is implemented by means of a 32.768 kHz crystal (X1) connected on the internal Timer/Counter0.

The radio unit is controlled via the SPI bus (to set the PLL chip parameters) and via several ports of the microcontroller for such operations as transmit and receive. In addition, the high current 5 volt LDO voltage source (U4) is switched on before the radio module's PA must be activated.The modem's output (implemented in software) is available on PB5 (**TXDI**), while the receiver output is fed to PD4 (**RXDO**).

The A/D subsystem is used to sample the inputs (ADC0 to ADC5); the 6th and 7th analog input are used for on-board measurements as local battery, internal temperature and **RSSI/PO** signal; the battery and temperature voltages are switched by means of the analog switch U19. A stable 2.5 Volt reference supplied by U8 is applied to the A_{ref} pin. The reference is powered by the microcontroller only when sampling the A/D inputs. The external sensors are powered through U17. In order to enlarge the maximum number of sensors sampled, several analog multiplexers are used (U3/U7/U10). After sampling the A/D once, the software switches the multiplexers (using the signal **MUX**, pin PD2) and samples the inputs once again, thus doubling to 12 the maximum number of analog inputs.

The sampled input values are stored in a FIFO memory based on a serial EEPROM chip, U18. These values may be retrieved when a request is received over radio, or over the serial line. The configuration parameters (e.g. the serial number of the device, the operating frequency, etc.) are stored in the microcontroller's on-chip EEPROM.

The pulse counter functionality is implemented by means of the four interrupt inputs INT4 to INT7 of the ATMega 103 microcontroller.

The power management supervises the charge/discharge of the battery (via Q1 and half of U15), senses when it reaches the "misery" state and switches off the unit in order to protect the battery (second half of U15). In addition, the software senses the unit's idle state (e.g. the unit is in a warehouse in storage condition), where no activities must be performed thus driving the unit into hibernation. If the unit is switched off due to an extremely low battery level, Q2 would start it up again only if external power is applied to the power connector (e.g. from a solar panel).

The terminal mode is implemented by means of the built-in UART. No on-board level drivers are present in order to minimize power consumption; a special adapter cable that performs the CMOS to RS232 level shift is available. By means of this cable and using the implemented commands, various parameters can be changed/configured.

A brown-out supervisor chip (U14) is used to assure a smooth start-up of the microcontroller and avoid possible erratic behavior when the battery level descends below the minimum operating value (2.7 volts). The same chip activates the write-protect signal of the serial EEPROM during reset, in order to protect the data in the EEPROM.

2.1.3. *The Analog + Digital I/O Interface Board*

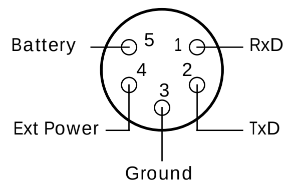
The two identical interface boards ensure the connection between the main board and the outside world (see Figure 3). The interface boards contain two connectors each (**I/O A** and **I/O B** or **I/O C** and **I/O D** respectively) and some active/passive components protecting the inputs. Each of the **I/O** connectors can accept:

- Three analog inputs
- One digital Input or Output (its function can be switched under program control, also remotely)
- One pulse counter input

Depending on the way R3 and R4 are populated, the power supply to the I/O devices can be either switched or permanent. This option is factory programmable only. If R3 is populated, the power will be permanently applied to the sensors while if R4 is populated, the power will be applied for a defined time (typically 2 seconds) only shortly before the microcontroller samples the inputs.

2.1.4. *The Power Supply and the Serial Interface*

The **POWER** connector allows for:



- External supply (battery or any DC source from 5.6 to 10 volts)
- External charge supply (either a solar panel or an AC adapter) if an internal rechargeable battery is used
- Communication over serial lines, at 19200 baud

Note: The serial line is 3 volt CMOS compatible, therefore a special adapter cable must be used to reach the RS-232 levels. Also, if an external battery is used, the internal battery must be disconnected.

when the battery voltage drops below 5.6 Volts, and under 5.9 Volts the RF operation may stop.

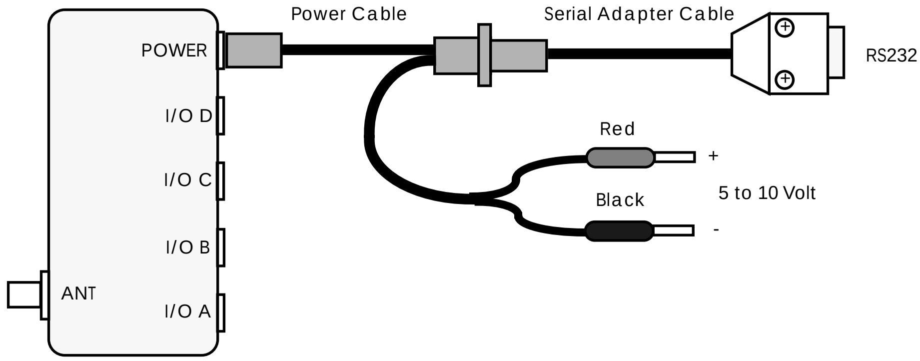


Figure 4. Connection of an external power supply.

2.2. Specifications

The A733 fulfills the specifications of the EN 300 220-1, Class 12, ETS 300 086 and ETS 300 113, as well as the FCC Part 90.214 (Subpart J) of the CFR 47.

Note: The parameters below were measured with the A733 + A431 combination.

Parameter	Min	Typ	Max	Unit
Common				
Supply	5.6	6.2	10.0	V
Operating Temperature	-30		+70	°C
Relative Humidity			99	%
Class Protection		IP65		
Data Rate (Using the On-board Software Modem)	1000	1500[a]	2000	bps
Operating Frequency (-44 version)[b]	430		450	MHz
Operating Frequency (-46 version)[b]	450		470	MHz
Frequency Stability (-20 to +50°C)			±1.5	kHz
Frequency Stability (-30 to +60°C)			±2.5	kHz
Receiver				
Sensitivity (12 db S/S+N)		-118		dBm
Image Frequency Attenuation (1st IF = 45 MHz)	-70			dB

Parameter	Min	Typ	Max	Unit
Local Oscillator Leakage			2	nW
Adjacent Channel Attenuation	-70			dB
RSSI dynamic	90			dB
Operating Current (incl. On-board Microcontroller)			25	mA
Transmitter (all measurements made on a 50 Ω resistive load)				
Output Power		27		dBm
Spurious Radiation			200	nW
Adjacent Channel Power (12.5 kHz version)			-34	dBm
Adjacent Channel Power (25 kHz version)			-44	dBm
Occupied Bandwidth (12.5 kHz version)			7.0	kHz
Occupied Bandwidth (25 kHz version)			12	kHz
Operating Current (incl. On-board Microcontroller)			600	mA

a. Data rate is content dependent.

b. This parameter represents the alignment range; the switching range can be limited in the software to a narrower space (even to the extent of a single channel).

2.3. PCB Parts Placement (A733)

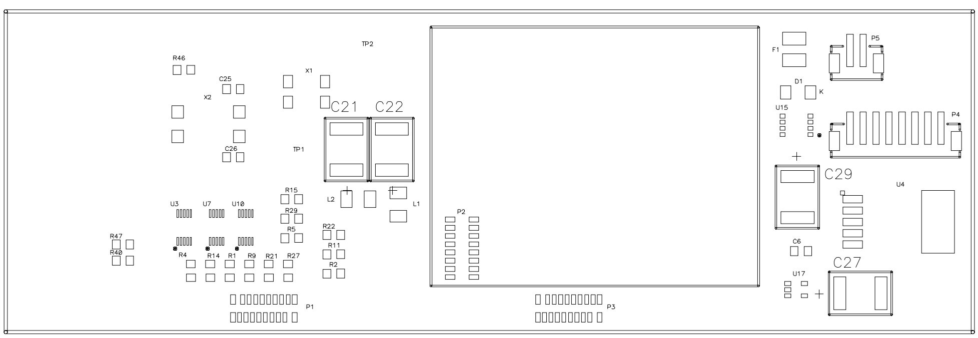


Figure 5. A733MB Parts placement (top).

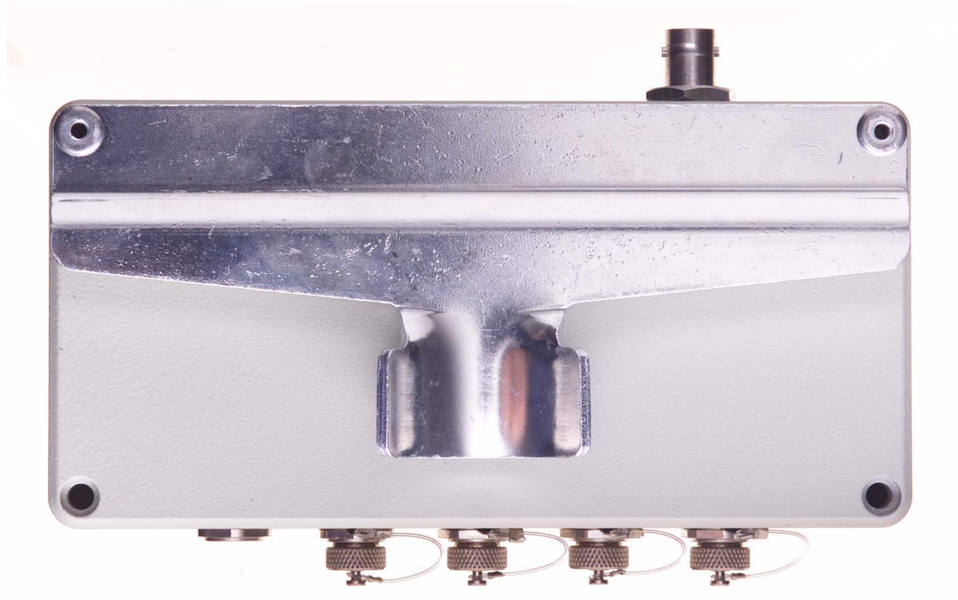


Figure 9. A733, Back view.

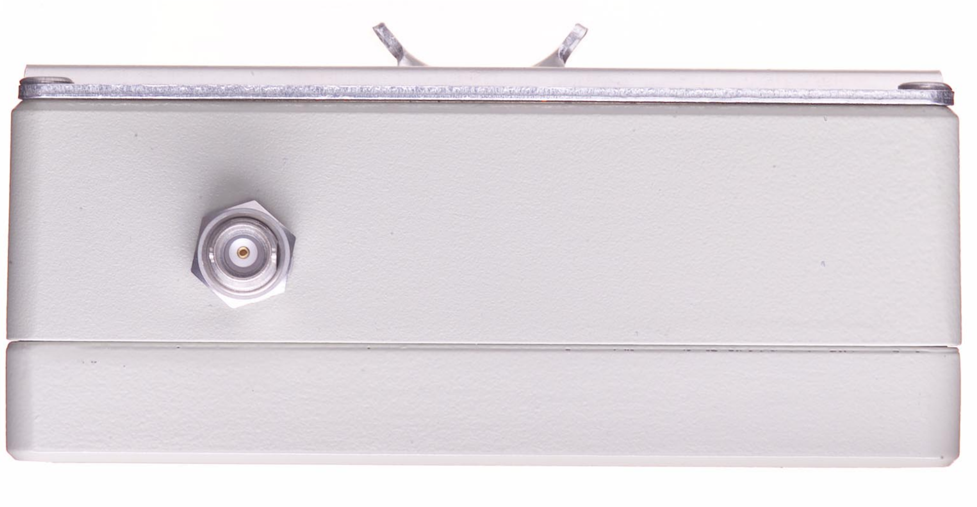


Figure 10. A733, Top view.

Figure 11. A733, Bottom view.

Figure 12. A733, Left view.

Figure 13. A733, Right view.

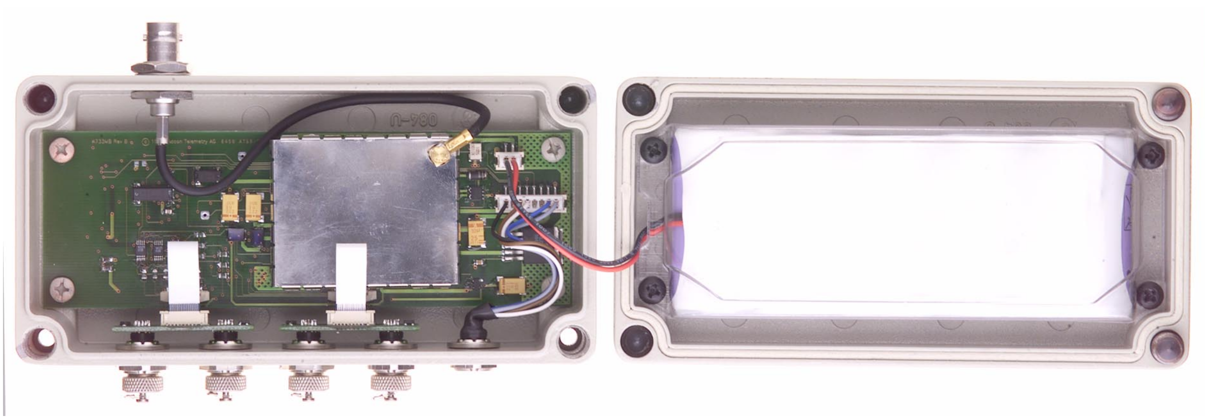


Figure 14. A733, Case opened.

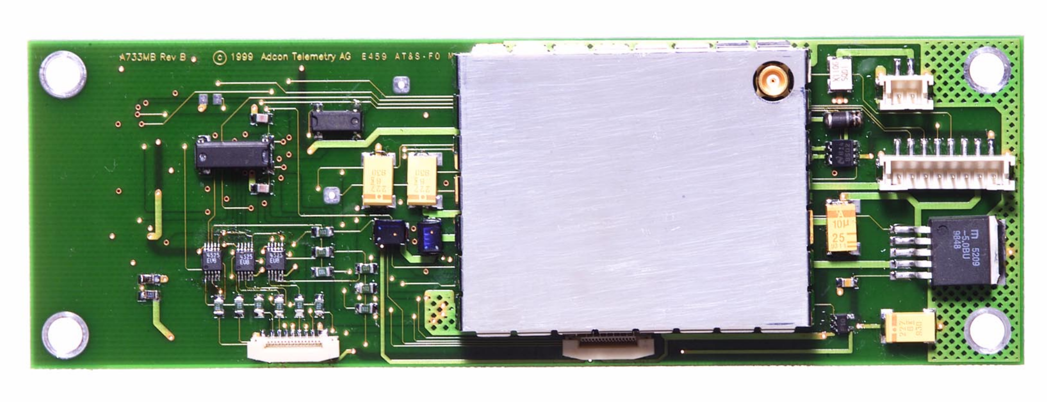


Figure 15. A733 Motherboard, top view.

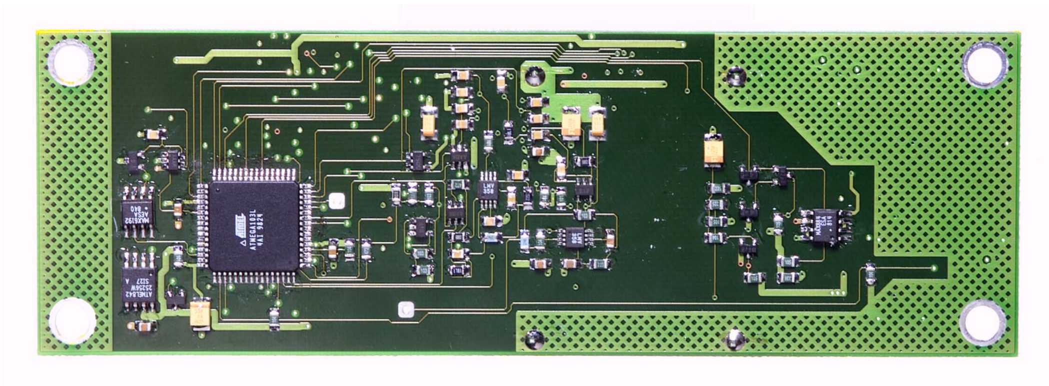


Figure 16. A733 Motherboard, bottom view.

3. The A431 Radio Module

3.1. About the A431 Radio Module

The A431 was specially designed for narrow-band FM data communication. It exhibits a relatively flat response in the audio band from 10 Hz to 2.5 kHz, both on send as well as on receive paths. Additionally, the receiver's group delay is very low.

The module operates in the 430 to 470 MHz range, making it compatible with most radio communication regulations in the world. The output power is 0.5 W, while the modulation is narrow-band FM (12.5, 20 or 25 kHz channel spacing). The power consumption in receive mode is remarkably low (under 25 mA), in spite of the excellent IP3 characteristics and high sensitivity. The switching from receive to transmit is fast, under 20 mS.

3.2. Functional description

The following functional description refers to the schematic diagram in Figure 17.

3.2.1. Receiver Section

The antenna signal is fed through the common low-pass filter for both receive and transmit and applied to the U3 antenna switch. From the J3 port of the switch, it is then fed to the FL1 helical filter and amplified by the LNA built with Q2 that assures a high amplification factor (over 20 dB). Another helical filter follows (FL2), giving a total of more than 70 dB attenuation of the first image frequency.

The incoming signal is then applied to the first mixer, U7, through an LC impedance matching network (L12/C48). The local oscillator signal is obtained by means of the VCO built around U10 and applied to the mixer. The VCO is locked to the OSC1 reference by means of the U9 dual-PLL chip.

The mixer's output on 45 MHz is filtered by means of XF1, which is needed to ensure a sufficient attenuation (over 70dB) of the second image frequency (at 44.090 MHz). The signal is pre-amplified with Q6 before entering the U8 mixer/IF chip. The second local oscillator is built around the IF chip, but it is locked by means of the second PLL of U9. In this way, all signals are generated from a common reference oscillator (OSC1, see also "Frequency Reference Specifications" on page 42).

The IF chain chip amplifies the signal to a proper level for FM detection. A particularity of this chip is that the FM detector is PLL-based, thus no coils or ceramic discriminators are needed. Two ceramic filters, CF1 and CF2, ensure the required adjacent channel separation. The audio output is delivered on pin 17 and is slightly amplified through U11 in order to bring it to 1Vpp, and centered on half the supply voltage (which is 3.3 volt approximately). The signal is inverted in order to compensate the inversion caused by the first mixer (the LO is higher than the received RF signal). The audio signal is fed out of the module on the pin **RXDO** of the interface connector. In addition, an RSSI level signal is obtained on pin 18 of U8 and is fed to switch U6. As long as the module is in receive mode, the RSSI signal will be present on the **RSSI/PO** pin of the interface connector.

3.2.2. Transmitter Section

The carrier is generated directly on the operating frequency by means of the VCO built around U2. The signal is locked on the reference OSC1 with the aid of the dual PLL chip based on U9. The chip, a National Semiconductor LMX2332L, was chosen for its fast locking scheme, low power consumption, and good RF characteristics.

The modulation is applied on both the VCO and the reference, in order to attain a flat characteristic in the whole band (10 Hz to 2.5 kHz). Due to the phase differences between the two modulation points, the signal applied on the reference is inverted by means of U4. Meanwhile, U4 is used to center the reference on the channel (using the trimpot R75). The PLL low-pass filter (third-order) composed of C66/C67/R69/R59/C64 is calculated around 800 Hz. R64 is used for the FastLock® mechanism. (For further details on the FastLock mechanism, please consult the National Semiconductor documentation.)

The signal is pre-amplified to approximately 0 dBm by Q1 and then it is applied to the PA built with U1. The output signal is pre-filtered and impedance-matched by means of theC21/L10/C22 low-pass filter and then fed to the antenna switch. Before reaching the antenna output, a three-cell, low-pass filter (used also on the receive path) is used to attenuate the unwanted harmonics and keep them below the required limits.

An Automatic Level Control (ALC) system is responsible for keeping the output power constant, regardless of the external influences (temperature, VCO excitation and/or supply). A small part of the RF energy is rectified by D2 and applied to the U5:A amplifier. By means of U5:B, the power is controlled according to the pre-set power level (ALC input). U5:A is basically an analog comparator between the actual and the programmed power output. Depending on the error signal obtained, a variable voltage is applied on the PD input of the PA chip, thus effectively controlling its output power. In addition, the actual power output level is fed to the U6 analog switch and presented to the RSSI/PO output while the unit is switched in transmit mode.

The modulation is applied on two-points: the VCO and the reference oscillator—this is needed to obtain a flat response in the audio range from 10Hz to 2.5 kHz and compensate for the counter-effect opposed by the synthesizer loop. The input signal (must be 1 Vpp) is fed through a resistive divider (R14/R13) to the "cold" end of the varactor diode controlling the VCO (D1). At the same time, the same modulation signal is applied to the inverting op-amp U4 and then to the OSC1 reference oscillator (a VCTCXO). The modulation signal is inverted in order to bring it in phase with the VCO modulation point.

3.3. Manufacturing Issues

3.3.1. Marking and labeling issues

The A431 Module is manufactured in two versions:

- Low band—able to operate between 430 and 450 MHz
- High band—able to operate between 450 and 470 MHz

From a manufacturing perspective, the difference between the high and low band are the two helical filters FL1 and FL2 used on the receiving chain. The low band version is marked as A733-44 while the high band is marked as A733-46.

3.3.2. Alignment Range and Switching Range

The A431 radio module's alignment range is 20 MHz, while the switching range is 10 MHz. According to the definitions formulated in the ETS 300086 and ETS 300013 specifications, the A431 radio module belongs to the AR1 category. Therefore, for the European testing, two units should be presented for test purposes, as follows:

- One A733 unit containing an A431-44 radio module, alignment range 430-450 MHz, switching range 435-455 MHz
- One A733 unit containing an A431-46 radio module, alignment range 450-470 MHz, switching range 455-465 MHz.

Consequently, two test reports will be provided to Adcon Telemetry AG.

For North America (FCC), only the portion 460 to 470 MHz will be used; therefore, a single device model A733-46 having the switching range between 460 and 470 MHz will be submitted for testing.

3.3.3. Tuning Procedure

The A431 modules are to be tuned by mounting them on a test fixture consisting of a specially modified A733 motherboard. The modification refers to certain mechanical aspects, in order to provide an easy plug in and out of the control connector (P2) as well as to the TP1 and TP2 test points.

The alignment operation must differentiate between following classes of units:

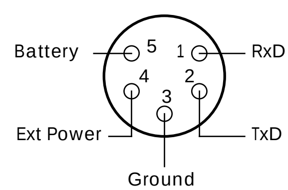
- Band 1: from 430 to 440 MHz
- Band 2: from 440 to 450 MHz
- Band 3: from 450 to 460 MHz
- Band 4: from 460 to 470 MHz

Note: The boards differ only through the FL1 and FL2, in that Band 1 and 2 use models TOKO 493S-1071A and 492S-1056A while Band 3 and 4 use models TOKO 493S-1075A and 492S-1060A, respectively. In addition, the tuning procedure and some software parameters differ. The differences are clearly stated in the following paragraphs, where applicable.

3.3.4. Setting Up the Default Parameters

The tuning procedure is not possible without first configuring some default parameters for the A733 motherboard used in the testing fixture. This is done via the serial interface of the motherboard by using a communication terminal program (e.g. Hyperterminal, in Microsoft® Windows™ 95). The terminal program must be configured as follows:

- 19200 Baud
- 1 Stop bit
- No parity
- No protocol (neither hardware, nor software)



To check if the communication is operational, press the **ENTER** key. An
nnnn 0
#
prompt should appear on the terminal screen (*nnnn* is the actual ID of the unit that is printed on its label). The following default parameters must be pre-loaded (for more information about the meaning of the commands, consult the section "Commands" on page 48):

Commands valid for all bands

```
ID 1
PMP 65 72
SLOT 900 15
RSSI 58
```

Commands required for band 1

```
TF 430000000
BL 430000000 440000000
FREQ 430000000 12500
```

Commands required for band 2

```
TF 440000000
BL 440000000 450000000
FREQ 440000000 12500
```

Commands required for band 3

```
TF 450000000
BL 450000000 460000000
FREQ 450000000 12500
```

Commands required for band 4

```
TF 460000000
BL 460000000 470000000
FREQ 460000000 12500
```

Note: The TF command sets the start tuning frequency, the BL command sets the band limits, and the FREQ command sets the actual operating frequency; before shipping and depending on the target country, the last two parameters may be changed. The BL command must always be issued before the FREQ command.

3.3.5. Definitions

The diagram of the setup environment is depicted in Figure 18.

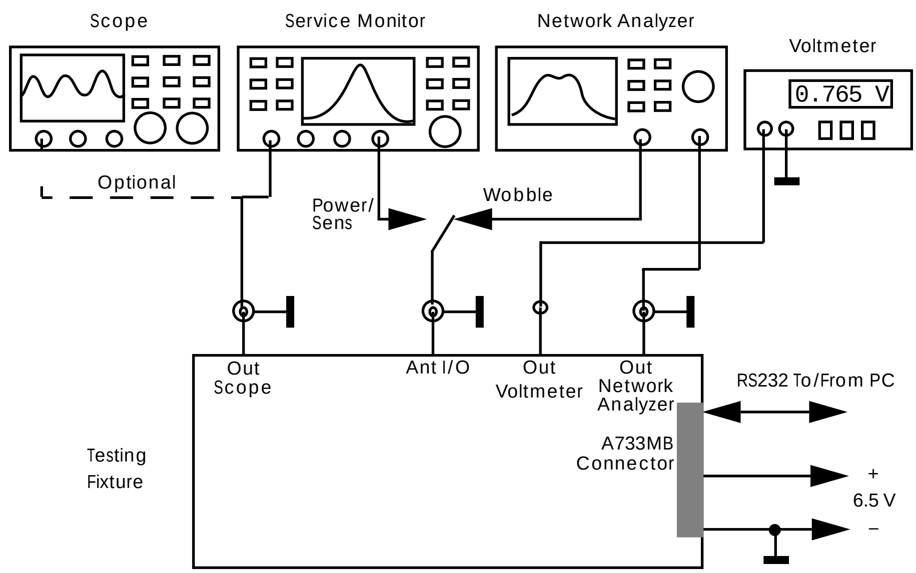


Figure 18. Trimming Setup.

The testing fixture is used to fasten the A431 Module under test both mechanically and electrically in such a way as to allow its rapid and comfortable alignment. It consists of a mechanical board with two screws that are used to fasten the board; two elastic pins are used to transport the relevant signals from the module to their corresponding test cables. The external coaxial switch or relay (**Power/Sens. <–> Wobble**) allows switching of the antenna input/output to the network analyzer or to the service monitor. The schematic diagram of the testing fixture is depicted in Figure 19.

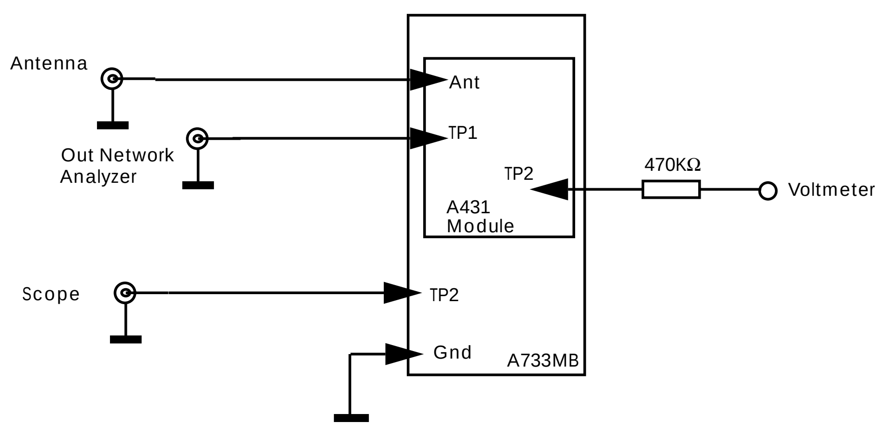


Figure 19. Schematic Diagram of the Testing Fixture.

3.3.6. Test Equipment Settings

Before proceeding, certain controls on the test equipment must be set; some of the settings depend of the operating band (high or low) of the device under test (DUT). In addition, it is highly recommended that the ambient temperature during alignment is kept to 24° C (±2°C).

3.3.6.1. Network Analyzer (HP 8712 or equivalent)

The settings for the Network Analyzer are as follows:

- Center frequency: 450 MHz
- Span: 100 MHz
- Display: 10.0 dB/div
- Power: -20 dBm
- Markers:
  — band 1: Mkr1 – 435 MHz, Mkr2 – 430 MHz, Mkr3 – 440 MHz
  — band 2: Mkr1 – 445 MHz, Mkr2 – 440 MHz, Mkr3 – 450 MHz
  — band 3: Mkr1 – 455 MHz, Mkr2 – 450 MHz, Mkr3 – 460 MHz
  — band 4: Mkr1 – 465 MHz, Mkr2 – 460 MHz, Mkr3 – 470 MHz

Note: *It is a good idea to store the instrument state for the four settings for a rapid recall when needed.*

3.3.6.2. Service Monitor (Rohde & Schwarz CMS50 or equivalent)

The setting for the receiver section check are as follows (RX-TEST):

- SET RF: 430000000 Hz (Band 1) / 440000000 Hz (Band 2) / 450000000 Hz (Band 3) / 460000000 Hz (Band 4)
- RF LEV: 1 µV
- SINAD
- AF1: 1kHz
- MOD1: 2.5 kHz
- SCOPE MODE
- BEST RANGE

The settings for the transmitter section check (TX-TEST):

- COUNT: (should show the transmitter carrier frequency)
- POWER: (should show the transmitter carrier power)

3.3.7. *Trimming Elements*

The location of the trimming elements on the A431 Module is shown in Figure 20.

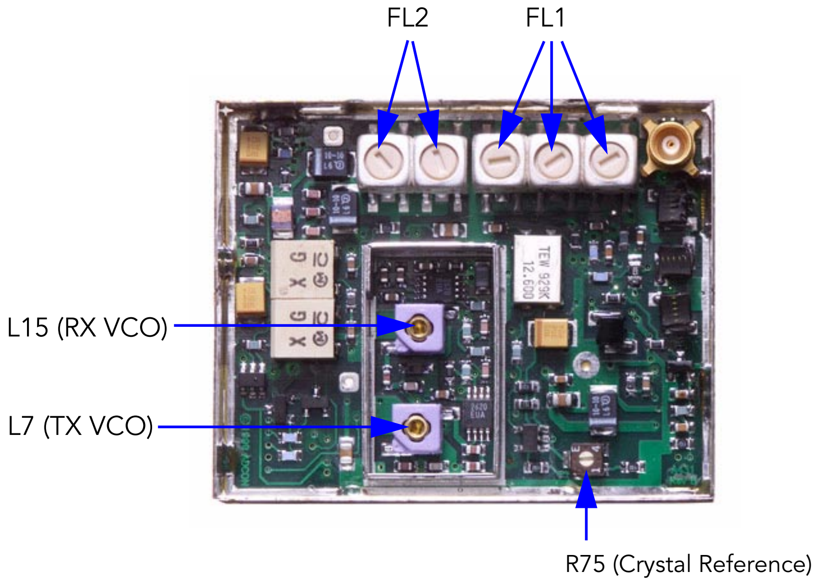


Figure 20. Location of the trimming elements.

3.3.8. *Adjusting the Receiver Front End*

1. Mount the DUT (Device Under Test) on the testing fixture and connect it to the host via the serial cable.
2. Select the appropriate instrument profile depending on the device's band.
3. Turn the DUT in permanent receive mode by entering the **RX** command at the terminal.
4. Check that the switch on the Testing Fixture is in the **Wobble** position.
5. Adjust the FL1 and FL2 filters (see Figure 20) until you obtain a curve similar to the one shown in Figure 21 (depending on the band, the markers may be different); this is done by successively adjusting the five trimming screws located on the filters.

If the adjustments do not achieve the appropriate curve, check the power supply, the cable connections to/from the test equipment, etc. Verify also that all the pins of the FL1 and FL2 filters are properly soldered.

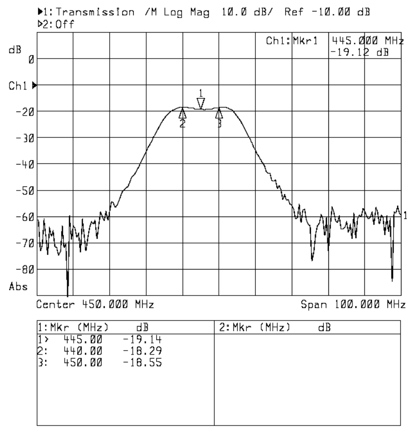


Figure 21. Helical Filter + LNA's selectivity diagram.

3.3.9. *Adjusting the VCOs*

1. Flip the switch on the Testing Fixture to the **Power/Sens.** position.
2. Verify that the DUT is in receive mode (enter the **RX** command at the terminal program).
3. Adjust the L15 coil (see Figure 20) until the voltage shown on the digital voltmeter is 900 mV, ±50 mV (see also the note below).
4. Switch the unit to transmit mode by entering **TX** at the terminal.
5. Adjust the L7 coil (see Figure 20) until the voltage shown on the voltmeter is again 900 mV, ±50 mV.
6. Press the enter key at the terminal to switch the unit off.

Note: A calibration may be needed due to the internal resistance of the voltmeter and the serial resistor mounted on the Testing Fixture. The calibration is performed by measuring the VCO voltage directly on the TP2 and by comparing the value with that measured through the Testing Fixture. The values given above are the real ones, measured directly.

If the above limits cannot be obtained, or the readout is unstable, verify the following:

- The programmed operating frequencies are indeed 430 (Band 1), 440 (Band 2), 450 (Band 3) and 460 MHz (Band 4). To check this, type the command **FREQ** at the terminal prompt; the device will answer by returning the current frequency.
- The respective commands (**RX** and **TX**) were issued.

- No parts are missing, or have the incorrect value, or are badly soldered (check the parts around U2 and U10).

3.3.10. *Adjusting the Crystal Reference*

1. Flip the switch on the Testing Fixture to the **Power/Sens.** position.
2. Switch the unit to transmit mode by entering **TX** at the terminal.
3. Observe the indication shown by the Service Monitor: adjust R75 (see Figure 20) until the carrier frequency indicates 430000000 (Band 1), 440000000 (Band 2), 450000000 (Band 3), or 460000000 MHz (Band 4) ± 200 Hz, respectively.

3.3.11. *Checking the Receiver Parameters*

1. Verify that the switch on the Testing Fixture is flipped to the **Power/Sens.** position.
2. Switch the DUT to receive mode by entering **RX** at the terminal.
3. Switch the Service Monitor to RX TEST mode, on the appropriate frequency (430 / 440 / 450 or 460 MHz respectively); the level should be 1 µV (see also "Test Equipment Settings" on page 32).
4. Verify that the S/N ratio is at least 12 dB; in addition, if a scope is also connected, a clear 1 kHz sine wave should be visible, with a relatively low amount of noise superimposed.
5. Switch the DUT to pulsed mode by pressing the Enter key. After several seconds, you will see the image on the scope pulsing at about one-second intervals.
6. Switch the RF generator output off.
7. Verify that the RSSI threshold is correct by typing the command **RSSI**; the actual value must be lower than the threshold set. If this is not the case, repeat the **RSSI** command several times—perhaps the frequency is in use (a radio receiver set on the operating frequency would help detect foreign transmissions). If the threshold difference is marginal, it must be increased by using the **RSSI <value>** command (it must be 20 to 30% higher than the actual value).

If any of the above targets are not reachable, visually verify first that the U8 chip is correctly soldered and that there are no shorts between its pins (most problems usually appear around this chip).

3.3.12. *Checking the Transmitter Parameters*

1. Verify that the switch on the Testing Fixture is flipped to the **Power/Sens.** position.
2. Switch the DUT to transmit mode by typing the command **TX 0** at the terminal.

3. Switch the Service Monitor to TX TEST mode, on the appropriate frequency (430 / 440 / 450 or 460 MHz respectively). You should see the following parameters on the Service Monitor readout:
    a. Carrier: 430000000 ± 200 Hz (or 440000000 / 450000000 / 460000000 respectively)
    b. Output Power: 26.5 dBm (+ 0.5 dBm / - 1 dBm)
    c. Frequency Deviation: ±2.0 kHz (±0.2 kHz)
4. Switch the unit to stand-by by pressing the Enter key.

For item 3.a above, adjust R75 (see Figure 20). For item 3.b, issue the command **PWR** at the terminal and use the **D** (down) and **U** (up) keys until the required value is reached. Finally, for item 3.c, issue the command **BW** at the terminal and again use the **D** and **U** keys to reach the required value.

3.3.13. Data Transfer Check

The last check is a radio data transfer. In order to perform it, at least a base station (model A730SD) or another remote station (model A733) must be installed and operated on the same test frequency, in the near vicinity (no more than 30 m).

Note: The base or remote station used for this test must be operated with a fictive antenna (a 50Ω resistor).

To perform the test, enter the command **B** at the terminal prompt: the base and/or remote station must answer with the RF in and out values. If an answer is not received after several seconds, retry the command. If an answer is still not received, then use a scope on TP1 on the A733MB board (the Text Fixture) to verify that the digital data is present (on receive). In addition, a radio receiver tuned on the operating frequency can also supply a rough indication of whether the receiver or the transmitter is defective.

3.4. PCB Parts Placement

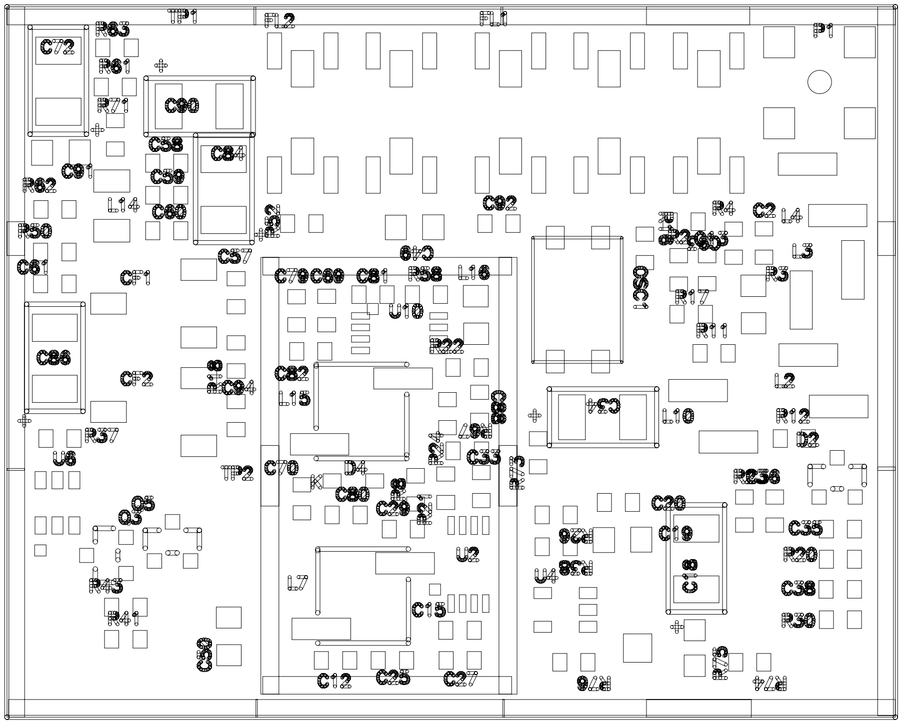


Figure 22. A431 Parts placement (top).

3.6. Frequency Reference Specifications

SPECIFICATION OF
VCTCXO TTS10V

13-11802

1. DESCRIPTION — This specification is applied for the VCTCXO.

2. MOUNTING TYPE — S.M.D (for reflow soldering)

3. ELECTRICAL CHARACTERISTICS

3. 1 Nominal Frequency	12.600000MHz
3. 2 Supply Voltage	DC+2.75V±0.15V
3. 3 Input Current	1.5mA max.
3. 4 Output Voltage	0.8Vp-p min. / Clipped Sinewave (DC cut)
3. 5 Load	(10KΩ//10pF) ±10%
3. 6 Operating Temperature Range	−30℃ ~ +60℃
3. 7 Storage Temperature Range	−40℃ ~ +85℃
3. 8 Frequency Stability	
Frequency − Operatingre Temp. Range	$\pm 2.5\times10^{-6}$ max. −30℃~+60℃
Frequency − Voltage Coefficient	$\pm 0.3\times10^{-6}$ max. DC+2.75V±0.15V
Frequency − Load Coefficient	$\pm 0.2\times10^{-6}$ max. (10KΩ//10pF)±10%
Frequency − Aging	$\pm 0.5\times10^{-6}$ max./ year
3. 9 Initial Frequency Tolerance	$\pm 2.0\times10^{-6}$ max./ before reflow at 25±2℃
Reflow soldering(2times)	$\pm 1.0\times10^{-6}$ max./ after reflow 60 mins stabilization
3.10 Voltage Controlled Range	$\pm 9.0\sim\pm 15.0\times10^{-6}$ Vc=1.4±1.0V

4. OUTLINE DRAWING AND PIN CONNECTIONS — Drawing Number 13-31039

Aug. 23, 1999 Designer : T. Suzuki

TOKYO DENPA CO., LTD.

3.7. A431 Module's Photographs

Figure 24. A431 Module, General view.

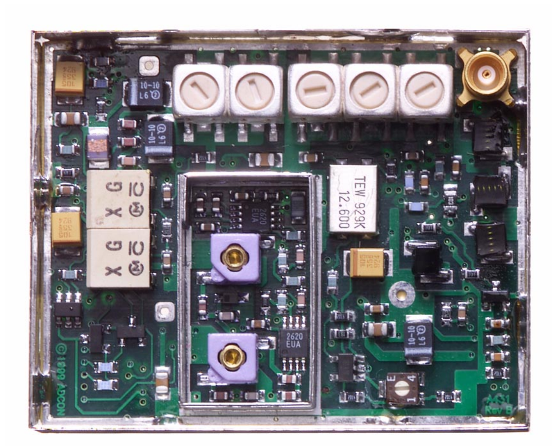


Figure 25. A431 Module, Top view.

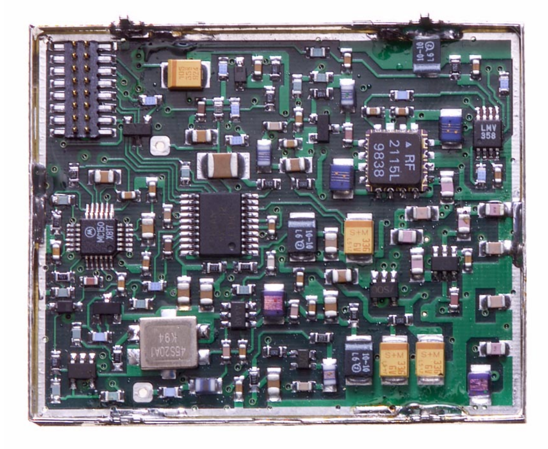


Figure 26. A431 Module, Bottom view.

4. Software

4.1. Short Description

The software is written entirely in C. It consists of a collection of standard C library functions, a pre-emptive multitasking operating system (CMX) offering basic configuration and administration functions (including a command line terminal on a serial port), and the application software itself, which assures the desired functionality of the device.

4.2. Tasks

Following tasks are currently implemented:

- Command Line Interpreter Task
- Radio Task
- Memory Management Task
- Real Time Clock (RTC) Task

The system usually remains in sleep mode. Each 0.5 seconds, an interrupt is generated by the local 32.76 Khz crystal oscillator. This wakes up the processor and activates the CMX RTOS, which allows all active tasks to perform their functions. After all the tasks have finished their jobs, CMX brings the system back to sleep. The 0.5 seconds interrupt routine is also used as time reference for the RTC task.

In parallel to the normal, regular operation of the CMX, the system responds to the pulse counter interrupts (they are generated by four inputs on the microcontroller and are used for event counting, e.g. rain gauges). These interrupts are handled by a separate driver.

One of the main concerns of the software design is the power consumption of the device. The software must ensure that all the peripherals are left in the correct state in order to reduce their consumption to a minimum; all operations are executed in the shortest possible time.

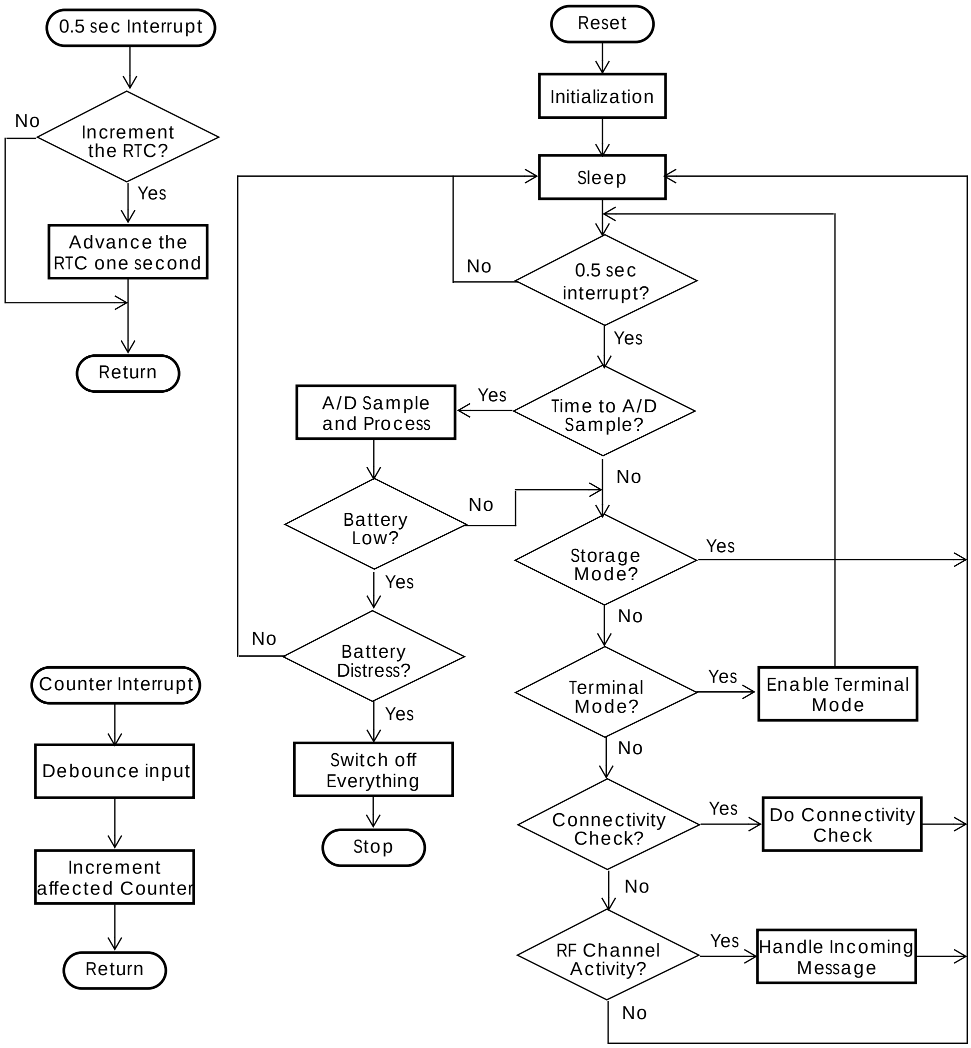


Figure 27. General flow chart of the A733 software.

4.3. Controlling the Unit

The unit under test can be controlled by means of the special serial cable supplied by Adcon Telemetry that is connected to a PC (e.g. a laptop) on one side and to the **POWER** connector on the other side. In order to switch the unit to various modes of operations, a simple communications terminal program will suffice (e.g. Terminal or Hyperterminal in Windows, or Kermit under other platforms). The terminal program must be configured as follows:

- 19200 Baud
- 8 Data Bits
- No Parity
- 1 Stop Bit
- Force LF after CR

Note: The interface is TTL, not RS-232. The adapter cable provided by Adcon must be used.

4.3.1. Serial Communication Protocol

This protocol is based on a master sending commands and a node answering; the whole communication is conducted in plain ASCII, as strings. When exchanging numbers, they are represented in decimal format. All commands are terminated with a CR/LF combination. All responses (answers) are terminated with the `#` character.

4.3.2. General Format of a Command

The commands have the following format:

ID Command Param1 Param2 ... ParamN

- `ID` is the destination device. If you include an ID as part of a command, the node checks whether `ID=ownID`. If it does, the node executes the command on itself. If the ID is not the node's ID, the node executes the command on a remote device, if such an ID exists. If the ID is missing, this implies that the command is addressed locally.

Note: Not all the commands can be relayed remotely.

- `Command` is the command proper, which can be composed of a variable string of characters (for example, `SLOT`). Each node can implement a set of commands depending on the functionality of the node itself. However, as a minimum requirement, a node recognizes the `CMDS` command, which returns a list with the commands recognized by the node.
- `Param1 Param2 ... ParamN` represent the parameters, which are command dependent. If you type no parameters when you issue a command, it is the equivalent of querying for information (the **GET** version of a command). If

you type parameters, you are issuing the **SET** version of a command and are setting the command to the parameters you typed.

4.3.3. General Format of an Answer

The answers have the following format:

ID Command Result1 Result2 ... ResultN ErrResult #

- `ID` is the answering device. If a command was further routed, it is the ID of the end device. The answer must always contain the ID on return.
- `Command` is the string representing the original command. It is supplied so that a master can distinguish between the answers it is waiting for, and out-of-band notifications (which may come, for example, over the radio port of a node). As with the ID, the command name must be always supplied.
- `Result1 Result2 ... ResultN` are the result values returned by the remote node. If the `ErrResult` is not zero, all other possible characters and/or strings until the end of the line may be ignored.
- `ErrResult` shows whether the command was successfully executed. If this value is 0, the command was successfully executed. If this value is other than 0, the command failed. The number may further indicate the error type. (See also “Returned errors list” on page 54.)

The answer string may contain any number of spaces or CR/LF characters between its components; however, after the terminator (#) no other characters are allowed.

4.3.4. Commands

Both uppercase and lowercase characters can be typed because the commands are not case sensitive. The commands list is not exhaustive, only those commands deemed necessary for type approval testing were included.

`CMDS`

DESCRIPTION Returns a list of supported commands.

PARAMETERS None.

REMARKS **GET** only.

RETURNS A list of strings separated by spaces.

REMOTE No.

EXAMPLE

```
CMDS
193 CMDS CMDS ID PMP RSSI TIME FREQ DEV DEL REPL SLOT DATA INFO RX TX ERA 0
#
```

TIME

DESCRIPTION	Sets/returns the real time clock.
PARAMETERS	The actual time, or none in the **GET** version.
RETURNS	The actual time as dd/mm/yyyy hh:mm:ss.
REMARKS	**GET/SET**.
REMOTE	No.

EXAMPLES

```
TIME 12/12/1999 22:10:10
193 TIME 0
#

TIME
193 TIME 12/12/1998 22:10:10 0
#
```

BL

DESCRIPTION	Sets/returns the band limits.
PARAMETERS	The frequency band limits (Hz), or none in the **GET** version.
RETURNS	The actual frequency band limits, in Hz.
REMARKS	**GET/SET**. This is a hidden command (i.e. not available for the normal user in the CMDS list).
REMOTE	No.

EXAMPLE

```
BL 432000000 450000000
193 BL 0
#

BL
193 BL 432000000 450000000 0
#
```

FREQ

DESCRIPTION	Sets/returns the operating frequency.
PARAMETERS	The operating frequency and step (Hz), or none in the **GET** version.
RETURNS	The actual frequency and step, in Hz.
REMARKS	**GET/SET**.
REMOTE	Yes, **SET** only.

EXAMPLE

```
FREQ 433925000 25000
193 FREQ 0
#
```

```
FREQ
193 FREQ 433925000 25000 0
#
```

DATA

DESCRIPTION — Returns data stored for a certain device.

PARAMETER — The ID of the device for which the data is requested and the date/time (in the standard format) the data was stored. If missing, it refers to the data of the local device.

RETURNS — A data block.

REMARKS — **GET** only. If the date/time parameter is not included, the latest data is returned. If the date/time parameter is included, the date and time closest to, but later than, the given date/time is returned.

REMOTE — Yes, for a **GET**, but only one frame at a time. The A733 can issue the command only for itself, locally.

EXAMPLE

```
DATA 193 12/12/1998 12:12:12
193 DATA b1 b2 b3 ... bn 0
#
```

The data block returned will typically contain a number of data frames (telegrams). The structure of a block is as follows:

dd mm yyyy hh mm ss si ft d1 d2 ... dn dd mm yyyy ... dn cs

where:

- `dd mm yyyy` is the date
- `hh mm ss` is the time
- `si` is the size of the frame (21 for frame type 37)
- `ft` is the frame type (37 for the A733)
- `d1 d2 ... dn` are the data values (the frame content)
- `cs` is a 16-bit checksum obtained by summing the bytes and discarding the carries over `0xFFFF`

The A733 devices always respond with a type 37 data frame (see also “Data12” on page 62). The composition of the data block of such a frame (the values marked as d1, d2... dn) is depicted in Figure 28, while the digibyte is depicted in Figure 29.

RF incoming
RF outgoing
Digibyte
I/O A Pulse Counter
I/O B Pulse Counter
I/O C Pulse Counter
I/O D Pulse Counter
Battery
I/O A Cabling 1
I/O A Cabling 2
I/O A Cabling 3
I/O B Cabling 1
I/O B Cabling 2
I/O B Cabling 3
I/O C Cabling 1
I/O C Cabling 2
I/O C Cabling 3
I/O D Cabling 1
I/O D Cabling 2
I/O D Cabling 3

Figure 28. Frame 37 description

b7							b0
SC	Dig 6	Dig 5	Dig 4	Dig 3	Dig 2	Dig 1	Dig 0

SC — Battery charge (0–off, 1–on) Dig n — Digital I/O n

Figure 29. The Digibyte

The remote version is limited to a single frame. An example of such a command is given below:

```
9999 DATA 9999 30/9/1999 14:50:00
9999 DATA
30 9 1999 14 54 55 21 37 255 255 77 0 0 0 0 89 156 126 20 0 0 0 0 0 0 0 0 0 3197 0
#
```

Notice that if you need to get data that is not the last (newest) slot remotely from a device, the ID must be supplied twice. If you need to get the last slot stored, you can ignore the ID and the date/time parameters:

```
9999 DATA
9999 DATA
13 9 1999 19 26 36 21 37 255 255 79 0 0 0 0 87 148 149 15 0 0 0 0 0 0 0 0 0 3148 0
```

```
#
```

IMME

DESCRIPTION Samples all inputs and immediately returns the sampled data.

PARAMETER The ID of the requested subsystem, default is the standard A/D subsystem of the A733 (ID=0).

Note: Currently only the default subsystem is implemented on the A733.

RETURNS A data block.

REMARKS **GET** only. The command needs a certain delay to execute, e.g. for the standard subsystem this delay amounts to two seconds. The delay is necessary to allow for the sensors to settle after applying power to them.

REMOTE No.

EXAMPLE

```
IMME
9999 IMME
13 9 1999 19 26 36 21 37 255 255 79 0 0 0 0 87 148 149 15 0 0 0 0 0 0 0 0 0 0 3148 0
#
```

INFO

DESCRIPTION Returns various status information.

PARAMETERS None.

RETURNS A list of a device's internal variables:

ID INFO rf_in rf_out date time ver clk stack cop batt temp days_uptime hr:min_uptime rssi pmp_low pmp_high type slot samples err_level
#

The formats for the above parameters are as follows:

- `rf_in` and `rf_out` as a decimal (`unsigned char`)
- `date` as dd/mm/yyyy
- `time` as hh:mm:ss
- `ver` as x.x
- `clk`, `stack`, and `cop` as decimal (`unsigned char`); they represent internal housekeeping parameters: the A733 uses `cop` to number watchdog occurrences, but `clk` and `stack` are currently undefined
- `batt` as battery level using the standard voltage conversion equation (0 is 0 volts, 255 is 20 volts)
- `temp` as internal temperature in the A733 housing, which is device dependent. The precision of the sensing element is low (±2°C), but it is sufficient for

battery power management (charge/discharge). To compute the actual value (in °C), the following equation must be used:

$$Temp_{[°C]} = \frac{internalTemp \cdot 400}{255} - 68$$

- `days_uptime` in days; together with hr:min_uptime, it represents the amount of time the device is up without a reset or watchdog
- `hr:min_uptime` in hours:minutes format
- `rssi` as decimal (`unsigned chars`); it is the programmed value with the **RSSI** command
- `pmp_low` and `pmp_high` are the programmed values with the **PMP** command
- `type` is used to represent the device type; following types are assigned currently:
  — 0 for A730MD
  — 1 for A720
  — 2 for A730SD
  — 3 for A720B
  — 4 for A733
- `slot` and `samples` are the actual values programmed by means of the **SLOT** command
- `err_level` is the error value; 0 means no error

REMARKS **GET** only.

REMOTE Yes, **GET** only. The A733 can issue the command both remotely and locally.

EXAMPLE **INFO**
193 INFO 255 0 18/4/1999 21:5:11 1.3 0 0 0 91 72 40 1:46 58 65 72 3 900 15 0
#

RX

DESCRIPTION Switches the unit to permanent receive mode (for tuning purposes).

PARAMETERS None.

RETURNS Nothing.

REMARKS The system stops, and exits the command only when a key is pressed. This command returns no message.

REMOTE No.

EXAMPLE **RX**
193 RX 0
#

TX

DESCRIPTION	Switches the unit to transmit mode (for tuning purposes).
PARAMETERS	None (sends an unmodulated carrier), **1** (sends a 1 kHz modulated carrier), **0** (sends a 2 kHz modulated carrier) or **5** (sends a mixed 1 + 2 kHz modulated carrier).
RETURNS	Nothing.
REMARKS	The system stops, and exits the command only when a key is pressed. This command returns no message.
REMOTE	No.

EXAMPLE

```
TX
193 TX 0
#

TX 1
193 TX 0
#

TX 5
193 TX 0
#
```

B

DESCRIPTION	Sends a broadcast frame.
PARAMETERS	None.
RETURNS	A data block.
REMARKS	After the device sends the broadcast frame, it will listen for answers. All valid answers will be listed with their IDs.
REMOTE	No.

EXAMPLE

```
B
193 B 0
#234 BA 0
#7851 BA 0
```

4.3.5. Returned errors list

Following are error messages you might get.

Command line interpreter

- 1 — nonexistent command
- 2 — command line buffer overflow (input line too long)
- 3 — internal error

- 4 — reserved
- 5 — missing or false parameters in command
- 6 — operation not implemented

Device descriptors and storage handler

- 10 — device not found (attempt to perform a command on a nonexistent device)
- 11 — device already exists
- 12 — reserved
- 13 — no more space for descriptors (too many devices)
- 14 — no more records for the specified device
- 15 — temporary communication break, no more data (the last request was not successful)
- 16 — time-out (the handler blocked or is busy)
- 17 — internal error
- 18 — attempt to insert a reserved device ID number (0 or 65535)

Real time clock

- 20 — incorrect time supplied (no conversion to `time_t` was possible)

Radio interface

- 30 — error at receive (CRC, etc.)
- 31 — unexpected frame received
- 32 — wrong length
- 33 — reserved
- 34 — reserved
- 35 — time-out (remote device not responding)
- 36 — receiver busy (for example, just making the request round)

Notifications

- 40 — request to read a notification when no notification is pending

4.4. Adcon Packet Radio Protocol

The A733 is basically intended as an end device in a radio network. Most frames defined by the Adcon Packet Radio Protocol are recognized and answered by an A733; a complete list is provided (see “Frame Types” on page 59). In addition, full source routing of frames for other destinations is implemented.

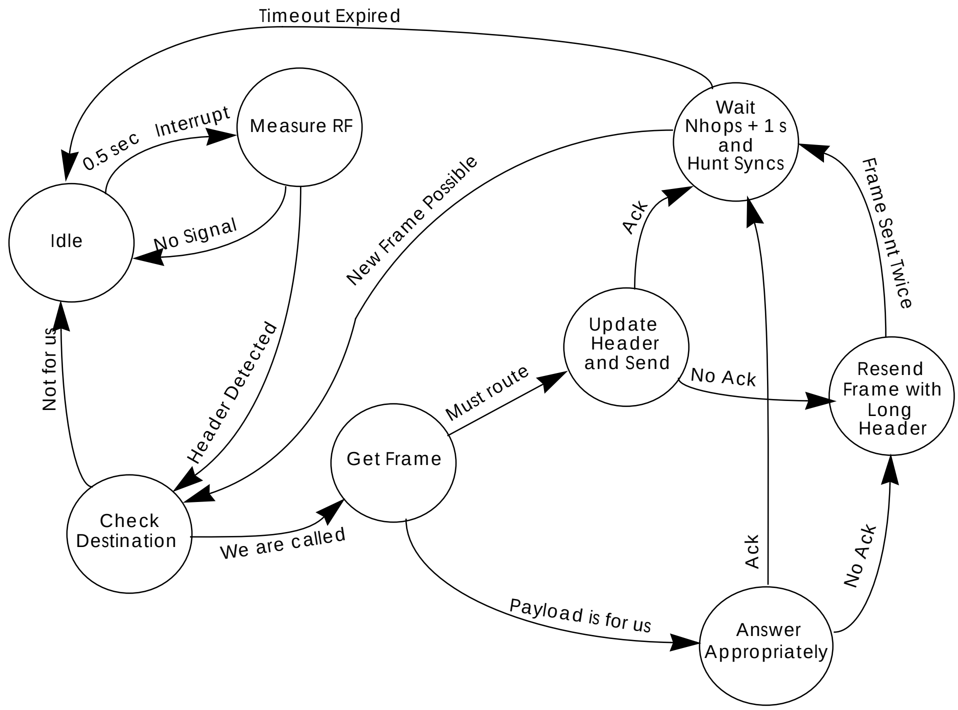


Figure 30. State Transition Diagram of the radio communication task.

4.4.1. Digital Squelch

In order to reduce the power consumption during receive mode, the unit uses a protocol developed by Adcon Telemetry for the A730 family, but with some additional refinements to further reduce the power consumption. The receiver is pulsed at a 0.5 seconds interval. At wake-up, the receiver samples first the RF channel for a carrier, by measuring the RSSI. The RSSI output is extremely stable due to the wide dynamic range that the IF chip exhibits (over 100 dB, temperature compensated). If the sampled RSSI is under a preset threshold, the unit will immediately go back to sleep. This procedure takes under 20 mS, typically (from wake-up to result).

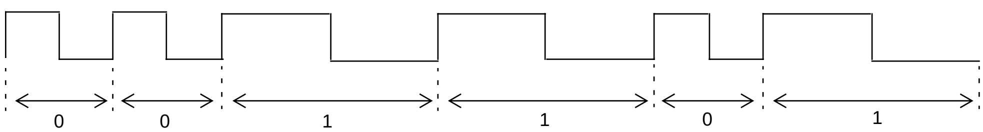
If, however, an RF level superior to the preset threshold is detected, the microprocessor will try to detect a valid header, which is composed of a 2 kHz tone of at least 0.5 seconds long. The tone detection is performed by the microcontroller in software, and takes at most 6 additional milliseconds. If no valid tone is detected, the unit goes back to sleep, otherwise it tries to decode the frame.

Based on the destination ID, the frame will be identified. If it is not for that particular unit (own ID), then the microcontroller will cease decoding it and will go immediately to sleep. The destination ID is positioned very early in the frame header (see also “Generic Format of a Radio Frame” on page 57).

From the above it becomes clear that in order to initiate a communication, a requester must send first a header which is at least 0.5 seconds long: these are called *long header frames*. Of course, after the communication is established the headers are short, of only 16 bytes (i.e. 8 msec. – called *short header frames*). If a timeout occurs, the system will restart by sending long header frames.

4.4.2. Modulation Technique Used

The communication via radio is made by using a special MSK (Minimum Shift Keying) scheme; both the encoding and the decoding of the MSK frames is made in software—there is virtually no hardware modem. A *zero* bit is transmitted as a sequence of 250 μs one level followed by a 250 μs zero level, while a *one* bit is transmitted as a 500 μs one level followed by a 500 μs zero level. A complete sequence of one and zero level forms a *bit cell*.



This modulation scheme is self-clocked. The transmission speed is content-dependent, varying from 1 kbps (when sending only ones) to 2 kbps (when sending only zeros). On the average, an 1500 bps transmission speed is reached.

The data interchange between stations is made by means of *frames*. The frames have a header, a 16 bit-sync character, a data block, and a 16-bit CRC number. The bytes forming the frame are send synchronously, with no start and/or stop bits. The data block is assembled after the sync character was detected. The LSB of a byte is sent first and the MSB is sent last.

4.4.3. Generic Format of a Radio Frame

The standard frame format used by the A730 family is as follows:

- The frame starts with a header of zeros and there are two header types: long and short. The long headers are used to wake up a remote station and must be 140 bytes long, while the short headers are only 16 bytes long.
- After the header, a synchronization character is used; this is a hex `0xAA` byte. The implementation must ensure that a 16-bit sync character is checked, i.e. `0x00AA`, and not only an 8-bit `0xAA` character.
- Following the synchronization pattern, the bytes are assembled by shifting the bits one by one: each 8 contiguous bits will be "cut" into a byte. First information assembled is the destination (**DST**) address: this is in order for all the receiving stations to know if they must assemble the whole frame, or they can go back to sleep. Only the addressed station will remain active after this information was decoded.

Note: The byte ordering convention used on the network is "big endian," i.e. the MSB is sent first and the LSB last.

- Next are the source (**SRC**) address and the length of the data field. The data field follows, and the frame is ended by a 16-bit CRC field. The CRC is computed starting with the first byte after the **SYNC** character until (but not including) the CRC bytes.

The data field can transport various type of data frames. After being successfully decoded and checked, these data frames are passed to the upper layer of the software. The data frames recognized by the A733 and their answers are detailed in "Data Frames" on page 59.

A device will answer to the requesting device with the answer frame. The answering device will poll the radio channel for an acknowledge; the acknowledge may be either the same frame send further up the network (if the communication has hops, i.e. routing stations in between the master and remote device), or an acknowledge send by the master – the master sends only a short radio frame containing the **SRC** and **DST**, both being its own ID. If the answering device does not receive the acknowledge, it will repeat the frame after a one second delay (only once).

Another notable feature of the system is the way it handles the long and short header frames. When a frame is sent by the master for the first time, it will be one with a long header; all the stations on the path of the frame participating in a certain transaction will relay the frame with a long header. After relaying the frame, the stations will remain active for a time calculated as (in seconds):

$$\text{Delay} = \text{Hops} + 1$$

The above scheme assures that as long as another frame will follow during this time interval (addressed to a station that is known to be also active), the header sent to that station will be a short one.

4.4.4. Data Frames

The data frames (payload) are the blocks of data extracted from the radio frames, after the CRC and other information (source address) was checked. The data frame and its length are passed to the upper layers of the software.

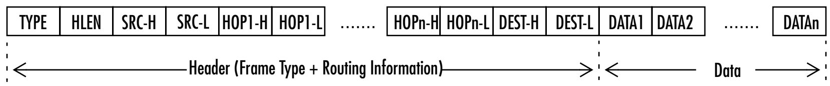


Figure 31. Generic Data Frame structure.

A data frame is composed of two main parts: a header, containing the frame type as well as the routing information, and a data block. The length of the data block can be easily computed by subtracting the header length (**HLEN** + 1 byte for the **TYPE**) from the original data frame length received from the lower layer of the software (the radio frame length). Additional explanations on the notation used in the diagram:

- **TYPE** is the type of frame; the types recognized and/or used by the A733 will be detailed individually later in this chapter (see "Frame Types.")
- **HLEN** is the header length: it represents the number of bytes used to describe the route the frame will go (or went). The maximum number of hops is 8, that is, 8 intermediate stations plus source and destination. Each station is described by its unique 16-bit address.
- **SRC**, **HOP** and **DEST**, are the source, the hops and the destination addresses. While the hops may be missing (no routing stations between source and destination), the source and destination are mandatory.
- **DATA** is the data proper field. It is limited in length, its maximum size being dependent also on the particular route: if the route is longer (8 hops) then the data block is limited to 48 bytes. Depending on the frame type, the data block may be nonexistent (zero length).

4.4.5. Frame Types

Although the original Adcon Packet Radio Protocol contains many frame types, only those relevant to the A733 are presented here.

Request

ID 1

FORMAT

```
struct {
        time_t          init_time;
        time_t          req_time;
} request;
```

DESCRIPTION The Request frame is used by a master to request data frames from a remote station. A remote will answer with a data frame. There are currently three types of data frames: normal (type 8), extended (type 37), and reduced (type 38); the A733 answers with the extended type (see also “Data12” on page 62).

- `init_time` represents the actual time to be used by the remote to re-initialize its local RTC; if its value is `time_t NULL` (default), then no re-initialization will be performed.
- `req_time` is the time for requested data. An A733 will search its internal data buffer for data that has a time stamp that is strictly newer than `req_time`. Therefore, if a master requests data with exactly the time stamp previously supplied by the remote, the remote must deliver a newer data slot. If the requested data is too old, the remote will send its oldest data, while if the requested data is too new, the remote will answer with the newest data it has. If the device is not yet initialized and has no data (i.e. its internal time is 1/1/1970), then it will send a Data12 frame with no relevant data, but with the time stamp of 1/1/1970. This mechanism will inform a master that the device needs initialization.

On the A733 this command can be initiated by means of the DATA command (see also “DATA” on page 50).

SEE ALSO Data12 frame.

Broadcast Answer

ID 2

FORMAT

```
struct {
        unsigned char   RF_levelOut;
} broadcast_answer;
```

DESCRIPTION This is the answer to a broadcast request frame; the `RF_levelOut` is the level recorded by the device when receiving the broadcast request frame. The A733 will receive and interpret such frames depending on the mode it was in when it issued the broadcast request (see also “Broadcast Request” on page 60). In terminal mode, all the broadcast answers will be displayed with their RF levels, while in connectivity check mode, the LED tool will be activated. The device will pulse the LED tool for the number of answers it identified.

If the A733 receives a Broadcast request, it must answer to it, but in a random manner. An 8 seconds time interval starting with the end of the Broadcast request frame is divided in 16 slots, each 0.5 seconds long. The A733 must select randomly one of these 16 slots for sending its answer. This frame, as well as the Broadcast request frame, is not routable.

SEE ALSO Broadcast Request frame.

Broadcast Request

ID 6

FORMAT The data frame body is empty.

DESCRIPTION This frame is sent by the device when the LED tool is inserted in the **POWER** connector, or if the command **B** is issued in terminal mode. This frame is special in that the destination address (**DST**) in the header is 0. This type of frame is not routable. All devices having received this frame must reply in a random fashion with a Broadcast answer frame.

SEE ALSO Broadcast Answer frame.

Ping

ID 9

FORMAT The data frame body is empty.

DESCRIPTION This frame is used to request an answer from a device; it is used to check if the device is available and reports on various conditions of the remote. The addressed device must answer with a Pong frame. On an A733, this command can be initiated from the terminal by means of the **INFO** command (see also "INFO" on page 52).

SEE ALSO Pong frame.

Pong

ID 10

FORMAT

```
struct {
        unsigned char   RF_levelIn;
        unsigned char   RF_levelOut;
        time_t          RTC;
        unsigned char   version;
        unsigned char   clkfail;
        unsigned char   stackfail;
        unsigned char   WDT;
        unsigned char   batt;
        unsigned char   internalTemp;
        time_t          uptime;
        unsigned char   rssi;
        unsigned char   pmp_low;
        unsigned char   pmp_high;
        unsigned char   type;
        unsigned int    slot;
        unsigned char   samples;
} pong;
```

DESCRIPTION The Pong frame is an answer to the Ping frame. In addition to informing a caller that a remote is active, it carries some useful information about the device's status:

- `RF_levelIn` is the left zero (it is a placeholder and will be filled by the first device receiving the frame).
- `RF_levelOut` is the RF level measured by the device when receiving the Ping frame.
- `RTC` is the actual value of the remote's Real Time Clock.

- `version` is the software/hardware version of the device.
- `clkfail` and `stackfail` are meaningless for an A733; they are kept for historical reasons.
- `WDT` is a counter incremented each time the device was reset due to a Watchdog timeout; its value is cleared at power-on reset.
- `batt` is the battery voltage (this value will be also found in the Data frame).
- `internalTemp` is the temperature in the A733 housing; the precision of the sensing element is vry low (±2C°), but it is sufficient for battery power management (charge/discharge). To compute the actual value (in C°), the following equation must be used:

$$Temp_{[°C]} = \frac{internalTemp \cdot 400}{255} - 68$$

- `uptime` is the time elapsed since the last reset (including a Watchdog reset).
- `rssi` is the programmed RSSI threshold value.
- `pmp_low` and `pmp_high` are the programmed power management parameters.
- *type* is the type of the device (will return always 4 – for A733).

Note: *Some of the values described above are specific to the A733. The implementation of the Pong frame, as well as its length (number of bytes), may vary from one device type to another.*

SEE ALSO Ping frame.

Fdev

ID 32

FORMAT `The data frame body is empty.`

DESCRIPTION This frame requests that a remote clear its data memory (format). The remote will answer with a General acknowledge frame. An A733 will never issue this frame type, but it will execute and answer it.

SEE ALSO General Acknowledge frame.

Data12

ID 37

FORMAT

```
struct {
        unsigned char   RF_levelIn;
        unsigned char   RF_levelOut;
        time_t          slot_timeStamp;
        unsigned char   digibyte;
        unsigned int    counter0; /* Pulse Counter I/O A input */
        unsigned int    counter1; /* Pulse Counter I/O B input */
        unsigned int    counter2; /* Pulse Counter I/O C input */
```

```
        unsigned int    counter3; /* Pulse Counter I/O D input */
        unsigned char   battery;
        unsigned int    analog_data[9];
} data_frame;
```

DESCRIPTION

This frame will be sent back by the device as an answer to the Request frame.

- `RF_levelIn` is the left zero (it is a placeholder and will be filled by the first device receiving the frame).
- `RF_levelOut` is the RF level measured by the device on the Request frame.
- `slot_timeStamp` is the actual time stamp on the data sent.
- `digibyte` represents the result of OR-ing the following bits:

b7							b0
SC	Dig6	Dig5	Dig4	Dig3	Dig2	Dig1	Dig0

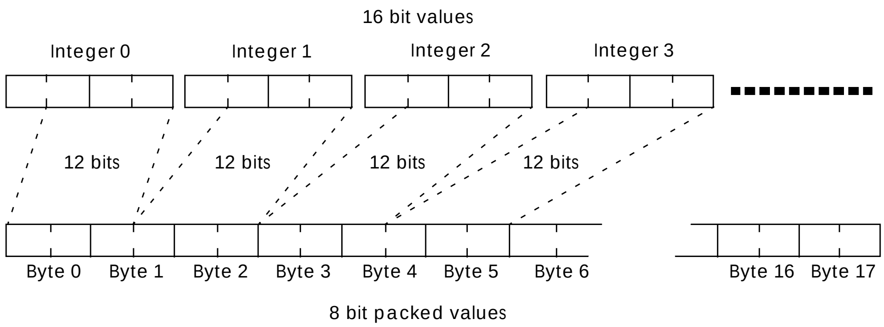
— **SC** represents the battery charge switch' status.
— DIG0 to DIG7 are the I/O pins on the I/O connectors. Note that only the first 4 DIGs are usable (there are only four I/O connectors on the A733).

Note: For additional info on the bits in the digibyte, check the hardware section of this manual.

- `counter0` to `counter3` are the values of the pulse counters.
- `battery` is the value of the main power supply; its actual value can be computed using the equation:

$$Batt_{[V]} = \frac{battery \times 20}{255}$$

- `analog_data[9]` is an array of 8 unisgned integers that represents the result of packing the 12 12-bit values. These are the values returned by the internal A/D converter from the respective I/O connectors (see the hardware section for more details). The packing mechanism is depicted below:



SEE ALSO

Request frame.

Set ID

ID

40

FORMAT

```
struct {
        unsigned int    ID;
} setId;
```

DESCRIPTION

This frame requests a remote to change its own ID number. The remote will answer with a General acknowledge frame *before* changing its ID. An A733 will never issue this frame type, but it will answer to it.

SEE ALSO

General Acknowledge frame.

Set Slot Time and Sample Rate

ID

41

FORMAT

```
struct {
        unsigned int    slot;
        unsigned char   rate;
} setSlot;
```

DESCRIPTION

This frame requests that a remote change the size of its slot (default 900 seconds, i.e. 15 minutes) and the sampling rate (default 15).

- `slot` is the number of seconds a new slot of sampled and averaged data will be stored in the internal FIFO memory of the device.
- `rate` is the number of samples per slot taken; these samples will be averaged before being stored.

The remote will answer with a General acknowledge frame. An A733 will never issue this frame type, but it will answer to it.

SEE ALSO

General Acknowledge frame.

Set Frequency

ID

42

FORMAT

```
struct {
        unsigned long   frequency;
        unsigned int    step;
} setFreq;
```

DESCRIPTION

This frame requests that a remote change its frequency. The remote will answer with a General acknowledge frame *before* changing its operating frequency. To further secure the transaction, the frequency change will be performed only after the remote receives the acknowledge frame from its next neighbor (for more details, see also “Generic Format of a Radio Frame” on page 57). An A733 will never issue this frame type, but it will answer to it.

SEE ALSO

General Acknowledge frame.

Set Battery Charge Levels

ID 43

FORMAT

```
struct {
        unsigned char   chargeStart;
        unsigned char   chargeStop;
} setBattCharge;
```

DESCRIPTION This frame requests that a remote change the battery charge management parameters. The device will answer with a General acknowledge frame. An A733 will never issue this frame type, but it will answer to it.

- `chargeStart` is the value where the external power (normally a solar panel) will be enabled to charge the battery.
- `chargeStop` is the value where the external power will be switched off.

From the above two values, the system will compute all other limits (e.g. misery, battery low, etc.).

SEE ALSO General Acknowledge frame.

General Acknowledge

ID 127

FORMAT

```
struct {
        int             result;
} generalAck;
```

DESCRIPTION This frame is sent as an acknowledge to various *Set* type of frames. The result field is `NULL` if the request was successfully performed; in case of failure, this field may contain information about the cause of the failure. Its value will depend on the type of the request.