# A720 – addIT™

## Technical Documentation

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**Proprietary Notice:**



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# *Wireless Sensor Interface A720 (addIT™)*

## *1. About the A720*

The A720 Wireless Sensor Interface (also known as *addIT™*) is a low power, short range telemetry device, capable of sampling up to 6 analog sensors and 4 digital inputs (of which 2 counter types); in addition, it can control two relays.

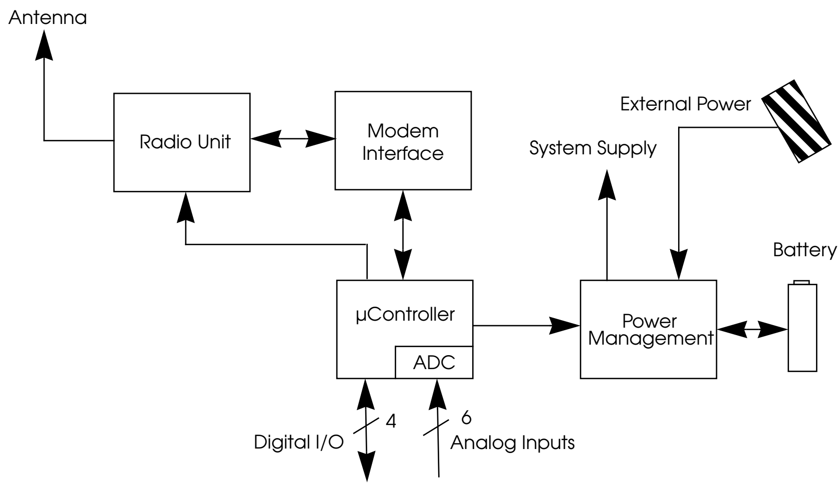
The frequency of operation is in the 432 to 470 MHz range, making it adaptable to most radio communication regulations in the world. The output power is under 10 mW, while the modulation is narrow band FM (12.5 or 25 kHz channel spacing).

Due to its construction, as well as to the software controlling it, the power consumption is extremely low (average 6 mW). The unit operates from a built in NiCd 6.2 Volt rechargeable battery, which is charged either using an 600mW 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 A720 is a ruggedized unit, complying with the IP65 environmental protection class (NEMA 4). It can be easily installed and it integrates perfectly in an Adcon A730 system. Depending on the terrain, it assures a reliable wireless connection to an A730MD or A730SD device to distances up to 800 meters, under favorable conditions even more.

# 2. Hardware

Most of the electronics are situated on the main board, while an interface board is used to connect the unit to the outside world. The main board contains a radio unit, a low speed modem interface, a microcontroller and a power management subsystem.




For further details you may want to consult the schematic diagram located on page 7.

## 2.1. The Radio Unit

It consists of a RF transceiver, that conforms or surpasses the ETSI 300 220 specifications. The receiver is a double superheterodyne type, first oscillator being synthesized. The transmitter is also synthesized, only the PLL chip and the frequency reference being common (there are two separate VCOs, one for the receiver's local oscillator and another for the transmitter).

### 2.1.1. Receiver Section

The antenna signal is fed through a low pass filter and the antenna switch (D1/D2) to a helical band-pass filter (it has a 20 MHz passband at 3dB), which attenuates the first image and the oscillator fed-through signal. A cascode chip (U3) is used for RF signal preamplification and first mixer, the LO being fed via the second emitter of the cascode. The resulting IF on 45 MHz is filtered through XF1 which in this case provides the image attenuation for the second mixer.

After a pre-amplification by means of the transistor Q11, the 45 MHz IF signal is applied to U10, which provides the second frequency change to 455 kHz, pre-amplification, limiting and FM demodulation. The second oscillator is also built into this chip, a third-overtone quartz oscillator oscillating on 44.545 MHz. The 12.5/25 kHz selectivity is obtained through the use of the two ceramic filters CF1 and CF2 (version GX for 12.5 kHz or EX for 25 kHz channel spacing), exhibiting a low group delay time. An interesting feature of U10 is its coilless demodulator, which is PLL based. By adjusting R67 and R60 one can change the bandwidth and the central frequency of the IF demodulator.

The data signal is obtained on pin 17 of U10 and is buffered by means of U8:D. In addition to the data signal, an RSSI signal is obtained on the pin 18 of the same U10. The signal is multiplexed with other DC signals (battery level and on-board temperature) by means of U6 and U7 and then is presented to one of the A/D inputs of the microcontroller.

The entire receiver section is enabled by the microcontroller through Q8.

### *2.1.2. Synthesizer Section*

The synthesizer is based on a very low power PLL chip, U2. An important feature of the chip is its FastLock™ mechanism, which improves the locking speed of the loop without compromising on the VCO noise. The operation of the PLL chip is directed by the microcontroller (operating frequency and channel step) and are therefore fully under software control. The frequency reference is obtained from the highly stable temperature compensated crystal oscillator OSC1.

There are two separated VCOs: one for the receiver section and a second for the transmitter section. The receiver oscillator is 45 MHz higher than the transmitter oscillator, the latter being on the programmed operating frequency. This solution optimizes the operating range of the individual VCOs, and keeps the noise level down.

The receiver VCO is realized with Q6 as oscillator and Q4 as buffer/amplifier, while the transmitter VCO with the pair Q2/Q1. The configuration of the two VCOs is very similar: in order to minimize the power consumption, the transistors are connected in series from a DC perspective, the buffer being the load of the oscillator.

A small amount of RF from each VCO is fed to the PLL chip input (to the internal prescaler) by means of the group C47/R27, and C16/R7 respectively. The output of the PLL from the phase comparator/charge pump is filtered by means of the low pass filter formed by C35/R29/C36/R22/C55 and applied to the two varicap diodes D4 and D3. In addition, the FastLock mechanism occasionally activates R21 to increase the current of the charge pump (you may want to consult National Semiconductor's Application Note AN-1000 "A Fast Locking Scheme for PLL Frequency Synthesizers", by D. Byrd, C. Davis, W.O. Keese, July 1995 for additional details on the FastLock mechanism).

### 2.1.3. Transmitter Section

The transmitter section uses the VCO composed by Q2/Q1. This VCO is modulated on the anode of its varicap diode (D3) by means of a small amount of the data signal. Before modulation, the data signal is filtered by a four-pole low-pass filter built around U1. The filter effectively removes the harmonics on the data signal in order to keep the adjacent channel power under the required level.

The output of the VCO/buffer amplifier is applied to the power amplifier, operating in class A thus minimizing the harmonics (Q3). The output of the amplifier is directed to the antenna through the antenna switch and the low pas filter. The antenna is switched on transmit mode when a positive current is applied on the anode of D1 via R12. The DC component is obtained from the collector of the power amplifier (Q3). C11 is used to pass along the RF component.

The transmitter is activated by the microcontroller in two steps:

- The PLL is switched on (by means of Q5);
- After a delay of about 5 mS when the PLL has settled, the power amplifier is switched on (by means of Q7).

The above mechanism assures a clean transmission start, avoiding that the transmitter "spills-out" its carrier on several channels before stabilizing. The switch off follows the same principles, but in a reverse order.

## 2.2. 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 functionality is essentially implemented in software. However, a signal conditioning is performed on both receive and transmit paths.

On receive, the buffered analog data signal from U8:D is applied to a 3 kHz low pass filter (U8:A). The filter output is further fed both to a Schmidt trigger (U8:C) and a 50 Hz low pass filter (U8: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 TP2). The microcontroller overtakes the decoding operation (see also "Modulation Technique Used" on page 43).

On transmit, only the low pass filter built around U1 is used: its role is to "smooth" the square signal **TXDI** generated by the microcontroller.

## 2.3. The Microcontroller and the Power Management Sections

The operation of the whole unit is under the control of U9, a PIC16C77L microcontroller. It is a powerful chip exhibiting an extreme low power consumption. Its main jobs 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;
- Increments the Real-time clock;
- Assures the power management;
- Implements a serial Command Line Interface (CLI).

*Note:* *For more details on some of these functions, see also the chapter "Software" on page 34.*

The chip operates at its maximum speed, in this case 4 MHz (the "L" version) and uses a crystal (X1). The real time clock is implemented by means of a 32.768 kHz crystal (X3) connected on the internal TIMER1.

The radio unit is controlled via the SPI bus on one hand (to set the PLL chip parameters) and via the switches Q8 (for receive) and Q5/Q7 (transmit). As already mentioned, the modem is implemented in software: the output signal is available on RB1 (**TXDI**), while the receiver output is fed on the RB0/INT pin (**RXDO**).

The A/D subsystem is used to sample the inputs (AN0 to AN5); the 7th analog input is used for on-board measurements (local battery, internal temperature and RSSI signal, switched by means of the analog switches U6 and U7); a stable 2.5 Volt reference supplied by U4 is applied to the RA3/AN3/Vref pin. The reference is powered by the microcontroller only when sampling the A/D inputs. The external sensors are powered through U13.

The sampled input values are stored in a FIFO built with a serial EEPROM chip, U5. These values may be retrieved when a pertinent request is received over radio, or over the serial line. Additional configuration parameters are stored in the EEPROM, e.g. the serial number of the device, the operating frequency, etc.

The pulse counter functionality is implemented by means of the two inputs RB6 and RB7, based on the *interrupt on change* feature implemented in the PIC16C7x series of microcontrollers.

The power management controls the charge/discharge of the battery (via Q9 and U11), senses the misery levels and switches off the unit in order to protect the battery (again U11). In addition, the software senses a storage condition, where no activities must be performed thus driving the unit in the hibernation mode. If the unit was completely switched off due to an extremely low battery level, Q10 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 TTL to RS232 level shift and vice-versa is available. By means of this cable and using the implemented commands, various parameters can be changed/configured (see also the chapter "Software" on page 34).

## 2.4. The Interface Board

The interface board assures the connection between the main board described above and the outside world. It contains the three connectors (**I/O A**, **I/O B** and **POWER**) and some passive components protecting the pulse inputs. Each of the **I/O** connectors can accept:

- Three analog inputs;
- One digital Input or Output (its functionality can be switched remotely);
- One pulse counter input.

The **POWER** connectors allows for:

- External supply (battery or any DC source from 5 to 10 volts);
- External charge supply (either a solar panel or an AC adaptor) if an internal rechargeable battery is used;
- Communication over serial lines, at 19200 baud.

*Note:* *The serial line is TTL compatible, a special adaptor cable must be used to reach the RS-232 levels. If an external battery is used, then the internal battery must be disconnected.*

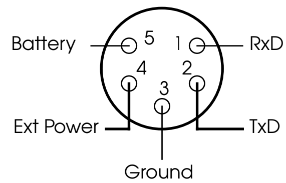
## 3.1. Programming the Boards

This section will be completed later.

## 3.2. Setting-up the Default Parameters

The tuning procedure is not possible without first configuring some default parameters on each unit. This is done using a special serial cable connected between the A720MB with an A720CA interface to a PC; in addition, a communication terminal program (e.g. Hyperterminal, in Microsoft® Windows™ 95) is needed to send the commands. The terminal program must be configured as follows:

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




To check that the communication is operational, press the **ENTER** key: an **OK** should appear on the terminal screen. Using the **SET** command, following default parameters must be pre-loaded (for more details on the meaning of the commands, consult the section "The Terminal Task" on page 39):

**SET OWNID 1**
**SET PMP 65 72**
**SET SLOT 900 3**
**SET RSSI 58**
**SET BL 432000000 450000000**
**SET FREQ 432000000 25000**

The last two **SET** commands are valid for the units that will be trimmed for the low band; for the high band, they must be replaced by:

**SET BL 450000000 470000000**
**SET FREQ 450000000 25000**

*Note:* *The SET BL command sets the band limits, while SET FREQ sets the operating frequency; before shipping and depending on the target country these two parameters may be changed. The SET BL command must be issued always before the SET FREQ command.*

## 3.3. Tuning

The tuning can be performed only after the units are programmed and the default parameters are set, as described previously.

### 3.3.1. Definitions

The diagram of the setup environment is depicted in *Figure 3.*

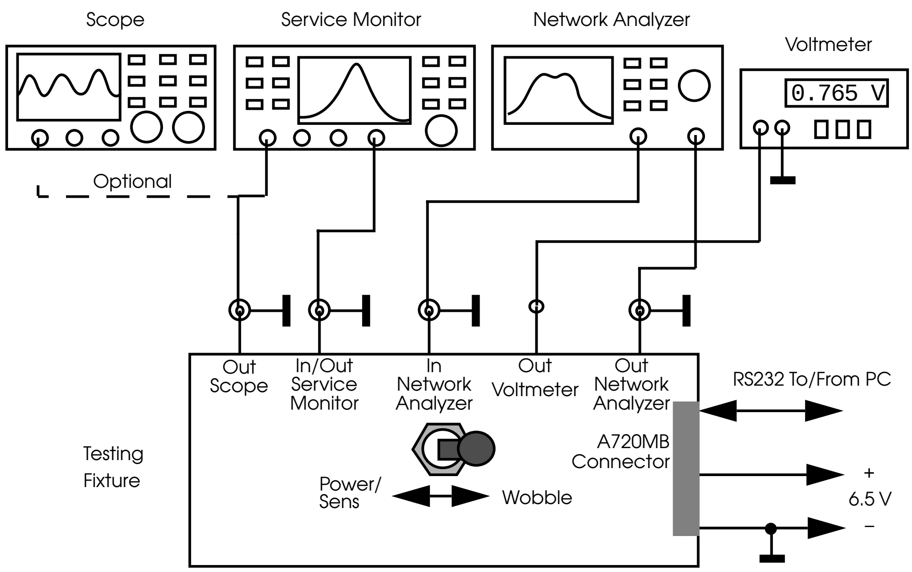



**Figure 2.** Trimming Setup.

The testing fixture is used to fasten the PCB under test both mechanically and electrically in such a way to allow its rapid and comfortable trimming. It consists of a mechanical breadboard with two screws that are used to fasten the board; 5 elastic pins are used to transport the relevant signals from the PCB to their corresponding apparatus test cables. In addition, a switch (**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 3.*

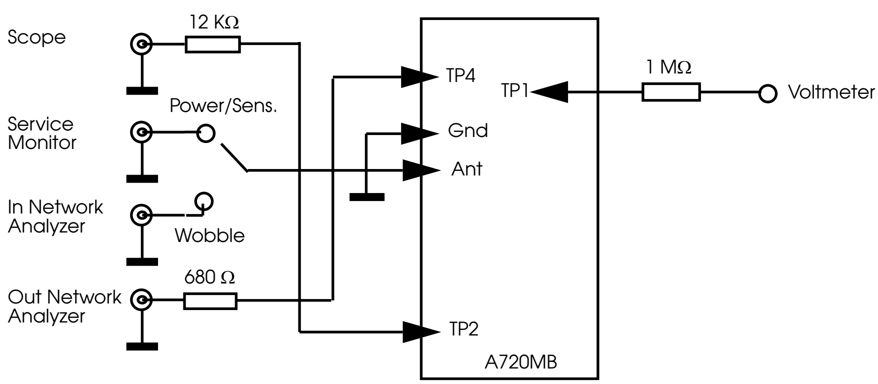
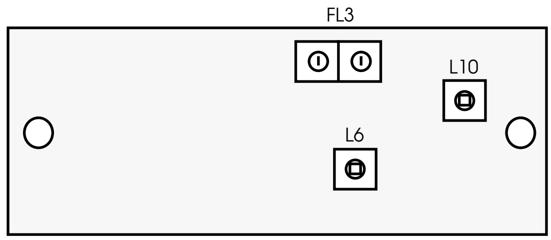



**Figure 3.** Schematic Diagram of the Testing Fixture.

There are only three tuning elements to be acted upon: FL3, L6 and L10. Their location on the PCB (all upper side) is depicted in the schematic below:




## 3.3.2. 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 trimming is 24° C (±2°C).

### 3.3.2.1. Network Analyzer (HP 8711)

The settings for the Network Analyzer are as follows:

- Center frequency: 450 MHz
- Span: 100 MHz
- Display: 5.0 dB/div
- Power: -20 dBm
- Markers:
  — low band Mkr1 – 440 MHz, Mkr2 – 430 MHz, Mkr3 – 450 MHz;
  — high band Mkr1 – 460 MHz, Mkr2 – 450 MHz, Mkr3 – 470 MHz.

*Note:* *A good idea is to store the instrument state for the two settings, low band and high band.*

### 3.3.2.2. Service Monitor (Rohde & Schwarz CMS50)

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

- SET RF: 432000000 Hz (Low band) / 450000000 Hz (High Band);
- RF LEV: 5 µV (see also note below);
- SINAD;
- AF1: 2kHz;
- MOD1: 3.5 kHz;
- SCOPE MODE;
- BEST RANGE.

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

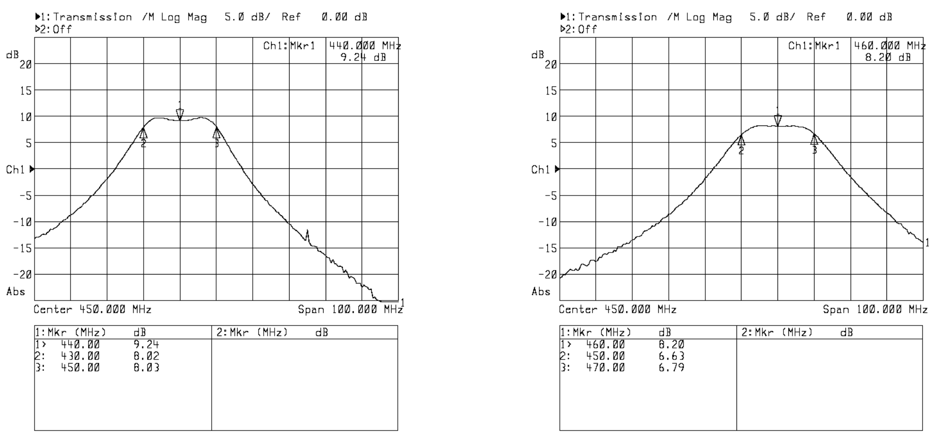
- COUNT: (should show the transmitter carrier frequency);
- POWER: (should show the transmitter carrier power).

Note: *If using the Testing Fixture, a calibration should be performed to check the losses in the antenna switch, cables, etc. Depending on these losses (which at 450 MHz can amount up to 6 dB), it may be needed to adjust the RF LEV value accordingly (up to 10 µV). Similarly, the measured output power must be correspondingly downgraded (see also “Checking the Transmitter Parameters” on page 18).*

### *3.3.3. Adjusting the Receiver Front End*

- Mount the DUT on the testing fixture and connect it to the PC via the serial cable;
- Select the appropriate instrument profile depending on the device’s band (High or Low);
- Turn on the receive subsystem of the DUT by entering the **RX** command at the terminal;
- Check that the switch on the Testing Fixture is in the **Wobble** position;
- Adjust the filter FL3 until you obtain a curve similar with one of those shown in *Figure 4.* (depending on the band); this is done by successively adjusting the two trimming screws located on the filter.

If this is not possible, check the power supply, the cable connections to/from the test equipment, etc. In addition, verify if you have approx. 1.1 volts on the test point TP4. Finally, check if all 8 pins of the filter FL3 are properly soldered.




Low Band High Band

**Figure 4.** Helical filter’s diagrams for Low Band and High Band devices.

### 3.3.4. Adjusting the VCOs

- Flip the switch on the Testing Fixture to the **Power/Sens.** position;
- Be sure that the DUT is in receive mode (enter the **RX** command at the terminal program);
- Adjust the coil L10 until the voltage shown on the digital voltmeter is 700 mV, ±50 mV (see also the note below);
- Switch the unit in transmit mode, by entering **XMIT** at the terminal;
- Adjust now the coil L6 until the voltage shown on the voltmeter is again 700 mV, ±50 mV;
- Press the enter key at the terminal to switch the unit off.

*Note:* *If using the Testing Fixture, a calibration may be needed, due to 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 TP1 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 attained, or the readout is very unstable, check the following:

- If the programmed operating frequency is 432 (Low Band) and 450 MHz (High band) respectively. To check this, type at the terminal prompt the command **FREQ**, the device will answer returning this parameter;
- If the respective commands (**RX** and **XMIT**) were issued;
- If some parts are not missing, have the incorrect value, or badly soldered (check the parts around Q2 and Q6).

### 3.3.5. Checking the Receiver Parameters

- Check that the switch on the Testing Fixture is flipped to the **Power/Sens.** position;
- Switch the DUT to receive mode by typing at the terminal the command **RX**;
- Switch the Service Monitor to RX TEST mode, on the appropriate frequency (432 MHz for low band and 450 MHz for high band); the level should be 5 µV (see also “Test Equipment Settings” on page 15);
- The S/N ratio should be at least 10 dB; in addition, if a ‘scope is also connected a clear 2 kHz sine wave should be visible, with a relatively low amount of noise superimposed;
- Switch the DUT in pulsed mode (press the enter key);
- After several seconds, you will see the image on the ‘scope pulsing at about one second intervals;
- Switch the RF generator output off;

- Check if the RSSI threshold is correct: type the command **RSSI** – the actual value must be lower than the threshold set. If this is not the case, repeat several time the **RSSI** command, maybe a transmission just happens (a radio scanner set on the operating frequency would help detect foreign transmissions). If the threshold difference is marginal, then you must increase it by using the **SET RSSI** command (it must be 20 to 30% higher than the actual value).

If the any of the above targets is not reachable, check first visually if the chip U10 is correctly soldered and that no shorts exist between its pins (most problems usually appear around this chip). If the S/N ratio test is positive but the last check is not, then check U8 and the components around it.

### 3.3.6. *Checking the Transmitter Parameters*

- Check that the switch on the Testing Fixture is flipped to the **Power/Sens.** position;
- Switch the DUT to transmit mode by typing at the terminal the command **XMIT 0**;
- Switch the Service Monitor to TX TEST mode, on the appropriate frequency (432 MHz for low band and 450 MHz for high band);
- You should see the following parameters on the Service Monitor readout:
  1. Carrier: 432000000, respectively 450000000 Hz (± 500 Hz);
  2. Output Power: 9 dBm (+1dBm, -2dBm);
  3. Frequency Deviation: ±2.3 kHz (±0.2 kHz) for 12.5 kHz units and ±4.0 kHz (±0.5 kHz) for 25 kHz units;
- Switch the unit in stand-by (press the enter key).

If item 1 above cannot be achieved, replace R36 with a 12 KΩ resistor to shift the frequency up, or R35 with a 10 kΩ resistor to shift the frequency down. If item 2 cannot be achieved, check the solder and components around Q1 and Q3; in addition, check if D1 and D2 are the right components (sometimes they are replaced by other visually similar parts). Finally, if item 3 cannot be achieved, replace R17 with a lower resistor to reduce the deviation, or a higher one to increase it. Note that depending on the device type, R17 can be either 470 Ω (12.5 kHz) or 1 kΩ (25 kHz). If no modulation is present at all, then check U1 and the parts around it.

### 3.3.7. *Data Transfer Check*

The last check is a radio data transfer. In order to perform it, at least a base station (model A730SD) or a normal remote station (model A730MD) should be installed and operated on the same test frequency (either 432 or 450 MHz), 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).*

The test is performed by entering at the terminal prompt the command **B**: the base and/or remote station must answer with the RF in and out values. If no answer is received after several seconds, then retry the command. If still no answer is received, then check with a scope on TP2 if the digital data is present (on receive); if not available, check U8:C and the parts around it. In addition, a radio receiver tuned on the operating frequency can also supply a rough indication whether the receiver or the transmitter are defective.

## 3.4. Additional Issues Related to Type Approval Testing

This chapter is intended for the bodies (laboratories) performing the tests required to obtain a Test Report.

### 3.4.1. Controlling the Unit

The unit under test can be controlled by means of the special serial cable supplied by Adcon Telemetry connected to a PC (e.g. a laptop) on one side and the **POWER** connector of the unit on the other side. In order to switch the unit in various modes of operations, a simple communications terminal program will suffice (e.g. Terminal or Hyperterminal in Windows, or Kermit under other platforms). The most important commands used are **XMIT**, **RX** and **SET FREQ**. For a list of all supported commands and the parameters they expect, see also "Supported Commands" on page 39. For additional details on how to configure your terminal program, see "Setting-up the Default Parameters" on page 13.

### 3.4.2. External Power Supply

In order to test the unit over the specified supply range, a special power cable is supplied by Adcon Telemetry. This cable must be connected to the **POWER** connector of the unit *before* the serial cable. The two wires with banana plugs can then be connected to an external variable power supply: the red plug to plus and the black one to minus. However, before doing this, the internal battery must be disconnected. Here is how:

- Open the lid by unscrewing the four screws in the corners of the addIT box;
- Gently remove the lid (the battery is fixed on the lid and is connected to the electronics board by means of two wires);
- Remove the battery's plug from the PCB connector;
- Mount the lid back, taking care that the rubber gasket sealing the box is not out of its place;
- Screw the four screws back, applying a moderate force.

*Note:* *If the rubber gasket is not properly mounted, the unit loses its IP65 environmental protection. In addition, certain radiated limits cannot be guaranteed.*

**WARNING!** Do not apply more than 10 Volts to the unit: permanent damage of the device may result. Note also, that the internal microcontroller will switch off the unit when the battery voltage drops below 5.5 Volts, and under 5.9 Volts the RF operations may be stopped.

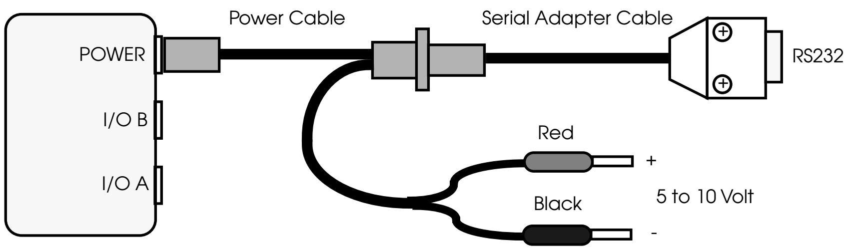



**Figure 5.** Connection of an external power supply.

## 3.4.3. *Specifications*

The A720 was intended to fulfill the specification of the ETSI 300 220, Class I, Subclasses a and b, but other national norms are similar to this (e.g. the CFR 47, Part 90, Subpart J). Following are the main operational parameters of the A720:

| Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|
| Common | | | | |
| Supply | 5.0 | 6.2 | 10.0 | V |
| Operating Temperature | -30 | | +70 | °C |
| Relative Humidity | 10 | | 99 | % |
| Class Protection | | IP65 | | |
| Data Rate (Using the On-board Software Modem) | 1000 | 150[a] | 2000 | bps |
| Operating Frequency (Low Band version)[b] | 432 | | 450 | MHz |
| Operating Frequency (High Band version)[b] | 450 | | 470 | MHz |
| Frequency Stability (-20 to + 60 °C) | | | ±1.5 | kHz |
| Frequency Stability (-30 to + 70 °C) | | | ±2.5 | kHz |
| Receiver | | | | |
| Sensitivity (10 db S/N) | | -93 | | dBm |
| Image Frequency Attenuation (1st IF = 45 MHz) | 70 | | | dB |

| Parameter | Min | Typ | Max | Unit |
|---|---|---|---|---|
| Local Oscillator Leakage | | | 2 | nW |
| Adjacent Channel Attenuation (both versions) | 70 | | | dB |
| RSSI dynamic | 90 | | | dB |
| Operating Current (incl. On-board Microcontroller) | | | 15 | mA |
| Transmitter (all measurements made on a 50 Ω resistive load) | | | | |
| Output Power | 7 | 9 | 10 | dBm |
| Spurious Radiation (0 to 862 MHz) | | | 2 | nW |
| Spurious Radiation (862 MHz to 3.5 GHz) | | | 200 | nW |
| Adjacent Channel Power (12.5 kHz version) | | | -32 | dBm |
| Adjacent Channel Power (25 kHz version) | | | -44 | dBm |
| Occupied Bandwidth (12.5 kHz version) | | | 8.5 | kHz |
| Occupied Bandwidth (25 kHz version) | | | 15 | kHz |
| Operating Current (incl. On-board Microcontroller) | | | 50 | mA |

a. Data rate is content dependent.
b. This parameter represents the tunning range; the switching range can be software limited to a narrower space (even to the extent of a single channel).

Several graphs obtained by means of a Rohde & Schwarz Spectrum Analyzer (model FSEA) are attached, reflecting some of the measured parameters.

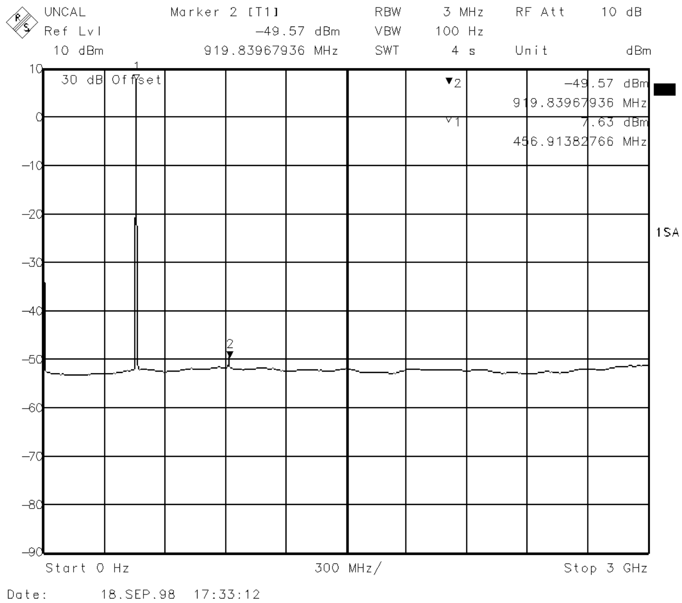



**Figure 6.** Spurious radiations (Marker 2); except the second harmonic, no other overtones are visible.

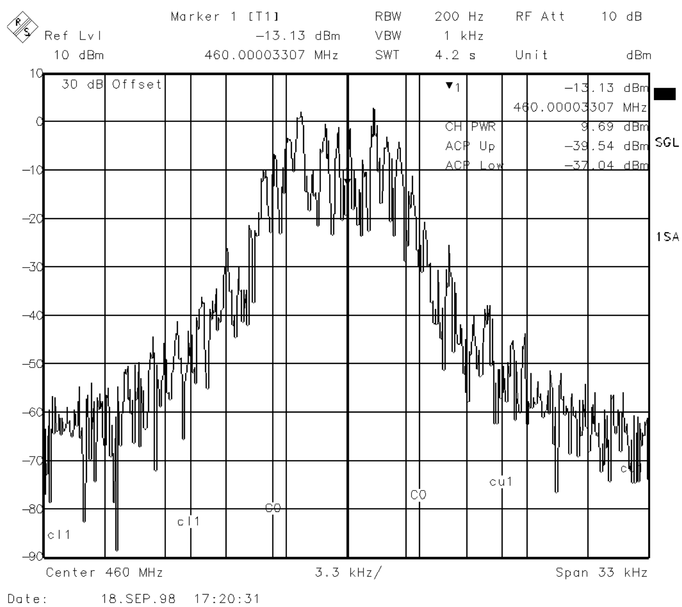



**Figure 7.** Adjacent Channel Power, 460 MHz, 12.5 kHz version, modulated with a `0x55` tone (1500 bps).

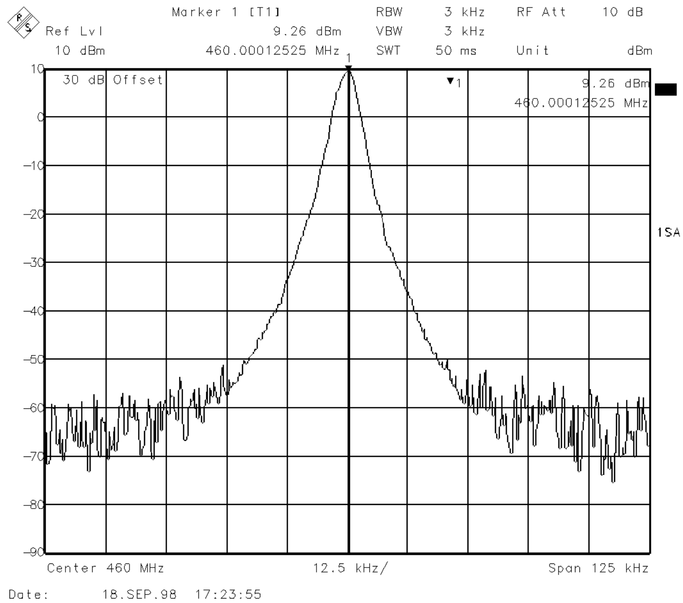



**Figure 8.** Spectral purity: an unmodulated carrier at 460 MHz is shown.

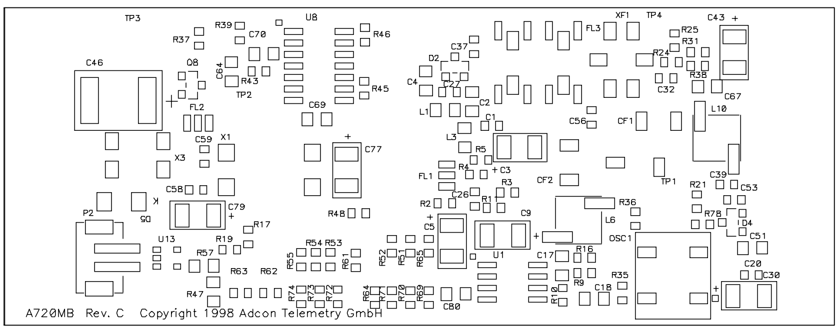



**Figure 9.** The TOP side of the printed circuit board.

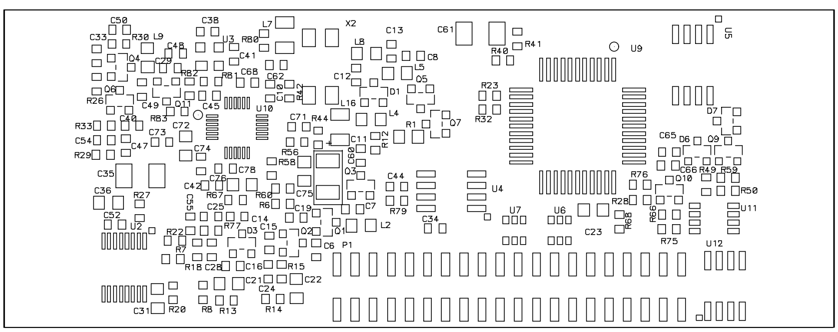


**Figure 10.** The BOTTOM side of the printed circuit board.

| SPECIFICATION OF VCTCXO TTS05V | 13-11463 |
|---|---|

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

2. ELECTRICAL SPECIFICATION

| | | |
|---|---|---|
| 2. 1 | Nominal Frequency | 12.600000MHz |
| 2. 2 | Supply Voltage | DC+3.0V±10% |
| 2. 3 | Input Current | 1.8mA max. |
| 2. 4 | Output Voltage | 0.8Vp-p min. / Clipped Sinewave |
| 2. 5 | Load | (10kΩ//10pF)±10% |
| 2. 6 | Operating Temperature Range | −30℃ ~ +70℃ |
| 2. 7 | Storage Temperature Range | −35℃ ~ +85℃ |
| 2. 8 | Frequency Stability | |
| | Frequency - Temperature at 25±2℃ | $\pm 5.0\times10^{-6}$ max. −30℃~+70℃<br>Not include initial tolerance. |
| | Frequency - Voltage Coefficient | $\pm 0.4\times10^{-6}$ max. DC+3.0V±10% |
| | Frequency - Load Coefficient | $\pm 0.2\times10^{-6}$ max. (10kΩ//10pF)±10% |
| | Frequency - Aging | $\pm 1.0\times10^{-6}$ max. / year |
| | Frequency - After reflow soldering | $\pm 1.0\times10^{-6}$ max. at 25±2℃, 3 times<br>as per attached 13-00223. |
| 2. 9 | Initial Frequency Tolerance | $\pm 3.0\times10^{-6}$ max. at 25±2℃, Vc=+1.5V |
| 2.10 | Voltage Controll Charac. | $\pm 9.0\sim\pm 15.0\times10^{-6}$ / V |
| | Tuning Range | 1.5V±1.35V |

3. OUTLINE DRAWING AND PIN CONNECTIONS — Drawing Number 13-30821A

| | |
|---|---|
| Mar.11,1998 Designer : T. Suzuki | TOKYO DENPA CO., LTD. |

**Figure 11.** The VCTCXO Specification. This part is used as frequency reference for the PLL synthesizer.

### *3.4.5. Device Photographs*


**Figure 12.** General view.


**Figure 13.** Front view.

**Figure 14.** Bottom view.

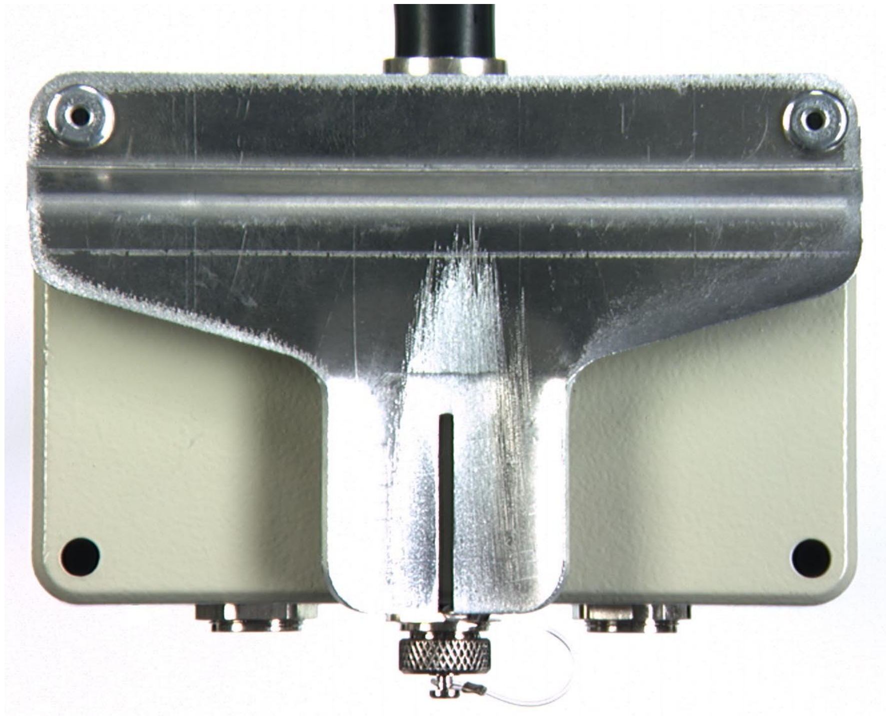


**Figure 15.** Back view.

**Figure 16.** Top view.

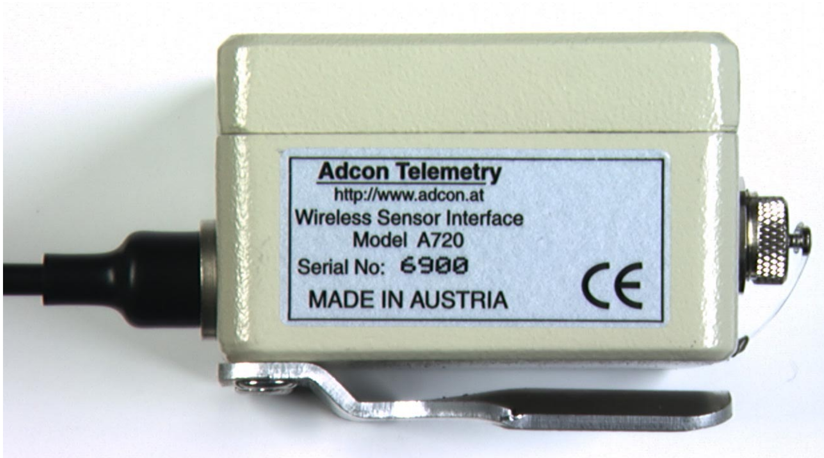



**Figure 17.** Left view.

**Figure 18.** Right view.

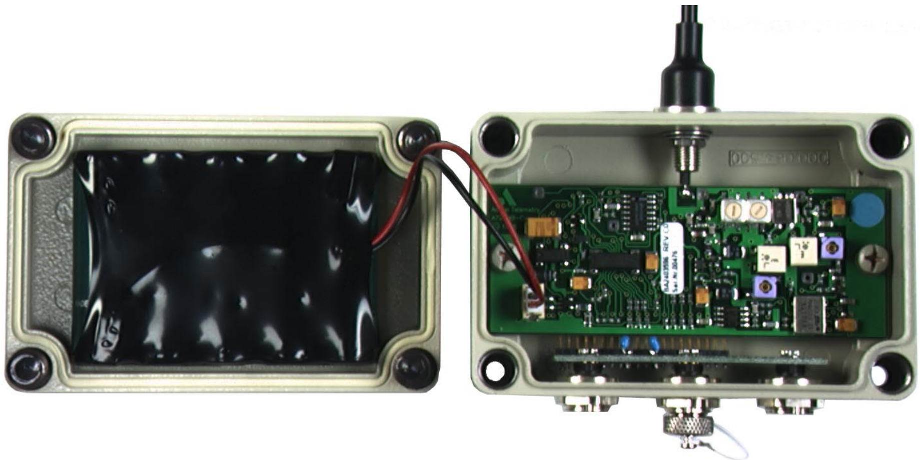
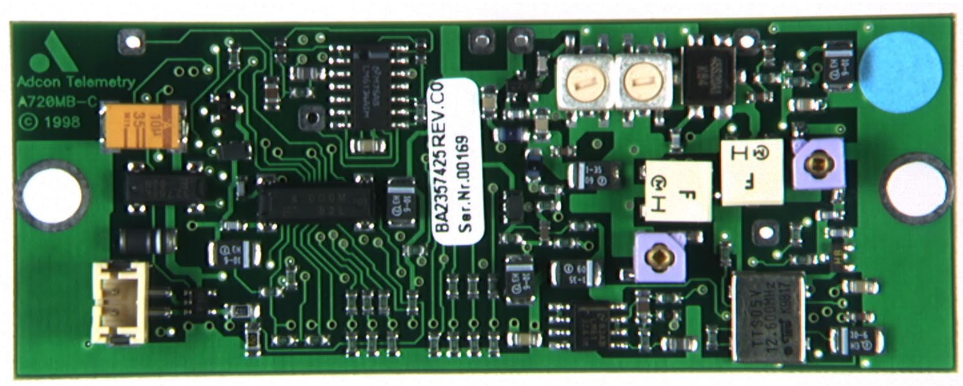
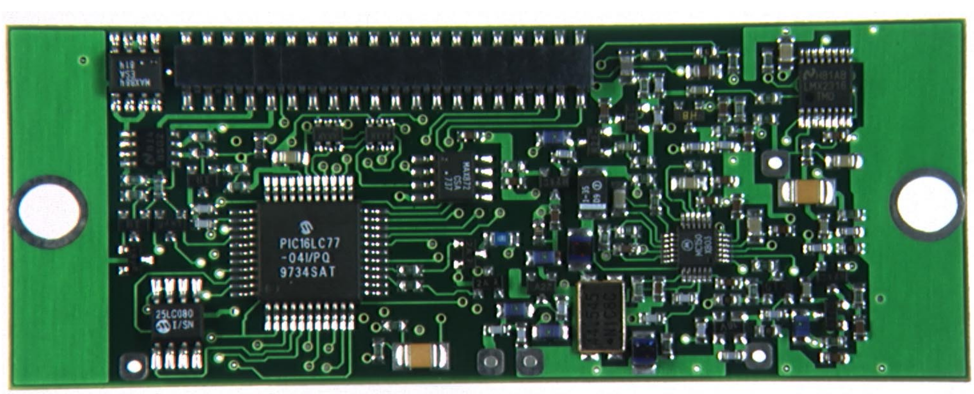


**Figure 19.** The A720 Opened.




TOP




BOTTOM

**Figure 20.** The PCB.

# 4. Software

The software is written entirely in C. It consists of a collection of standard C library functions, a minimalistic operating system (AMOS – Adcon Minimal Operating System) 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.

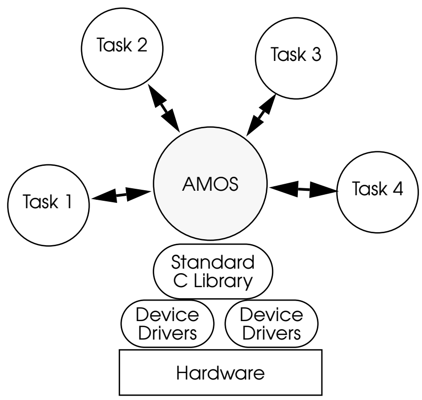



**Figure 21.** General structure of the A720 software.

## 4.1. AMOS

Most of its time, the system is in sleep mode. Each 0.5 seconds, an interrupt is generated by the local 32.76 Khz crystal based real time clock (RTC). AMOS will check what tasks need attention (i.e. must be executed) and pass them the control accordingly. After all the tasks have finished their jobs, AMOS brings the system back to sleep. The 0.5 seconds interrupt routine is used to increment the RTC.

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

One of the main concerns of the software design is the power consumption of the device. The software must assure 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.

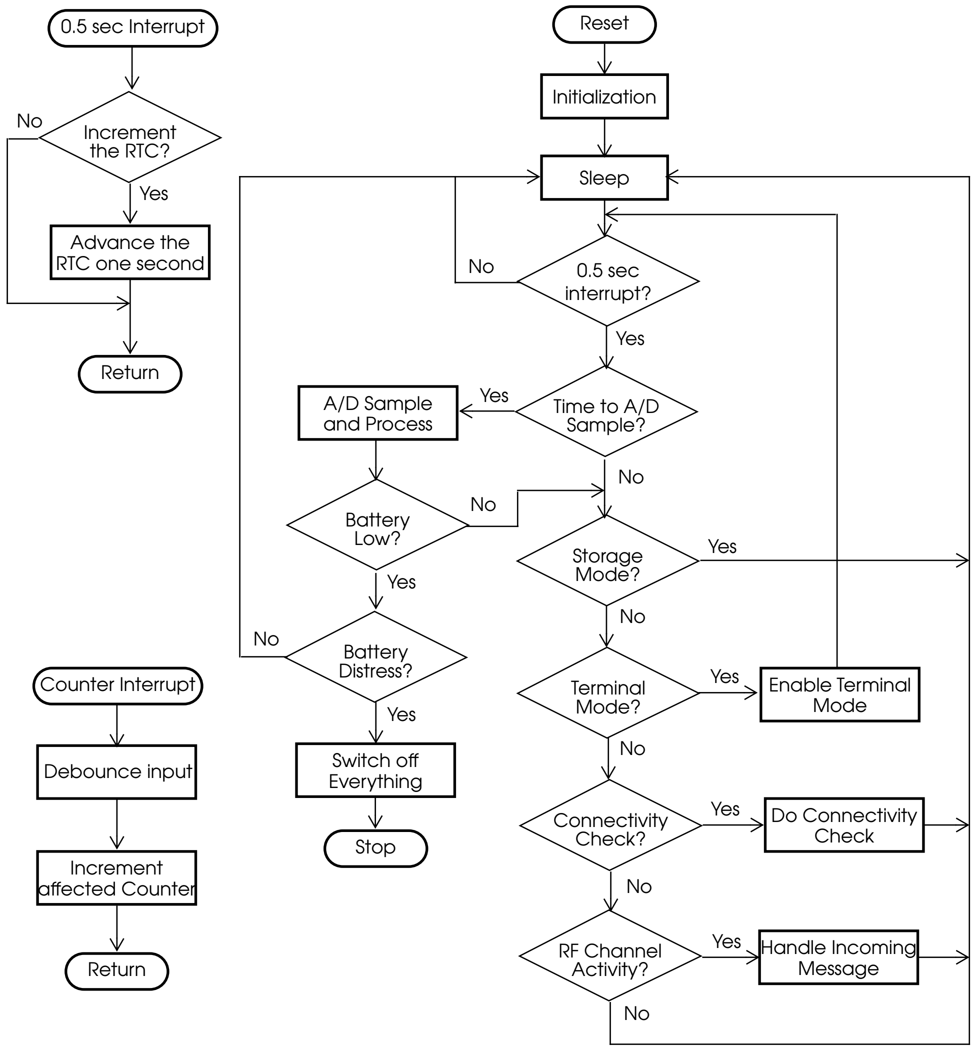



**Figure 22.** General flow chart of the AMOS.

### *4.1.1. Initialization*

This section initializes the peripherals needing an one time configuration, like:

- Microcontroller option registers;
- The RTC timer (Timer 1), in order to generate the 0.5 sec RTC interrupts;
- Various peripherals (SCI, Timers, A/D Converter, parallel ports).

### 4.1.2. 1/2 Second Interrupt

The interrupt handler will only increment the RTC, when needed (every other interrupt); no other tasks are performed on this interrupt level. The interrupt is generated by **TIMER1** of the microcontroller.

### 4.1.3. Pulse Counters Interrupt

Interrupts are generated by two pins on the **PORTB**, having the *Interrupt on Change* feature. The interrupt handler must store the previous state of the port, to act only on a certain level (user programmable, by default is zero). Additionally, a debouncing mechanism is implemented, allowing for different types of pulses to be counted. By default, the filter is set at 1 ms (user configurable).

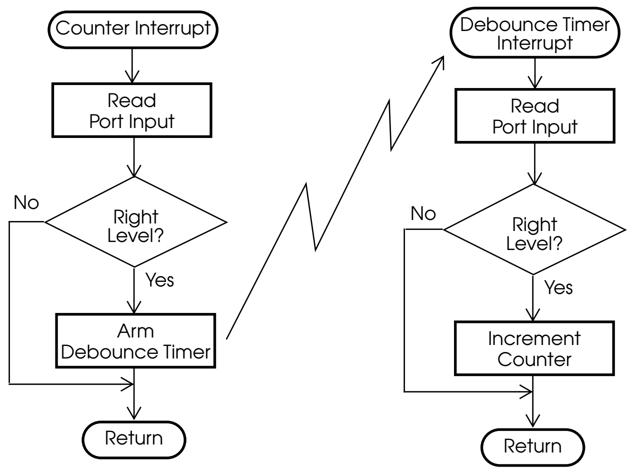



**Figure 23.** Flow chart of the Pulse Counters Interrupt handlers.

*Note:* *The commands to configure the level and filter values must be documented; they are not yet implemented in the current version.*

## 4.2. Mode Check

The system has the ability to check two input ports to switch itself in one of four operating modes:

- **Storage mode**: in this mode, the unit is in a stand-by state, possibly stored in a warehouse. The power supply is reduced to a minimum, by switching off almost all the functions of the device: the radio interface, the A/D sampling and storage (only the battery will be monitored), and the pulse counter interrupts will be disabled. To further reduce the power consumption, the 0.5 second interrupt is switched to 2 second. However, the software accounts for this change and the internal RTC will be correctly maintained.

- **Terminal mode**: the device notices that a serial cable is connected to its **POWER** connector, and is ready to accept commands. In this mode, all the subsystems are enabled (A/D, pulse counters, radio interface, etc.), and the complete functionality of the device is available.
- **Connectivity check mode**: in this mode, a special tool is plugged in the **POWER** connector, in order for a user to check if the device is able to contact other devices (normally an A730MD or an A730SD). The tool has a LED that will be pulsed in several modes, depending on the results of the connectivity check operation. After the operation is finished, the device will enter automatically the normal operating mode (see next paragraph).
- **Normal operating mode**: this is the mode where the device polls every 0.5 seconds the RF channel and waits for requests from a master (an A730MD or an A730SD). In addition, it samples the analog and digital inputs every 5 minutes and stores the averaged values in the EEPROM FIFO every 15 minutes. The pulse counters are operated normally.

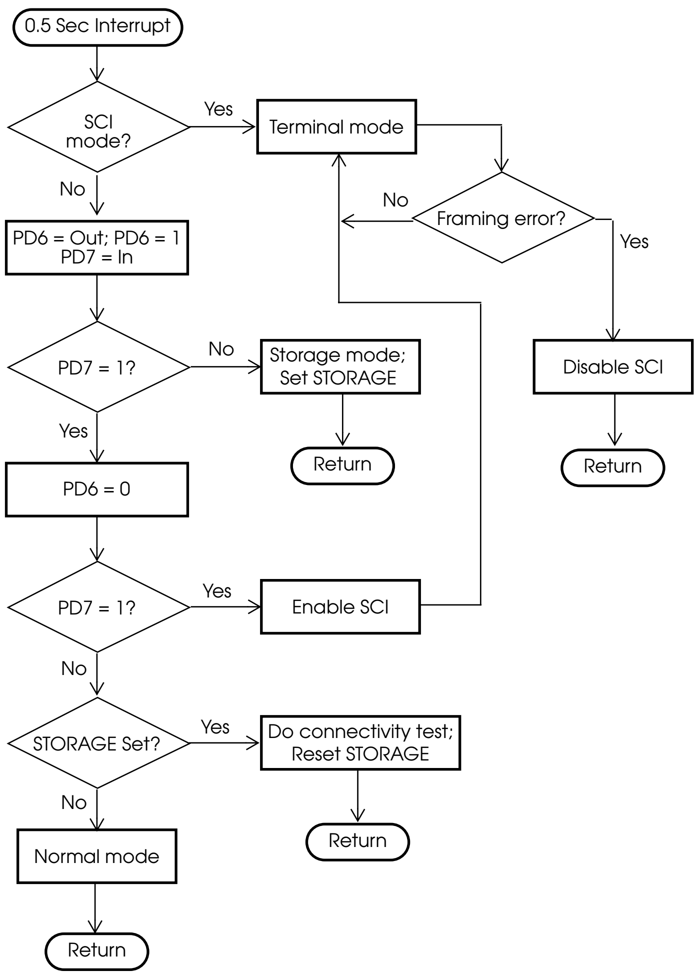



**Figure 24.** Flow chart of the Mode Check procedure.

More details on the functionality of each mode will be described when dealing with the individual tasks.

## 4.3. A/D Task

This task is responsible for the actual sampling of the A/D inputs (where the sensors are connected). In addition, the task is responsible for the power management of the system: it checks the battery level and performs the following actions:

- Switches on and off the solar panel (that charges the battery), depending on the battery state and internal temperature of the device;
- Brings the system in a low consumption mode if the battery is low;
- Switches the system off if the battery is in a misery state, in order to protect it.

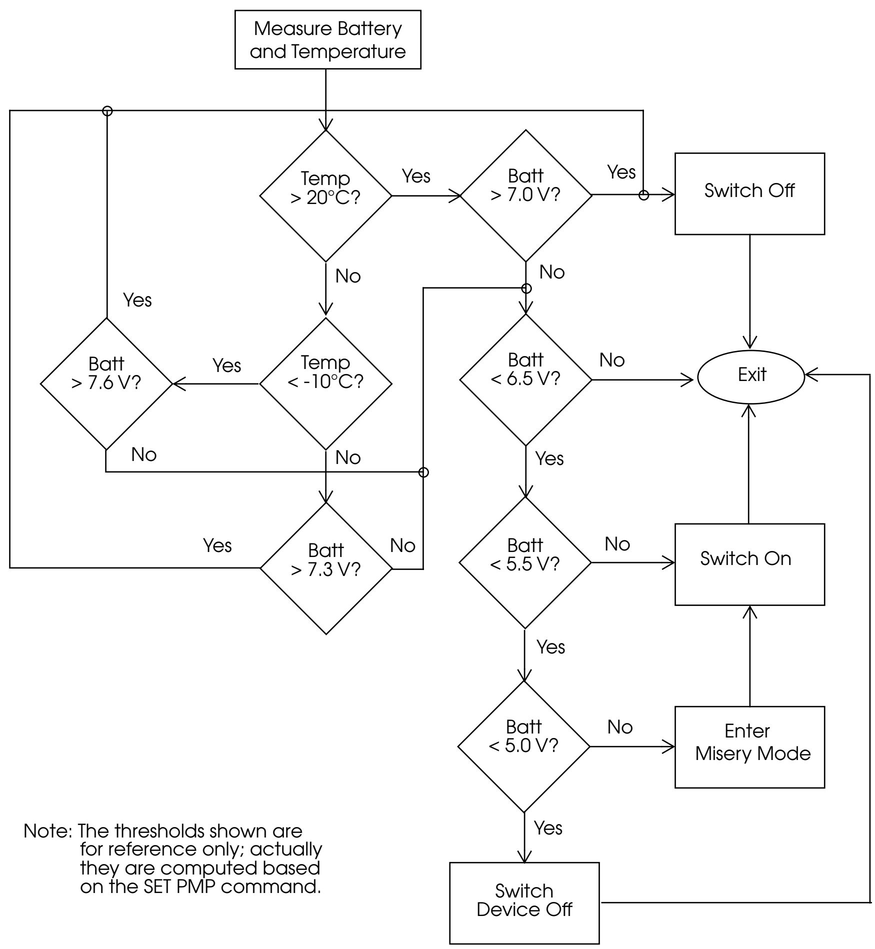



**Figure 25.** Power Management flow chart.

The A/D task is not executed at each 0.5 seconds interval, but rather every 5 minutes (default). This parameter can be user configured (it is stored in the EEPROM section). After the sensors inputs are sampled their values are averaged and stored as a slot in the EEPROM FIFO buffer, time stamped. The number of samples is by default 3, but is user configurable (this parameter is stored in the EEPROM section). These parameters are defined and can be changed by the **SET SLOT** command (see also "Supported Commands" on page 39).

A special method of averaging is used in order to deal with various sorts of sampled values (e.g. wind direction). In addition, the pulse counters are stored in the EEPROM with the slot and cleared afterwards.

## 4.4. The Terminal Task

The terminal offers a minimum of commands needed to configure and administer the device, like setting and reading parameters (time, frequency, sampling rate, etc.), checking the radio subsystem (switch it in various modes – receive, transmit, etc.). The device enters in terminal mode whenever the mode checking routine senses that a serial cable is inserted in the **POWER** connector. Periodically, it checks for that condition, in order to automatically exit this mode (see also "Mode Check" on page 36). In the inset are depicted the connection pins on the **POWER** connector, where the serial cable is plugged.

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

### 4.4.1. Supported Commands

Following is a list of available commands and an explanation of their use (the commands are listed in upper case, but you can use lower case too, the device is not case sensitive).

#### 4.4.1.1. The SET Series of Commands

- **SET OWNID nnnn** – where *nnnn* is the Id number of the unit. The Id number must be identical to the one written on the unit's label.
- **SET PMP bl bh** – set the power management parameters. *bl* is the lower battery level (the threshold where the charging of the battery will be switched on) and *bh* is the higher battery level (the charging will be switched off). Both *bl* and *bh* are expressed in volts x 10 (e.g. 72 means actually 7.2 V). Default values (factory programmed) are 65 and 72, meaning 6.5 and 7.2 volts respectively. Example:
  — if you want to change the switch on threshold to 6.3 and the switch off threshold to 7.0 volts, issue the command **SET PMP 63 70**.
- **SET SLOT storage samples** – configures the input sampling and storing intervals: *storage* represents the time (in seconds) elapsed between two slots stored in the internal memory, while *samples* represents the numbers of samples used

to build the average that will be stored. The default *storage* is 900 (15 minutes) and *samples* is 3 (3 samples per quarter of an hour). Example:
— if you want to sample the inputs (sensors) every minute and build an hourly average, issue the command **SET SLOT 3600 60**.
— if you want to sample the inputs once per hour and store the values as they are, then the command **SET SLOT 3600 1** will do the job.

In order to better understand the importance the *samples* parameter has, a table is provided showing addIT's expected operation time on a fully charged battery and a 50 mA total consumption for the sensors:

| Radio activity | Sensor sampling (samples/15 min) | Average consumption (µA) | Estimated operation (days) |
|---|---|---|---|
| No | No sensors | 450 | 92 |
| Yes | No sensors | 540 | 77 |
| Yes | 1 | 750 | 55 |
| **Yes** | **3 (default)** | **1080** | **38** |
| Yes | 5 | 1450 | 28 |
| Yes | 15 | 3100 | 13 |

*Note:* *Radio activity refers to the fact that one base station and between one and three A730MD stations/addITs are active on the same operating frequency as the addIT under test.*

- **SET BL ll ul** – sets band limits; *ll* is the minimum allowable frequency, while *ul* is the maximum allowable frequency. This command effectively limits the user's possibility to change the device's operating frequency and it can be used to fulfill specific requirements existing in certain countries. Example:
  — if the law in a country limits the operation of the device between 433.150 and 434.750 MHz, then the command is **SET BL 433150000 434750000**.
  — if the users are not allowed to change the frequency at all, then use the same frequency for both *ll* and *ul*: **SET BL 433925000 433925000**.

*Note:* *The SET BL command is not documented in the user manual.*

- **SET FREQ freq step** – sets the unit's operating frequency; *freq* is the frequency and *step* is the channel spacing (both expressed in Herz). Example:
  — suppose you want to change the frequency of an addIT to 467.1125 MHz with a channel spacing of 12.5 kHz. After converting all the values to Hz, the command to be used is **SET FREQ 467112500 12500**.

*Note:* *The SET FREQ command may return an error if trying to program a frequency outside the band limits; see SET BL command.*

- **SET RSSI value** – set the Relative Signal Strength Indicator threshold. The factory default is set to 58 units. The RSSI threshold is used to detect if there is any radio activity on the channel. The value set must be approximately 30% higher than the actual measured value when no signal is present on the channel. To measure the actual value use the command RSSI (explained later in this chapter). Example:
  — to set the RSSI threshold to 55, use the command **SET RSSI 55**.

*Note:* *The values of RSSI have no units, they are arbitrary; however, a value of 85 corresponds more or less to the maximum value in addVANTAGE, i.e. 8 µV.*

#### *4.4.1.2. Querying the Actual Configuration Parameters*

You can query an addIT to find out its actual configuration parameters. Typing **OWNID**, for instance will return the actual ID an addIT answers to (it should be the same as the one on its label). In addition to **OWNID**, **PMP**, **SLOT**, **BL**, **FREQ** and **RSSI**, the command **VER** will return the current software version of the device.

The **RSSI** commands returns two values: the actual measured value of the RSSI and the value set as threshold. As noted elsewhere, the threshold must be approximately 30% higher than the actual measured value. The actual RSSI is unstable due to the channel's random noise, receiver's internal noise, and/or to transmissions just taking place. If the actual RSSI value is consistently higher than the programmed value, something must be wrong, or the channel is very noisy (however, before re-adjusting the RSSI threshold, check this with a handheld radio receiver or a scanner).

Other commands available in terminal mode are:

- **DUMP addr** – displays 256 bytes of the internal EEPROM memory, starting with the address *addr* (specified as hex values). Valid addresses for the model A720 are B600 to B9FF. The last 16 slots of data (for 15 minutes slots, that makes 4 hours of data) are stored at B900 to B9FF. The remainder are used for internal configuration parameters or reserved for future use.
- **RX** – switches the device to receive mode until a key is pressed. This command is used for trimming or checking purposes.
- **XMIT param** – switches the device to transmit mode until a key is pressed; *param* may be 0 – a 2 kHz tone will be modulated on the transmitted carrier, 1 – a 1 kHz tone will be modulated on the transmitted carrier, T – a mixture of 1 and 2 kHz test tones, or missing – an unmodulated carrier will be transmitted. This command is used for trimming or checking purposes.
- **B** – sends a broadcast frame and displays all the answers, with the RF levels recorded for each received station.

## *4.5. The Radio Interface Task*

The A720 is intended only as an end device in a radio network. Following frames are recognized and serviced by an A720:

- **PING** – used to check if a device is alive; returns a **PONG** frame;
- **REQUEST** – returns a reduced data frame (**DATA**);
- **RSETIO** – switches the digital outputs and returns the digital inputs value;
- **RDUMP** – returns a dump of a block of memory;

- **RSET** – sets remotely certain parameters (id, frequency, slot, power management parameters).

Note: *RSETIO frame is provided only for backwards compatibility with the A730MD. Better ways to control the ports will be implemented at a later date.*

The device will not recognize a broadcast frame and will not answer to such frames. It will however send a broadcast and wait for answers in the *Connectivity Check Mode*, or if a *Broadcast* command is issued at the terminal. Even if the device is not intended to be used as a router, the current software version implements routing; due to power consumption reasons, this mode of operation is not recommended.

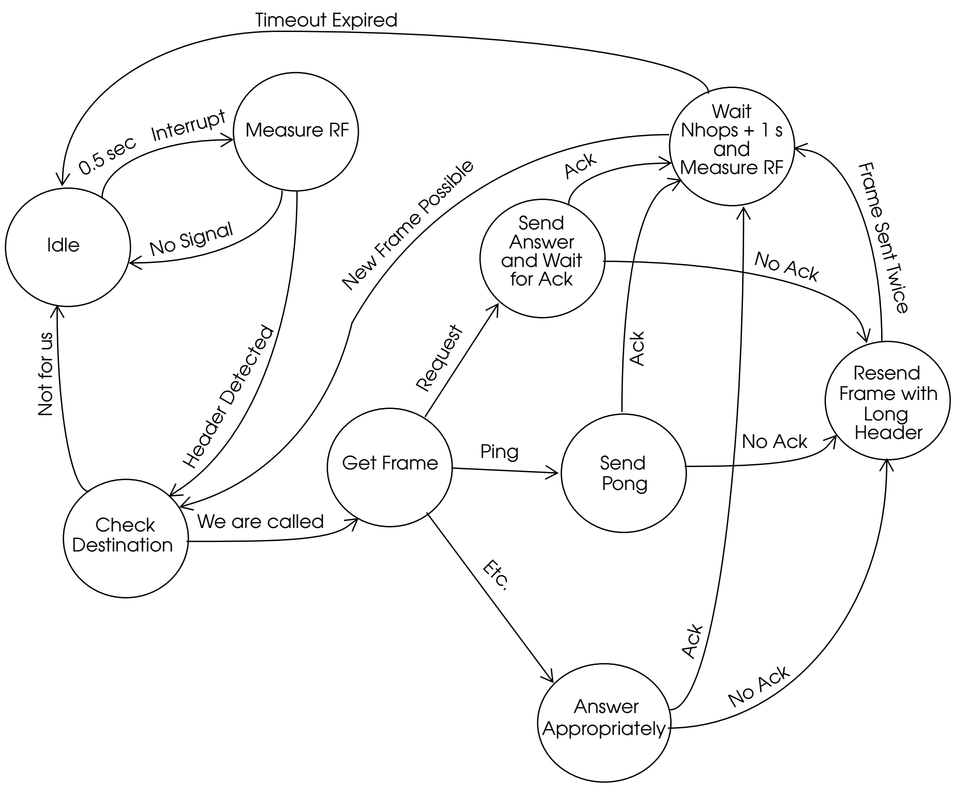



**Figure 26.** State Transition Diagram of the radio communication task.

### *4.5.1. 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 needs under 20 mS, typically (from wake-up to the result).

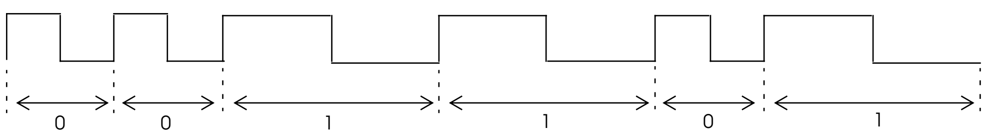
If however, a RF level superior to the preset threshold is detected, the microprocessor will try to detect a valid header, which is composed of a 2 kHz tone of at least 0.5 seconds long. The tone detection is performed by the microcontroller in software, and takes at most 6 additional milliseconds. If 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 situated very early in the frame header (see also "Generic Format of a Radio Frame" on page 44).

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.

## 4.5.2. 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* byte is transmitted as a sequence of 250 µS one level followed by a 250 µs zero level, while a *one* byte 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*.




The 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 zeroes). 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.

### 4.5.3. Generic Format of a Radio Frame

The standard frame format used by the A730 family (and therefore by the A720) is as follows:

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 00 | 00 | ....... | 00 | 0xAA | DST-H | DST-L | SRC-H | SRC-L | DLEN | DATA1 | DATA2 | ....... | DATAn | CRC-H | CRC-L |

← Data Frame →

- The frame starts with a header of zeroes; 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 assure 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 A720 and their answers are detailed in the next chapter.

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 send by the master for the first time, it will be a long header one; 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):

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

As long as another frame will follow in 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.

### 4.5.4. Data Frames

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

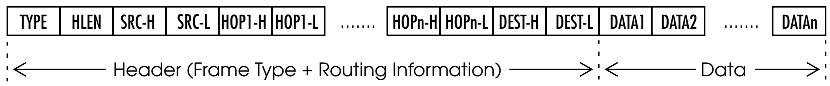



**Figure 27.** Generic Data Frame structure.

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 for the **TYPE**) from the original data frame length received from the lower layer of 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 A720 will be detailed individually later in this chapter.
- **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 inexistent (zero length).

### 4.5.5. Frame Types

Although the original Adcon Radio Protocol contains many frame types, only those relevant (recognized and /or used) to the A720 will be presented here.

#### 4.5.5.1. 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 two types of data frames: normal and reduced – the A720 answers with the reduced type – see also “Data” on page 49).

- `init_time` represents the actual type to be used by the remote to re-initialize its local RTC; if its value is `time_t NULL` (default), then no re-initalization will be performed;
- `req_time` is the time for requested data. A remote will search its internal data buffer for data which has a time stamp that is strictly newer than `req_time`. Therefore, if a master will request data with exactly the time stamp previously supplied by the remote, the later 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.

### *4.5.5.2. 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. An A720 will never send such frames, but will receive and interpret them depending on the mode it was when it issued the broadcast request frame (see also “Broadcast Request” on page 47). 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. This frame is not routable.

### *4.5.5.3. Set I/O Request*

ID 3

FORMAT

```
struct {
        unsigned char   DDR;
        unsigned char   PORT;
} setio_request;
```

DESCRIPTION This frame is issued by a master and instructs a remote device to switch its ports to a certain state, as follows:

- `DDR` specifies if a port will be set as input or as output; if the corresponding bit is a one, that port will be set as output;
- `PORT` is evaluated only for the bits set as outputs; it will set or reset the respective port according to its value in `PORT`.

The device will answer with the Read I/O frame.

### 4.5.5.4. *Read I/O Answer*

ID 4

FORMAT

```
struct {
        unsigned char   RF_levelIn;
        unsigned char   RF_levelOut;
        unsigned char   DDR;
        unsigned char   PORT;
} readio_answer;
```

DESCRIPTION This is the answer to a Set I/O request frame. It returns the actual state of the port and its data direction register.

### 4.5.5.5. *Broadcast Request*

ID 6

FORMAT The data frame body is empty.

DESCRIPTION This frame is send 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. In addition, this type of frame is not routable. All the devices having received this frame must reply in a random fashion with a Broadcast answer frame.

### 4.5.5.6. *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. The addressed device must answer with a Pong frame. The A720 does not send such frames, but must answer to them.

### 4.5.5.7. *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   reserved[4];
} pong;
```

DESCRIPTION

The Pong frame is an answer to the Ping frame. In addition to inform 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 A720 – they are kept due to historical reasons;
- `WDT` is a counter incremented each time the device was reset due to a Watchdog timeout;
- `batt` is the battery voltage (this value will be also found in the Data frame);
- `internalTemp` is the temperature in the A720 housing; the precision of the sensing element is very low (±4C°), but it is sufficient for battery power management (charge/discharge). To compute the actual value (in C°), the following equation must be used:

$$Temp = internalTemp \bullet \frac{1087}{255} - 275$$

- `uptime` is the time elapsed since the last reset (including a Watchdog reset);
- `reserved` – these bytes are reserved for future use.

*Note:* *Some of the values send in the Pong frame are specific to the A720 only.*

### 4.5.5.8. Memory Dump Request

ID 20

FORMAT

```
struct {
        unsigned int    startAddress;
        unsigned char   length;
} memoryDump_request;
```

DESCRIPTION

This frame requests a remote to return a number of `length` bytes, starting from its internal address `startAddress`. In general, the useful addresses are located at address `0xB600`. An A720 will not issue such frames, but answers to them using the Memory dump answer frame. The length parameter is limited to the amount of memory available, therefore if more bytes are requested than a device can cope with, the maximum possible will be sent (depending on the memory availability). However, an A720 will send always a fixed amount of bytes, that is 32.

### 4.5.5.9. Memory Dump Answer

ID 21

FORMAT

```
struct {
        unsigned int    startAddress;
        unsigned char   32;
        unsigned char   data[32];
} memoryDump_answer;
```

DESCRIPTION This is the answer to a Memory dump request frame; although the frame has a flexible format, an A720 will always return 32 bytes of data.

### 4.5.5.10. Data

ID 38

FORMAT

```
struct {
        unsigned char   RF_levelIn;
        unsigned char   RF_levelOut;
        time_t          slot_timeStamp;
        unsigned char   digibyte;
        unsigned char   counter1; /* Pulse Counter I/O B input */
        unsigned char   counter2; /* Pulse Counter I/O A input */
        unsigned char   battery;
        unsigned char   analog0; /* I/O B input, pin x */
        unsigned char   analog1; /* I/O B input, pin x */
        unsigned char   analog2; /* I/O B input, pin x */
        unsigned char   analog4; /* I/O A input, pin x */
        unsigned char   analog5; /* I/O A input, pin x */
        unsigned char   analog6; /* I/O A input, pin x */
        unsigned char   internalTemp; /* Internal Temperature */
} 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 |
|---|---|---|---|---|---|---|---|
| RD7 | RB7 | u | u | RB6 | RD2 | RD1 | RD0 |

— **RD7** represents the battery charge switch' status;
— **u** means undefined;
— **RD2**, **RD1** and **RD0** are the DIG2, DIG1 and DIG0 pins respectively.

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

- `counter1` and `counter2` are the values of the pulse counters;

- `analog0` to `analog2` and `analog4` to `analog6` are the values returned by the internal A/D converter from the respective connectors (see the hardware section for more details).
- `internalTemp` is the temperature in the A720 housing (it's the same value transmitted with a Pong frame – see "Pong" on page 47 for more details).

### *4.5.5.11. 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 A720 will never issue this frame type, but it will answer to it.

### *4.5.5.12. Set Slot Time and Sample Rate*

ID 41

FORMAT

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

DESCRIPTION This frame requests a remote to change the size of its slot (default 900 seconds, i.e. 15 minutes) and the sampling rate (default 3).

- `slot` is the number of seconds a new slot of sampled and averaged data will be stored in the internal memory FIFO 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 A720 will never issue this frame type, but it will answer to it.

### *4.5.5.13. Set Frequency*

ID 42

FORMAT

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

DESCRIPTION This frame requests a remote to 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 44). An A720 will never issue this frame type, but it will answer to it.

#### *4.5.5.14. Set Battery Charge Levels*

ID 43

FORMAT

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

DESCRIPTION This frame requests a remote to change the battery charge management parameters. The device will answer with a General acknowledge frame. An A720 will not issue such a frame, 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.).

#### *4.5.5.15. Set Pulse Counters Parameters*

ID 44

FORMAT

DESCRIPTION This frame will set the trigger level and the delay of the pulse counters of a remote. The device will answer with a General acknowledge frame. An A720 will not issue such a frame, but will answer to it.

*Note: The format and description of this frame must be detailed later; it is not yet implemented.*

#### *4.5.5.16. 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 on the cause of the failure. Its value will depend from the type of request requested.