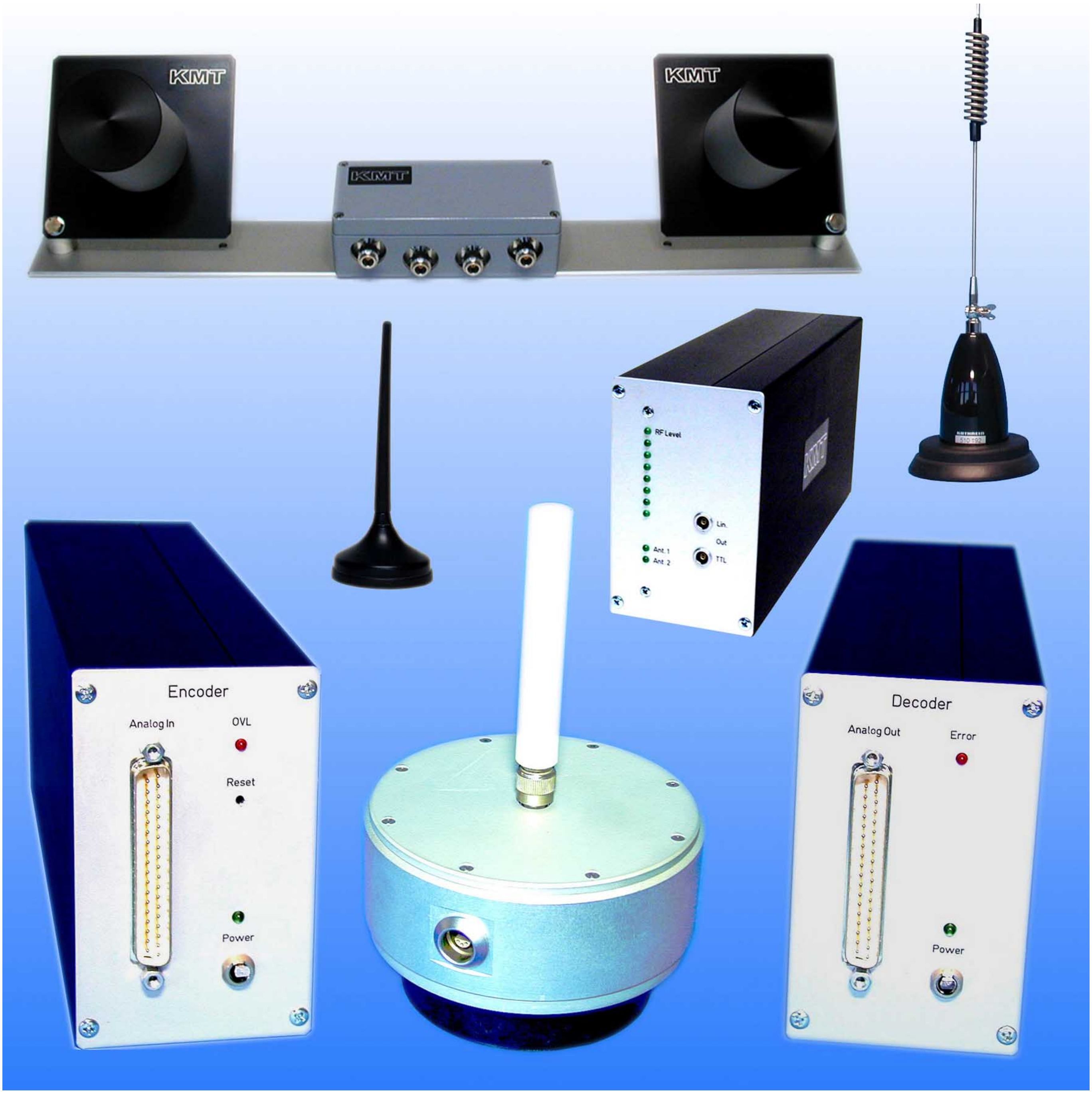
Kraus Messtechnik GmbH
Gewerbering 9, D-83624 Otterfing, ☎ +49-8024-48737, Fax. +49-8024-5532 – Germany
Web: www.kmt-gmbh.com E-mail: info@kmt-gmbh.com

TEL8-128
User manual



8 to 128 analog channels telemetry system

Table of Contents

1 Introduction 3

1.1 System description 3

1.2 How to arrange the telemetry system 5

1.3 Security and application notes 9

2 Installation 10

3 Components 12

3.1 Encoders and Decoders 12

3.2 Transmitters 14

3.3 Receivers and converter 15

3.4 Antennas 16

4 Periphery 17

4.1 PCM-Recorder 17

4.2 AC/DC Power supply 18

4.3 PC Link 19

4.4 Data Acquisition with µLab 20

4.5 Data Analysis with µGraph 21

5 Specifications 22

1 Introduction

1.1 System description

- **Highlights**

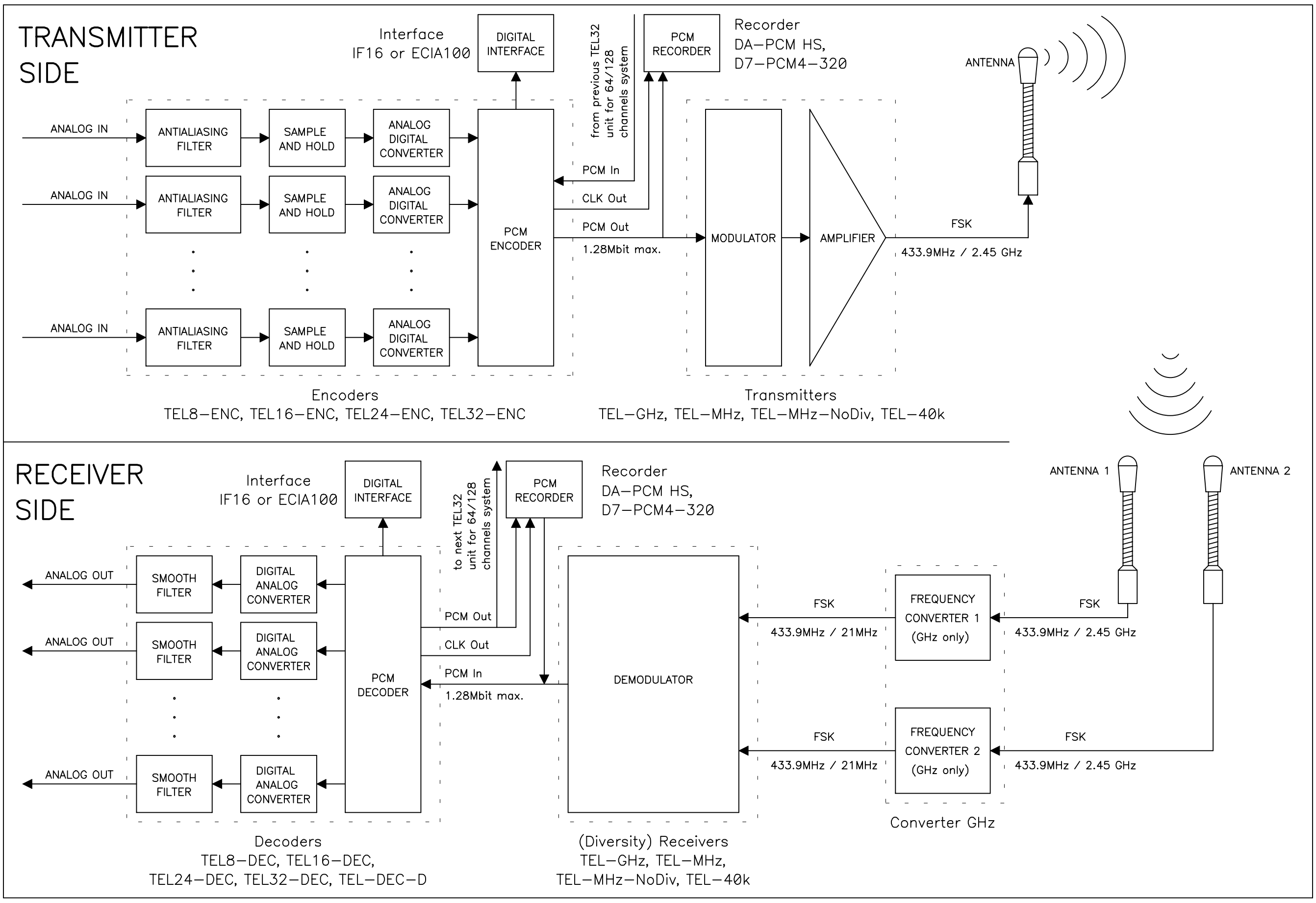
  The TEL8-128 is a powerful telemetry system, designed for wireless transmissions of 8 to 128 analog signals. One unit is equipped with 8, 16, 24 or 32 channels. By daisy-chaining of up to 4 units any telemetry system with a channel number between 8 and 128 in steps of 8 is configurable. The small system size, robust design and modular concept allow a wide range of applications for collecting data from mobile objects and inaccessible areas under harsh environment conditions, like shocks, vibrations, dust, etc. A variable transmitter power makes flexible transmission ranges possible.

  With the implemented diversity function, the best transmission safety also under worst-case environment conditions is guaranteed. The wide range digital phase-locked loop circuit (PLL) eliminates a phase jitter of the received signal of more than 20%. A field strength bar graph indicator and an error LED allow an optimization of the antenna positions.

  Due to the digital conversion and modulation a theoretical unrestricted transmission dynamic range will performed. In practice a 72dB limit is set by the 12 bit A/D conversion of the encoder.

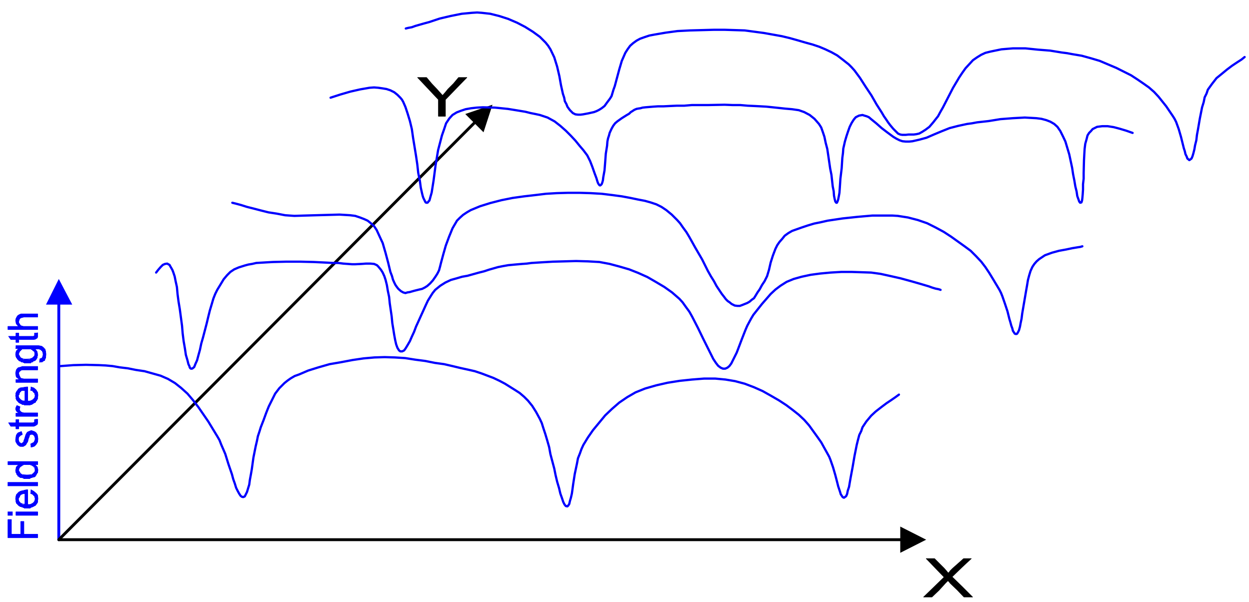
  The simultaneous sample and hold circuit enables accurate time correlations between all channels during evaluation and analysis. Implemented 8-pole Butterworth low pass filters avoid aliasing effects by automatically adaptation of the cut-off frequency to the current sample rate.

  A great number of periphery devices, like PCM data recorder, digital interfaces as well as comfortable acquisition and analysis software complete the system performance.

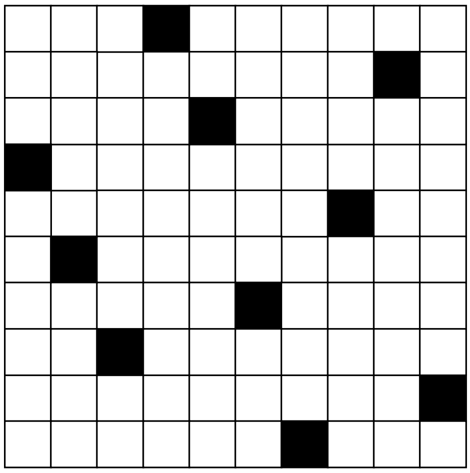


- **Measuring chain**
  The input signal voltages of ±5V (standard) or ±10V (optional) are routed via an 8-pole antialiasing filter to a sample and hold circuit for simultaneous acquisition of all channels. The analog values will converted into 12 digital bits, encoded in a PCM format and transferred to the HF transmitter. Here takes place a frequency shift keying modulation (FSK) with carrier frequencies of 433,9MHz or 2,45GHz. This electromagnetical wave will emitted via the antenna in the environment. Depending on the distance to the receiver, the transmitter power is variable from 10mW to 5W.
  The receiver unit demodulates the received HF signals into a digital PCM current, which is decoded, converted to an analog signal and output via a smooth filter as a voltage in the ±5V range. In the GHz range additional down-converters decrease the carrier frequency from 2.45GHz to 21MHz for reducing signal attenuations in the connector cables. The function principle of the diversity receiver will described with a simple example in the next section.
  All digital signal values can recorded simultaneously by a PCM recorder. This is a special version of the DA-PCM-HS digital high speed data recorder, which supports the bit rates 1280, 640, 320 and 160kbit/s of the TEL telemetry system. Reproduction takes place via the PCM input at the demodulator, which outputs the associated analog signals.
  Two interfaces are available for digital data acquisition in desktop computers (IF16 ISA board) and notebooks (ECIA100 PCMCIA card). The powerful software packages µLab and µGraph enables real time data storage on hard disk, online data visualization and a great number of tools for evaluation and analysis.

- **Diversity**
  A very important point regarding the transmission quality is the diversity receiver. It consists of 2 independent receivers with own antennas and in case of a GHz telemetry also an own 2-channel down-converter. The two modulated input signals will added phase-locked and therefore the resulting signal has always an improved quality against any one of the input signals. This is also the main difference between diversity systems and simple antenna couplers, where the existing phase difference can lead to an addition of the signals, but also to an extinguishing. An using of a diversity system is recommended in case of dynamical changings of the electromagnetical environment conditions, like mobile systems with moving transmitter or receiver antennas and indoor applications with many reflections on walls, bottoms, ceilings, moving objects, persons, etc. In practice the transmission quality of a diversity system against a non-diversity system is improved by a factor of approximately 10. This will now explained on a simple example.



The diagram on the previous page shows the measured field strength distribution in a XY-plane inside a testing stand cabin for cars. Here exist extremely complex conditions, because of the small dimensions and the metal covered walls. Following the graph in X-direction for a fixed Y-value, we see wide sections with high field strengths and small section with low field strengths due to interferences. For different Y-values the graphs are similar with a relation between good and low field strengths of approximately 10 to 1. With the premise, that we have an equivalent distribution in Y-direction for fixed X-values, we can derive a discrete XY-plane, marked with good field strength areas (white) and wrong areas (black). From ten squares in every row and column are nine good and one wrong. Next scheme shows such a possible distribution for a fixed time.



To get a feeling for practical field strength conditions, we must suppose now, that every moving object, e.g. an opening door, a person or the incoming car, will indefinable change the distributions of the black squares in the 10x10 area, but not the number (1 per row and 1 per column). Suppose, that the receiving antenna position is in one square, we have a probability for a black square area of 10/100 = 1/10. Using a diversity system with 2 independent antennas, this value is reduced to 10/100 * 9/99 = 1/10 * 1/11. So, in this example, the diversity function will increase the insensibility against transmission errors by a factor of 11. Additional, in the case of two antennas in black squares, the two low field strengths will added and therefore increased, so that further transmission errors can be avoided.

1.2 <u>How to arrange the telemetry system</u>

- Generally there are many applications for telemetry systems, each with its own requirements and special environment. So it doesn’t exist one universal system for all, but it’s necessary to combine various components. To find the most suitable system for your application, use the following check list.

1. What is the maximum number of analog channels?
2. What is the necessary maximum channel bandwidth?
3. What are the requested transmission quality and environment conditions?
4. What is the maximum transmission range?
5. What is the type of data acquisition on receiver side?

The next sections show a detailed description of every check point with all important hints for the user. At the end of this chapter you have specified a complete telemetry system consisting of one pair of encoder/decoder, one pair of transmitter/receiver and the accessory equipment as well as the necessary options.

- **Number of analog channels**
  Depending on the number of channels the user can choose between 4 types of encoder/decoder pairs TEL8, TEL16, TEL24 and TEL32 with 8, 16, 24 or 32 analog channels. Up to 128 channels in steps of 8 will realized by combining of up to 4 encoders on transmitter side and 4 decoders on receiver side. The coupling takes place by daisy-chaining using 1 BNC cable between 2 devices. As a result only one transmitter/receiver pair is necessary for telemetry transmission. If a digital acquisition is desired, the analog decoder on receiver side will replaced by a digital one with an additional computer interface IF16 (desktop) or ECIA100 (notebook), data acquisition software µLab (necessary) and data analysis software µGraph (recommended).
  Has the application more than 128 channels it’s possible to combine 2 or more systems, e.g. for 192 channels a TEL128 and a TEL64 system. Note, that such a multi-telemetry system leads to some general restrictions. At first the type of data acquisition on receiver side is important. For analog outputs there are no effects, but for a digital acquisition, if a simultaneous sampling of all channels is desired. That means in our example with 192 channels, that the first 128 channels will sampled at a time 1 and the other 64 at a time 2. Because you need for every of the 2 decoders an own digital interface with independent free running FIFO memories on the acquisition cards, there is no way to correlate the first 128 channels with the other 64 in time. For simple test measurements it’s possible to use one channel of every system for transmitting the same signal to detect the fixed time delay between the 2 systems. But any type of correlations between one channel of system 1 and a second channel of system 2 during data analysis will not supported in software. A further restriction of multi-telemetry systems exists, if you will work with a more cost efficient TEL-MHz transmitter/receiver pair. In the authorized ISM band (Industry, Science and Medicine) from 433,15 to 434,65MHz it’s only possible to transmit a maximum total bit rate of 320kbit/s. So the upper limit for a multi-telemetry system is 256 channels, build with two TEL systems and a transmission rate of 160kbit/s per system. For more information regarding the bit rates see also section “Channel bandwidth”.

- **Channel bandwidth**
  Because of the digital data transmission of the TEL telemetry system every analog value must sampled, hold and converted in a digital one. The total sample rate (number of samples per second for all channels) can derived by dividing the bit rate by 16. These 16 bits are one data word composed of 12 bits for the analog data value and 4 bits for internal transmission purposes, like error detection and synchronization.
  The channel sample rate can always derived by dividing the total sample rate by the number of virtual channels. The virtual channel number is 8, 16, 32, 64 or 128. That means, for example, that the channel bandwidth of a 40 channel system is equal to a 64 channel system with the same bit rate, because the 40 channel system is indeed a system with 64 virtual channels, where only 40 channels are physically implemented in hardware. For more information see also next table.
  According to Shannon’s theorem this channel sample rate must be at least two times higher than the highest analog signal frequency to avoid aliasing effects. Because the highest signal frequency is an unknown value, it’s necessary to filter the input signal. In the TEL encoder this is realized by implemented 8-pole low pass filters with Butterworth characteristic. The 3dB cut-off frequency of these filters is equivalent with the channel bandwidth and can derived by dividing the channel sample rate by 3.125.
  For monitoring and controlling systems with fast reaction activities it’s also important to know the time delay between the analog encoder input and the decoder output. In the field of measurement this has no influence for e.g. cross-correlations, because the time delay is constant for all channels.
  Following table shows the relationship between bit rate, sample rate, analog signal bandwidth and time delay for the different channel modes.

System bit rate		40kbit/s	160kbit/s	320kbit/s	640kbit/s	1280kbit/s
Total sample rate		2.5kS/s	10kS/s	20kS/s	40kS/s	80kS/s
8 channels	Channel sample rate	312.5S/s	1.25kS/s	2.5kS/s	5kS/s	10kS/s
	Channel bandwidth	100Hz	400Hz	800Hz	1.6kHz	3.2kHz
	Channel time delay	22.4ms	5.6ms	2.8ms	1.4ms	0.7ms
16 channels	Channel sample rate	156.25S/s	625S/s	1.25kS/s	2.5kS/s	5kS/s
	Channel bandwidth	50Hz	200Hz	400Hz	800Hz	1.6kHz
	Channel time delay	44.8ms	11.2ms	5.6ms	2.8ms	1.4ms
24/32 channels	Channel sample rate	78.125S/s	312.5S/s	625S/s	1.25kS/s	2.5kS/s
	Channel bandwidth	25Hz	100Hz	200Hz	400Hz	800Hz
	Channel time delay	89.6ms	22.4ms	11.2ms	5.6ms	2.8ms
40/48/56/64 channels	Channel sample rate	39.0625S/s	156.25S/s	312.5S/s	625S/s	1.25kS/s
	Channel bandwidth	12.5Hz	50Hz	100Hz	200Hz	400Hz
	Channel time delay	179.2ms	44.8ms	22.4ms	11.2ms	5.6ms
72/80/88/96/ 104/112/120/128 channels	Channel sample rate	%	78.125S/s	156.25S/s	312.5S/s	625S/s
	Channel bandwidth		25Hz	50Hz	100Hz	200Hz
	Channel time delay		89.6ms	44.8ms	22.4ms	11.2ms
Transmitter/receiver pair		TEL-40k	TEL-MHz(-NoDiv), TEL-GHz		TEL-GHz	

This time are 2 frequency bands for data transmission available, one in the MHz range and one in the GHz range. The TEL-40k telemetry is also placed in the MHz range with the exception, that the transmission rate is fixed to 40kbit/s. For bit rates greater than 320kbit/s only the TEL-GHz transmitter/receiver pair is possible, but for 160 and 320kbit/s the decision depends on various factors. These will described in the next section.

- **Transmission quality and environment conditions**
  The most important point for the well-function of a telemetry system is the suitable adaptation to the environment conditions. This section summarized all information and relationships for the user. Note, that in the TEL-40k telemetry no diversity is implemented, the TEL-MHz system can delivered with or without a diversity receiver and in the TEL-GHz system it's included by default.
  Inside of buildings in most cases the standard transmission power of 10mW for TEL-MHz and 20mW for TEL-GHz is sufficient. For short distances, e.g. from door to door, the MHz telemetry fulfill almost all applications. Because of many reflections on walls, floors and ceilings and the resulting interferences, a diversity system is recommended. For longer distances, e.g. from the 1st to the 9th floor in great buildings, a GHz system offer an improved performance. Here the shorter wave length enables an advanced ability to get through mediums like iron, steel, concrete, etc. Examples for such applications are transmissions from the inside of great dams, stoves and vacuum systems.
  On open air conditions we have to separate between fixed and mobile applications. Will the position of the transmitter and receiver not moved during the data transmission, the electromagnetical environment is relative stable. So, if the user has found the best transmission performance by checking different placements of the antennas, he has a constant transmission quality. For such point-to-point telemetry systems a diversity in the MHz range is not necessary.
  In mobile applications, where the transmitter and/or the receiver are not fixed, the electromagnetical conditions are changing permanently. Here a diversity system will reduces the transmission errors considerable.
  In GHz range the properties of the electromagnetic waves approaches to these of light, so that the insensitivity against electromagnetic influences from the environment is greater than in MHz range. A second conclusion is, that in GHz range for long transmission ranges a line-of-sight connection between the transmitter and receiver antennas is necessary, because the reflected energy, e.g. from mountains, is lower. Vice versa the higher reflected power in the MHz range leads to the result, that the transmitter antenna has to placed on the highest possible point to minimize reflections from the ground.

To summarize the free field conditions in simple examples, the best transmission is guaranteed from mountain to mountain, followed from a transmission from mountain to valley with a line-of-sight connection (no trees between transmitter and receiver antennas) and the worst case from valley to mountain. In flat regions the mountain can replaced by a high transmitter mast.
The maximum transmission range in free field depends from the last 3 conditions, the transmission power and the antenna design. This questions will answered in next section.
Regarding the bit rate, it’s clear, that the required analog channel bandwidth is the determined value. Generally we recommend not to work with bit rates higher than necessary, because every decreasing of the data rate will increase the transmission stability.
For telemetry applications in industrial and commercial areas, please check the availability of the specified frequency band on site and the authorization by government for your country! In case of reservations it’s possible to modify the transmitter/receiver pair for alternative carrier frequencies.

<table>
<tr><th>Transmitter/receiver pair</th><th>TEL-40k</th><th>TEL-MHz</th><th>TEL-GHz</th></tr>
<tr><th>Frequency range</th><td colspan="2">433.15MHz – 434.65MHz</td><td>2.400 – 2.483GHz</td></tr>
<tr><th>Wave length</th><td colspan="2">70cm</td><td>12.5cm</td></tr>
<tr><th>Supported bit rates</th><td>40kbit</td><td>160 / 320kbit/s</td><td>160 / 320 / 640 / 1280kbit/s</td></tr>
<tr><th rowspan="2">Advantages</th><td colspan="2">• Cost efficient
• Low attenuation on rain and fog conditions
• High insensitivity against interferences</td><td rowspan="2">• High modulation bandwidth (high bit rates and channel bandwidths, parallel function with other services possible)
• High insensitivity against shielded rooms, stoves, metal vessels, etc.
• Smaller transmitter antennas</td></tr>
<tr><td></td><td>• with or without diversity</td></tr>
<tr><th rowspan="2">Disadvantages</th><td colspan="2">• Many other services in band (higher liability due to alarm systems, door opener, etc. in the neighborhood)
• For long transmission ranges are higher transmitter antenna positions necessary, because of energy loss by ground reflections</td><td rowspan="2">• More expensive
• On receiver side only diversity available, because of more interferences due to shorter wave length</td></tr>
<tr><td>• No diversity</td><td></td></tr>
</table>

- **Transmission range**
As mentioned in last section the height of the transmitter antenna against ground, the transmission power and the antenna design are the primary aspects for the possible maximum transmission range. Generally the real range must determined in practice on actual conditions, but as a rough formula the next table shows approximated values for a standard transmitter antenna 10m above ground.

<table>
<tr><th>Transmission power</th><th>TEL-40k</th><th>TEL-MHz</th><th>TEL-GHz</th></tr>
<tr><th>10mW</th><td colspan="2">300m</td><td></td></tr>
<tr><th>20mW</th><td></td><td></td><td>500m</td></tr>
<tr><th>1W</th><td></td><td colspan="2">1000m</td></tr>
<tr><th>5W</th><td></td><td colspan="2">2000m</td></tr>
</table>

For ranges higher than 2km we recommended to contact our company to discuss the increasing of transmitter power and the using of direction antennas or for example tracking antennas for transmissions from an air craft to ground. Please read also the security notes in next chapter, especially for high power systems with 1W and more.

- **Type of data acquisition**
  The last point for specifying your telemetry system is the question of analog or digital data acquisition on receiver side. This depends on the type of application and the acceptable budget.
  For complex systems, where the telemetry is only one part of many components with the only task to transmit analog data from place A to place B, the decision is normally analog, because the user has its own digital acquisition system with his standard evaluation software.
  In stand-alone systems with the task to measure data on place A, to transmit these to place B and to store the data on hard disk of a notebook or a desktop computer, we recommended a digital telemetry interface on receiver side. Some users work in this case with analog telemetry outputs and a PC-integrated analog data acquisition card, but this reduces the signal quality, because the digital transmitted data will converted additional to analog and later back to digital. Furthermore inside the PC will inject a higher noise into the analog lines and the most multi-channel data acquisition cards don't support a simultaneous sample and hold, what is necessary for exact time correlations between the channels during analysis.
  Regarding the budget, a digital system becomes with an increasing number of channels more cost efficient against an analog one. So, for more than 32 channels, a digital decoder TEL-DEC-D, with computer interface IF16 or ECIA100, data acquisition software µLab with OBE option and data analysis software µGraph is cheaper than an accessory analog decoder. In every case also all analog decoders are equipped with a digital interface output. For detailed information see chapters "Components" and "Periphery".

1.3 Security and application notes

- In high power systems with 1 Watt and higher it's very important, that the whole power will emitted via the antenna. Therefore, don't power-up the transmitter without connected antenna or attenuator, because the irradiated electromagnetical wave will reflected on the antenna connector and the power of the return wave can destroy the final output stage of the transmitter. Such telemetry systems are designed for long transmission ranges, so that the minimum distance between transmitter and receiver antennas is 100m for a 5W system working with full power output. This is important, especially for first transmission checks in laboratories, where users place the receiver antennas wrongly close to the transmitter antenna. In this case the receiver is overloaded, loss the synchronization and the diversity doesn't work. To avoid this, connect a 10 or 20dB attenuator between transmitter output and antenna to reduce the emitted power.
  Another negative influence of HF power have to be considered for sensitive measurement devices. When high frequencies are injected in the measuring signal path, a differentiated rectification normally occurs in semiconductors, which results in an offset shift at the output, especially by using large gains (e.g. 1000 for strain gage amplifiers). This offset shift can be as much as 10% of the measuring range. So, the minimum distance of the transmitter antenna from other electronically components should be at least 5m for a 5W system.
  A further important point is the hot discussed topic of electromagnetical influences (EMI) to organic cells, like the human brain. Although a scientific proof is missing, it's recommended to handle high HF power devices with a given respect. The problem is, that people can't recognize electromagnetical waves, they are not to see, not to hear and not to feel. A simple experiment will help to get a sentiment for the emitted energy. Power-up a 5W transmitter in the near of a computer monitor and you will see the result on the screen. Therefore, avoid staying over long times in the near of high power transmitter antennas (minimum distance should be at least 5m for a 5W system).
- If you use antennas with magnetic sockets, avoid any contact with transmitters or receivers, because the ferrite cores of the internal band filters will premagnetized and change their center frequency. For transportation put every time an iron plate on the magnetic socket area to absorb the magnetic field strength.

2 Installation

- Connect at first the antennas on transmitter and receiver side. In case of a GHz telemetry connect the two receiver antennas with the outer connectors of the converter using the short HF cables (1m). After them establish the connection from the two middle converter connectors to the diversity receiver using the long HF cables (10m). If you test high power systems with 1Watt or more in laboratory with short transmission ranges, implement a 10 or 20dB attenuator between transmitter and antenna, because otherwise the receiver will overloaded and the diversity function doesn't work.
- Plug the 7-pole Tuchel in the female connectors labeled with "DC 10...30V" of the encoder and the decoder and the Banana connectors into a DC voltage supply (plus is red, **minus** is **black**) or establish the connection to the delivered AC/DC power supply. The DC input voltage range is from 10 to 30V or otherwise specified beside the power connector or on the type sign of the device. Check, that you have enough power and the voltage is not to high, because in this case the internal overvoltage protection circuit will destroy the fuse. If the power source is checked, power on the encoder and decoder with the "Power" switch on the front side. The active state is signalized by the green LED above. In standard applications, the transmitter will powered from the encoder and the receiver from the decoder. Furthermore the down-converter in GHz systems will powered always from the diversity receiver. This power supply is integrated in the 2 HF cables from converter to the receiver.
- Connect the transmitter with the encoder and the receiver with the decoder via the 9-pole SubD connector cables. In some applications, especially when using the TEL-40k, the transmitter is integrated in the encoder and/or the receiver in the decoder housing. Check, that you have enough field strength on the "RF Level" bar graph on the receiver. At least 4 LEDs should be light up, if not, change the positions of the antennas until the maximum field strength is reached. Test the diversity function by manually moving the transmitter or receiver antennas. The "Ant. 1" and "Ant. 2" LEDs have to go on and off alternately, otherwise the receiver is overloaded and you have to reduce the transmitter power by an additional attenuator. If the "Error" LED on the demodulator is permanently off, the telemetry transmission is successfully established. Otherwise you have different set bit rates between encoder and decoder. To avoid this, be sure, that the "kbit/s" switch on the rear side is on the same position for the encoder and decoder. To change the bit rate use only the delivered screw driver for the switch behind the hole. A first step to check the transmission function is to put in an analog signal, e.g. a 1Hz sine wave, on channel 1 on the encoder and to measure the output signal of channel 1 at the decoder.
- When using a digital interface switch off the computer and plug the ECIA100 PCMCIA card in your notebook (pay attention to the marked top side) or the IF16 ISA board in your desktop. Plug the software security key (dongle) on the LPT1 printer port and power up the PC. The IF16 card is not "Plug and Play" compatible and therefore the installation of the driver takes place manually. To save time, follow this procedure for the Windows95/98 operating system.

    1. Open "Start → Settings → Control Panel"
    2. Start the "Add New Hardware" wizard
    3. Click the "Next" button twice
    4. Enable "No, the device isn't in the list" and click the "Next" button
    5. Enable "No, I want to select the hardware from a list" and click the "Next" button
    6. Choose as the type of hardware "Other devices" and click the "Next" button
    7. Click the "Have Disk ..." button
    8. Insert the MicroEdition CD-ROM in your drive - if the start up installation program begins running automatically, click the "Exit" button
    9. Select the path for your CD-ROM drive as source in the active window, e.g. "D:\", and click the "OK" button.

10. Choose as manufacturer “CAESAR Datensysteme GmbH”, as model “IF16” and click the “Next” button
11. The last window will inform you about the chosen resources from the operating system. This must be “Input/Output Range: 0310-031F” by default in accordance with the jumper settings on the IF16 card and an unused “Memory Range”, e.g. “000D4000-000D7FFF”.
12. After them restart your system
13. For checking the successful installation open “Start → Settings → Control Panel → System”, select the “Device Manager” card, click on the plus sign of the “Data Acquisition Cards” folder, double click the “IF16” card and check the “Device status”. Here you must find the message “The device is working properly.”, otherwise you have conflicts with other system resources, like the “Interrupt request (IRQ)” or the “Input/Output (I/O)”. In this case start, if possible, the “Hardware trouble shooter” procedure or contact our local sales office.

The ECIA100 PCMCIA card meet the “Plug and Play” standard. If you plug the card the first time in the PCMCIA slot of your notebook, the Windows95/98 operating system will automatically detect the card and ask you for a suitable driver. Specify as location the path name of your CD-ROM drive, e.g. “D:\”, and follow the next instructions. After successful installation, you hear a short beep and you see the card icon on the right side in the taskbar.

For WindowsNT systems the installation of both cards is a little bit more complicate, because this operating system doesn’t support any type of external devices. However, the drivers also exist and you can contact our local sales offices as well.

Now install the software packages µLab and µGraph and start the µLab application. For every customer an example configuration for µLab is delivered on a separate floppy disk. Copy the files “*.mhc” and “*.mlb” in a new folder, e.g. “Examples” in the “MicroEdition” directory, and open the “*.mlb” file in µLab. Save the configuration as “Test.mlb” using the *SaveAs* command in the File menu to avoid an overwriting of the presentation settings. Click the start button on the symbol panel for activating the measurement. A graphical display with all physical channels will appear. If you get an error message, make a double click on “Hardware” in the “Resources” folder (“Extras” in other languages) of the project tree and load the configuration file “*.mhc”. Then click on “Job”, choose the “Clock source” card and select under “Device name” the new hardware path, e.g. “*ECIA 100@KMT TEL32@PCM-Frame32*”, if you work with an ECIA100 card and a TEL32 telemetry system. After them try again to start the measurement by clicking the start button. If the graphical window don’t appear please contact our local sales office. Otherwise use this example as a base for more complex configurations and for your first steps with the µLab software.

- At last connect the 37-pole SubD decoder interface output with your interface card using the accessory cable. Input an analog signal on the encoder, e.g. 1Hz sine wave with 3V amplitude and 0V offset, and you have to see it on the graphical display on the computer. If the graphical window don’t visualize the signal with the right frequency, you have a discord between the set bit rate on the hardware and software. To remove this difference make a double click on the “Job” icon in the project tree of the µLab software and select the hardware bit rate compatible sample rate from the following table. Of course, you can also calculate the sample rate by dividing the bit rate (unit bit/s) by 16. For further operations see the µLab and µGraph tutorials.

Hardware bit rate	Software sample rate
1280kbit/s	80000
640kbit/s	40000
320kbit/s	20000
160kbit/s	10000
40kbit/s	2500

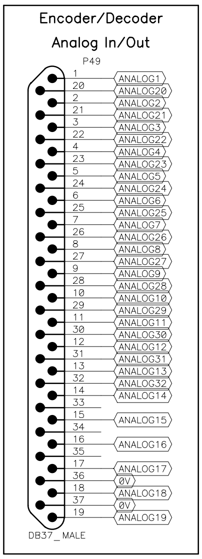
3 Components

3.1 Encoders and Decoders

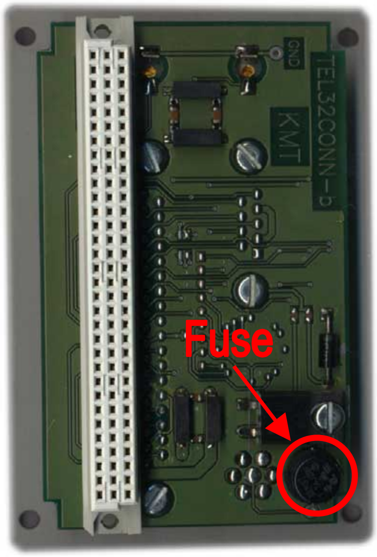
- All types of Encoders and Decoders have the same mechanical dimensions and exist by default as stand-alone units in a separate housing or for special applications also as slide-in modules for 19” frames. The base device is a 32 channel unit and will physically equipped for channel numbers less than 32 only with 8, 16 or 24 internal hardware channels. The pin assignment and outside view is always the same, with the only difference, that, e.g. for a 24 channel unit, the analog transmission from the encoder inputs to the decoder outputs of the channels 25-32 doesn’t work. Note that, for the digital decoder TEL-DEC-D no analog outputs are available, although the “Analog Out” connector is implemented by default.

Encoder front side

Decoder front side



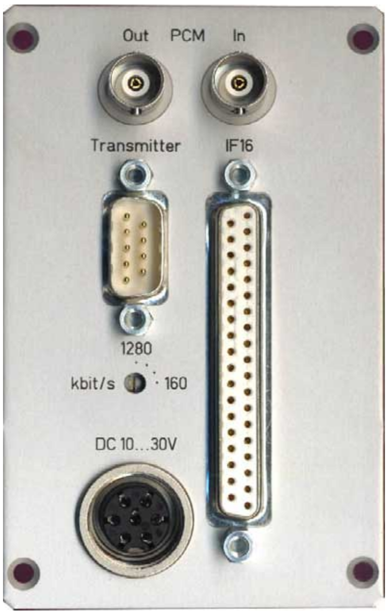
Pin assignment of encoder and decoder



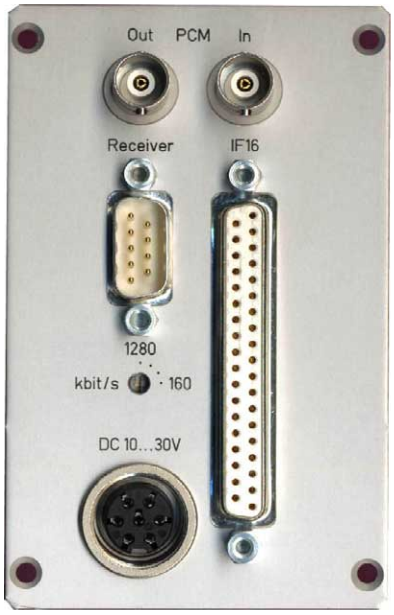
Fuse location inside encoder and decoder (rear side)

- Before connecting the power source, be sure that you work with the correct supply voltage with at least 15W output power. All systems are designed for DC input voltages from 10 to 30V by default, but for special applications it’s possible, that this range is limited from 10 to 18V or from 18 to 30V. In this case the valid input range is engraved beside the power connector or labeled on the type sign. Note, that if the voltage is to low, the system don’t work properly, if it’s to high, the internal fuse will destroyed immediately (see picture above). The pin assignment for the power connector you find in the following drawings, and for the delivered DC cable the red banana plug is plus and the other one **minus** (**black**). When working with AC power use only the recommended “AC/DC” power supplies from our company. Otherwise it’s possible, that you inject additional noise in the sensitive measurement electronic. If the power sources are checked you can power up the encoder and decoder using the “Power” switches on the front panels. The green LEDs above the switch have to light up.
- The “kbit/s” switches of the encoder and decoder on the rear side have the function to select the desired bit rate (160-320-640-1280kbit/s by default). The anti-clockwise stop position is the highest bit rate (1280kbit/s by default) and with every step in clockwise direction the data bit rate is the half of the previous down to 160kbit/s. By reducing the data rate you reduce simultaneously the channel bandwidth. This effect you can use to eliminate undesirable high frequency noise by the encoder-integrated and bit rate adapted anti-aliasing low pass filters. But the actually reason for the implemented “kbit/s” switch is the possibility to increase the transmission stability in a wrong high frequency environment. The 40kbit/s system is normally an encoder with build-in transmitter and an decoder with build-in receiver, where the bit rate is fixed to 40kbit/s.

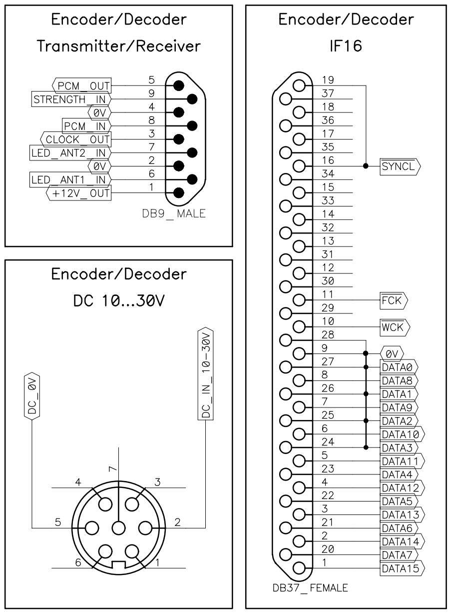
- The analog input range for all encoders is ±5V by default or optionally ±10V. If at least one input signal goes out of this specified range, the red “OVL”-LED on the front panel lights up. The LED remains also on, if all the signals are returned into the valid range and will only goes off, when you press the overload „Reset“ key. Therefore use only the delivered 2mm hexagon key. In the case, that the LED doesn’t goes off, the input signal is in the overload range permanently or temporary with a high frequency, so that the LED immediately light up again after resetting. The analog output range for all decoders is fixed to ±5V.



Encoder rear side



Decoder rear side



Pin assignments of encoder and decoder

- The „IF16“ interface output is the connector to the computer using the digital interface IF16 (desktop) or ECIA100 (notebook). Normally, digital data acquisition takes place on the decoder on receiver side, but it works also with the encoder. Here it can used for test purposes or as a stand-alone data acquisition system. Note, that all encoders and decoders have an digital interface output, also the analog ones.
- The connectors on the rear side are the same for all types of encoders and decoders, with the exception that some signals are not implemented. The transmitter will connected via a cable with the 9-pole SubD “Transmitter” connector and will powered from the encoder. Additional exists a “PCM Out” BNC connector for test purposes or for data transmission to the decoders “PCM In” connector via an up to 100m long BNC cable. Note, that you have to cut the connection from the decoder to the receiver, before you establish this cable connection. Also in case of malfunction of the telemetry system, the first step for locating the problem is to disconnect the transmitter and receiver from the encoder and decoder and to realize this cable connection. If the cable transmission works („Error“ LED of decoder goes off and signal transmission is without problems) the encoder/decoder pair is OK and the distortion comes from the telemetry system, e.g. from another transmitter working with the same carrier frequency. If the cable transmission fails, the reason are in most cases different bit rates of the encoder and decoder.
- The receiver will connected via a cable with the 9-pole SubD “Receiver” connector and will powered from the decoder. For some applications the decoder and the receiver are together in one unit, e.g. in a 19” frame. Here this cable connection is established inside the housing. The same is valid for applications with the transmitter and the receiver in one package, e.g. for the TEL-40k telemetry. Instead of a transmitter/receiver pair it’s also possible to use a digital DAT recorder DA-PCM HS (TEL32 version) to record the data on the encoder side and to replay them on the decoder side. For more details see chapter “PCM-Recorder”.
- The “PCM In” connector of the encoder and the “PCM Out” connector of the decoder could be used for daisy-chaining of up to 4 encoders on transmitter side and up to 4 decoders on receiver side to build a telemetry system with up to 128 channels.

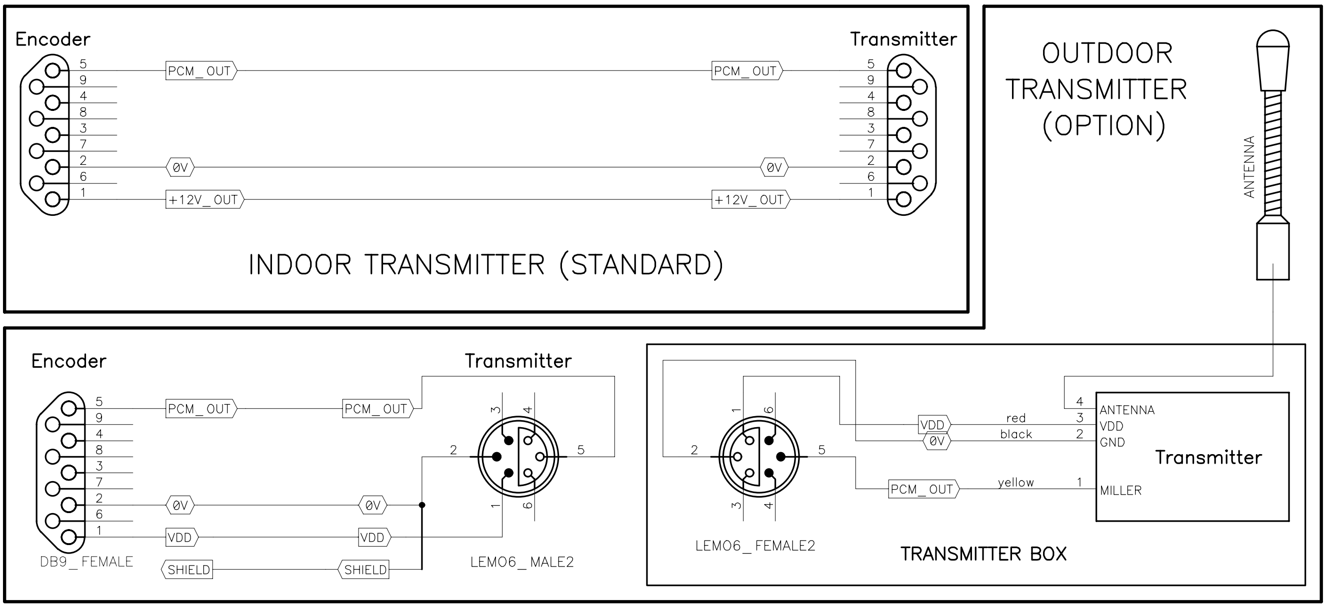
3.2 Transmitters

- Regarding the carrier frequencies of the transmitters, there exist two types, one for the TEL-MHz telemetry and one for TEL-GHz. For both systems different transmission powers are available (10/20mW, 1W, 5W by default, others on request) to adapt the telemetry to the desired transmission range in outdoor applications. Here it's very important to place the transmitter antenna on the highest possible point above ground with a line-of-sight connection to the receiver antennas, especially for GHz telemetry. Actually the TEL-40k transmitter works in the same frequency range like the TEL-MHz telemetry, but for this type are no options or adaptations regarding the bit rate (fixed to 40kbit/s) and the transmission power (fixed to 10mW) available. All further necessary information you find in chapter 1.2.

Indoor transmitter front side (TEL-MHz)

Outdoor transmitter (TEL-GHz)

Outdoor transmitter cable (TEL-GHz)



Pin assignment for different types of transmitters

- The transmitters are designed in many different forms and packages and they will powered via cable from the encoder.

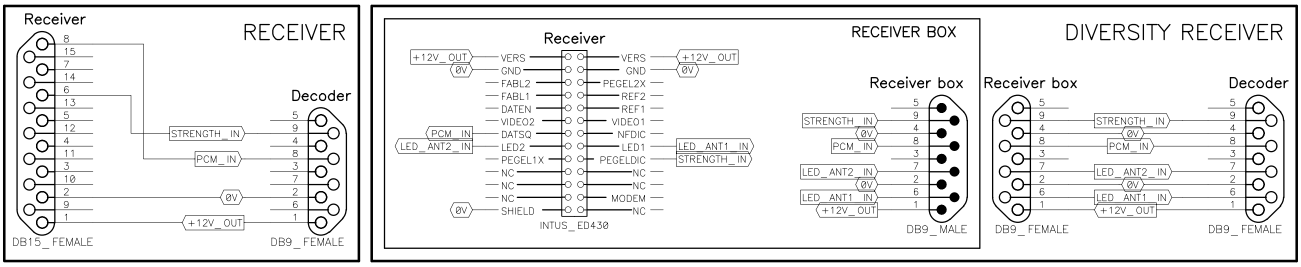
3.3 Receivers and converter

- On the receiver side we distinguish between two general types, a single receiver (TEL-40k and TEL-MHz-NoDiv) and the diversity receiver (TEL-MHz, TEL-GHz). The difference between the MHz and the GHz diversity is the additional 2-channel down-converter, which converts the incoming GHz modulated signal to a carrier frequency of 21MHz. The “RF Level” bar graph displays the received field strength and is useful for optimizing the antenna positions.

Converter (TEL-GHz only)

Diversity receiver front side (TEL-MHz)

Diversity receiver rear side (TEL-MHz)



Pin assignment for different types of receivers

- The receivers are designed in many different forms and packages and they will powered via cable from the decoder. The converter for the GHz telemetry then will powered from the diversity receiver via the 2 HF coaxial cables.

3.4 Antennas

- The antennas are also in many different types available. Additional to the standard types for TEL-40k, TEL-MHz and TEL-GHz exist also many specials in the area of directional antennas, because the design of the transmitter and receiver antennas is an important criteria for the transmission range together with the antenna positions (height above ground) and the transmission power.
- To find the antenna position for optimal transmission use at first the field strength LED bar graph labeled with “RF Level”. Here the best adjustment is given for a maximum number of LEDs with a minimum of 4 LEDs. The second criteria is the “Error” LED. Optimal conditions you have, if the LED is continuously off.

TEL-GHz antennas with converter | TEL-40k transmitter antenna | TEL-MHz antenna

- On receiver side of the TEL-GHz telemetry you have an additional down converter. This device should be always placed near the antennas to keep the length of the HF cables very short, because for the carrier frequency of 2.4Ghz the cable attenuation is very high. The converter move the carrier frequency down to 21MHz and here the attenuation is uncritical. Therefore the cables will manufactured by default with 1m length from the antennas to the converter and with 10m length from the converter to the diversity receiver.

4 Periphery

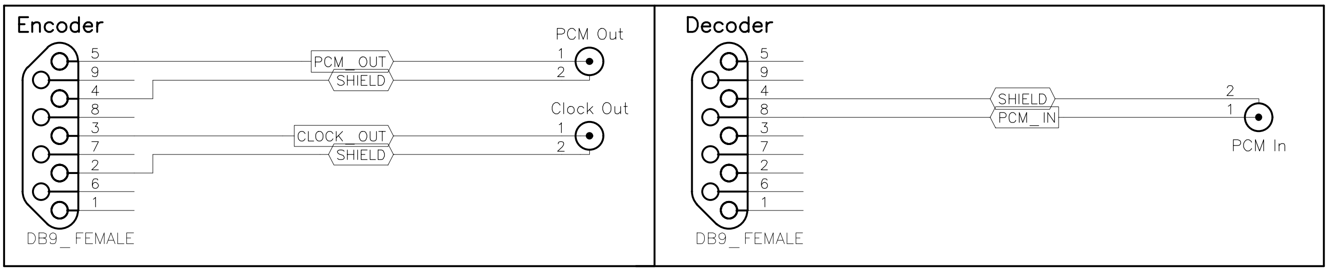
4.1 PCM-Recorder

- The small and rugged DA-PCM HS (Version TEL32) enables the option to record and replay the digital PCM data stream either simultaneously to the telemetry transmission or also instead of the it in offline applications.
- For recording the analog input signals connect the delivered adapter cable labeled with “Encoder” on the “Transmitter” output of the encoder. The 2 BNC outputs on the other end have to connected with the inputs of the digital recorder, specific the “PCM Out” of the cable with the “PCM In” from DAT and the “Clock Out” of the cable with the “Clock In” from the DAT.

DA-PCM HS (TEL32 version)

Connector cable from Encoder to DAT

Connector cable from DAT to Decoder



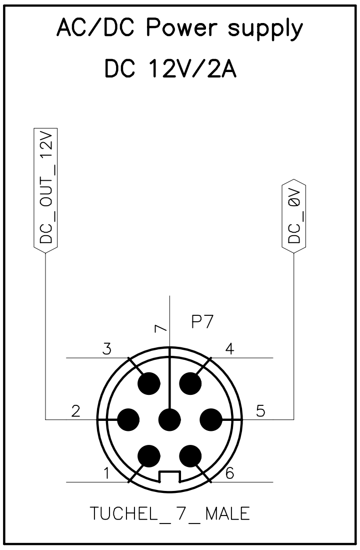
Pin assignment for DAT cables

- For reproducing the stored analog input signals connect the delivered adapter cable labeled with “Decoder” on the “Receiver” input of the decoder. The BNC input on the other end have to connected with the output of the digital recorder, specific the “PCM Out” of the DAT with the “PCM In” from the cable.
- The DA-PCM HS supports in TEL32 version 4 different bit rates by automatically detection. These are 160, 320, 640 and 1280kbit/s. For systems with 40kBit/s (TEL-40k) the special low speed DAT version D7-PCM4-320 is available, which is able record and reproduce up to 4 40kbit/s tracks without clock. The maximum recording capacity is approximately three hours. An additional voice channel is useful for acoustical comments during measurement. See user manual of DA-PCM HS and D7-PCM4-320 for further information.

4.2 AC/DC Power supply

- The AC/DC power supply enables the option to power all the devices also from AC power sources. The input voltage is 100-240V AC with 47-63Hz frequency range. The output is 12V DC with a maximum current of 2A, what is equivalent to a maximum output power of 24W.
- For safe operation use only this power supply together with KMT devices. Uncertified supplies from other manufacturers normally don't have a protective earth conductor (ground connection) and can inject additional noise into the high sensitive measurement electronic.

AC/DC Power supply



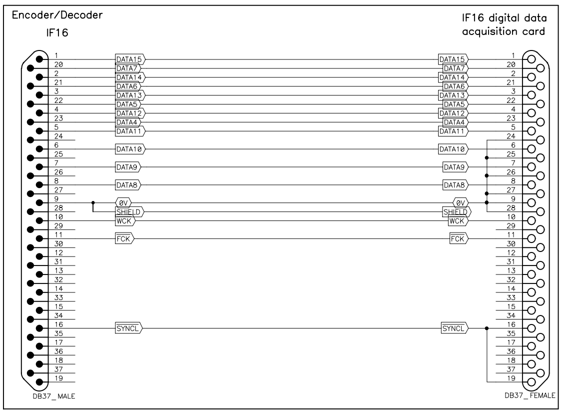
Pin assignment for AC/DC Power supply

- For safe operation use only this power supply together with KMT devices. Supplies from other manufacturers normally don't have a protective earth conductor (ground connection) and can inject additional noise into the high sensitive measurement electronic. Pay also attention to the following safety instructions:
  1. This power supply is for indoor use only! Do not expose the unit to water, rain or dust. The power supply must not be covered over.
  2. Do not attempt to remove the casing – this should only be done by a qualified engineer.
  3. Remove the unit from the wall socket when not in use.
  4. The unit is protected against short circuit and overload by a thermal fuse. Never use a fuse with a higher rating than specified.
  5. The power supply is insulation class II approved.
  6. The socket should always be easily accessible.
  7. Warning: Dangerous voltage!

4.3 PC Link

- The digital “IF16” interface output of the encoder and decoder has a standard 16 bit parallel word format, where only the most significant 12 bits will used and the least 4 significant bits are set fixed to zero. The hand-shaking with the data acquisition card takes places via the word clock and the frame clock signals on Pin 10 and 11. A loss of synchronization will signalized via the signal on Pin 16. Especially for telemetry systems it’s very important, that the card property “Synclost-Buffer” is enabled in the MSetup software, which defines the connected hardware on the outside. Otherwise the software can’t find the synchronization again after a transmission error, occurred e.g. by unfavorable environment conditions. This results in most cases in a channel moving, for example that you see the analog input signal of channel 1 on channel 2, the input of channel 2 on channel 3 and so on.

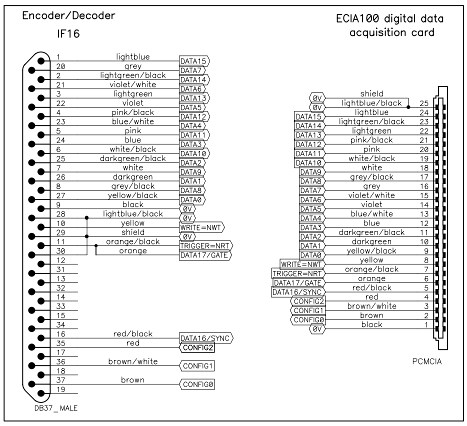
IF16 data acquisition card for ISA slots in desktop computers



Pin assignment for IF16 cable

- For the “IF16” output two types of digital interfaces are available for transferring the data into the PC. These are the ECIA100 for PCMCIA slots in notebooks and the IF16 for ISA slots in desktop computers.

ECIA 100 data acquisition card for PCMCIA slots in notebooks

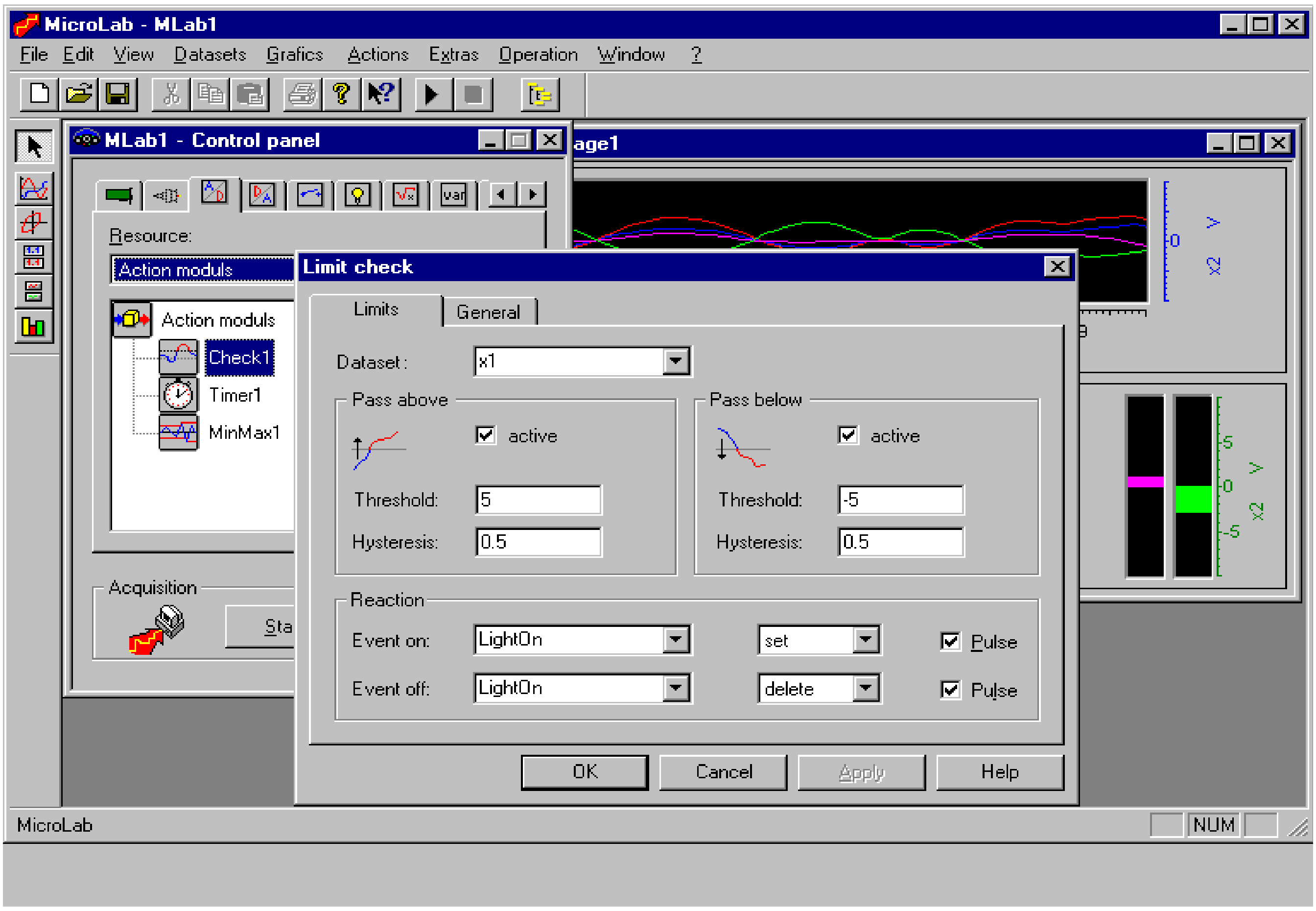


Pin assignment for ECIA100 cable

- All further data processing is performed by the convenient µEdition software for Win95/98/NT. The program modules µLab and µGraph use the full 32bit qualities of these operating systems for real-time data storage on hard disk, online visualization and calculations as well as evaluation and analysis. More information you find in the next two section and in the chapter “Installation”.

4.4 Data Acquisition with µLab

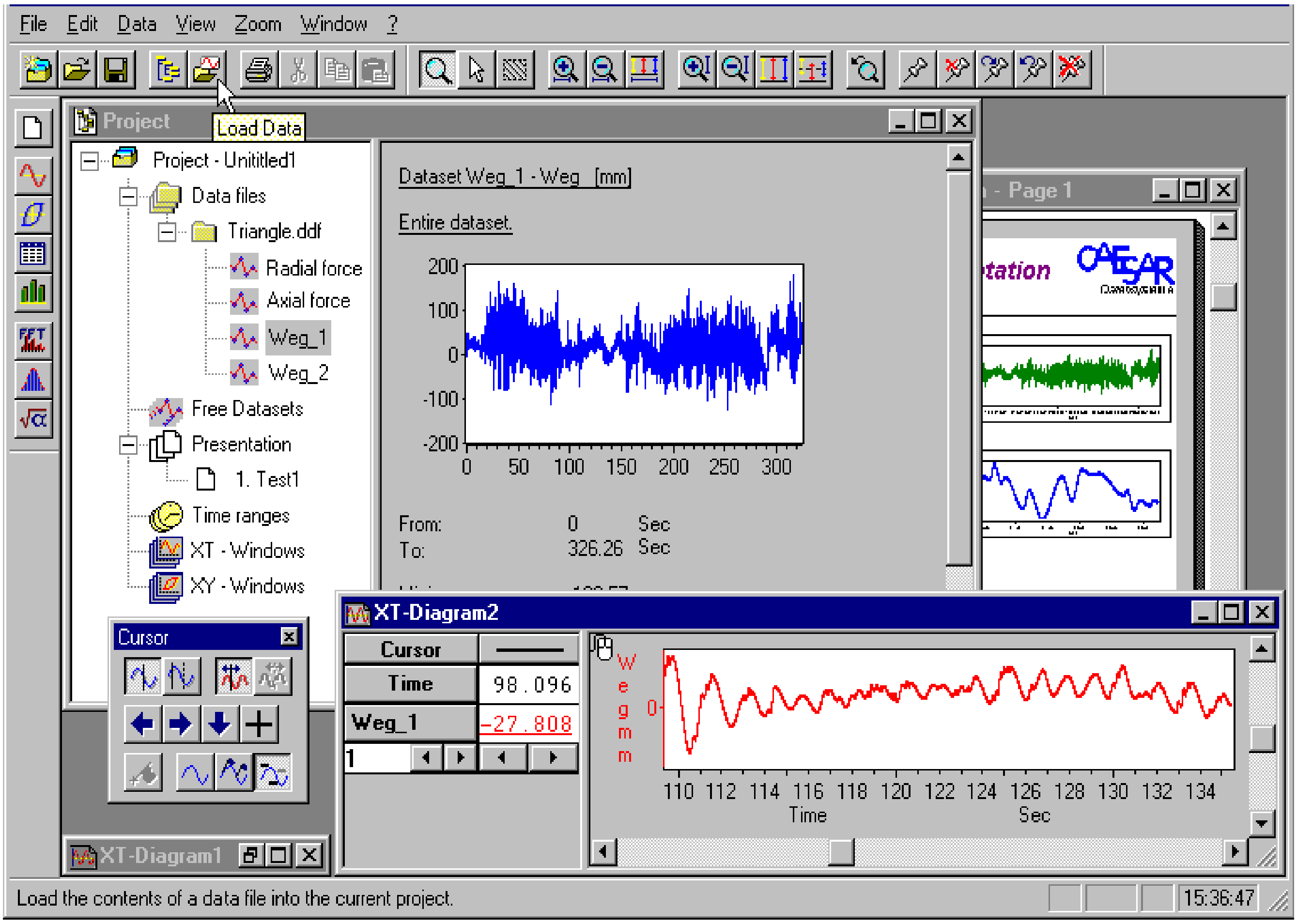
- µLab enables the analog measured data to be acquired, processed online, saved and displayed again. The basic µLab version together with the recommended OBE option for on-line calculations contain a wide range of trigger functions and action modules for limit surveillance, time control, data reduction and various smoothing algorithms. Each channel can be calibrated either linearly or non-linearly.



- By means of the online graphics, an unlimited number of graphical objects can be displayed simultaneously, e.g. xt-diagram (incl. scroll and scope mode), xy-diagram, bar graph, numerical display or text switch. The properties, e.g. axis scaling, color, text fonts, can be defined separately for each individual object. The functionality of the basic version can be extended, if desired, with the help of additional modules, e.g. for DIN and Rainflow classification, online frequency analysis and signal generation. For detailed description see the µLab tutorial.

4.5 Data Analysis with µGraph

- µGraph is a flexible, graphical analysis program for all kinds of measured data. It combines the following functions: quick-look, interactive processing, data management, presentation graphics, statistics, formula generator and optionally, frequency and bin analysis in an user interface, which is particularly intuitive and easy to use. The analysis is carried out simply by dragging the marked data sets and dropping it to the corresponding button in a toolbar, e.g. for printing or FFT calculations.



- A special highlight is the incredibly fast quick-look function, which enables the largest data sets to be displayed in a fraction of a second - simply click on the data set name and even several megabytes of measured data appear at once on the screen without any noticeable delay together with the most important statistical parameters. The quick-look has even more to offer. With the help of the mouse, any particular data set can be marked and either printed or displayed in the interactive cursor mode. Here a wide range of functions are available, e.g. line, crosshair and difference cursor, zooming, scrolling, marking and labeling. While scrolling through long sequences of data, bookmarks can be set, so that points of particular interest can easily be found again. Each data set can be displayed in a xt-diagram, xy-diagram, bar diagram or table with manual or automatic scaling. The flexible presentation graphics in µGraph enables records and reports to be freely defined. Together with standard functions for drawing and labeling, the OLE interface makes it possible to include objects from other Windows programs (e.g. Excel or Word). A report that has been designed once can be stored as a template and used again, when required, simply by clicking a button. For detailed description see the µGraph reference manual.

5 Specifications

Encoder	Type			TEL8-ENC	TEL16-ENC		TEL24-ENC	TEL32-ENC
	Analog inputs	Number		8	16		24	32
		Input range		±5V (±10V)				
		Input impedance		100kΩ				
		Antialiasing filter		8^{th}-pole Butterworth low pass				
		Simultaneous sample & hold		X				
	Power supply	Input voltage		10-30V DC				
		Average Consumption	without transmitter	3.0W	5.2W		7.4W	9.6W
			with transmitter	5.6W	7.8W		10.1W	12.3W
	Digital interface support	IF16 ISA board		X				
		ECIA100 PCMCIA card		X				
		Bitrate		40kbit/s fixed or 160, 320, 640 and 1280 kbit/s selectable				
	Dimensions	without connectors		254x65x106mm				
		with connectors		274x65x106mm				
	Weight			1390g	1440g		1490g	1540g
Decoder	Type			TEL8-DEC	TEL16-DEC	TEL24-DEC	TEL32-DEC	PCM-DEC-D
	Analog outputs	Number		8	16	24	32	-
		Output range		±5V				-
		Output impedance		2Ω, 10mA				-
		Smoothing filter		8^{th}-pole Butterworth low pass				-
	Power supply	Input voltage		10-30V DC				
		Average Consumption	without receiver	3.6W	6.3W	9.1W	11.8W	1.0W
			with receiver	7.3W	10.0W	12.8W	15.6W	4.8W
	Digital interface support	IF16 ISA board		X				
		ECIA100 PCMCIA card		X				
		Bitrate		40kbit/s fixed or 160, 320, 640 and 1280 kbit/s selectable				
	Dimensions	without connectors		254x65x106mm				
		with connectors		274x65x106mm				
Transmitter/ receiver	Type			TEL-40k	TEL-MHz		TEL-GHz	
	Supported bitrate			40kbit/s	160 / 320kbit/s		160 / 320 / 640 / 1280kbit/s	
	Wave length			70cm			12.5cm	
	Frequency range			433.15MHz – 434.65MHz			2.400 – 2.483GHz	
	Transmission range and power	10mW transmitter power		≈300m			-	
		20mW transmitter power		-			≈500m	
		1W transmitter power		-	≈1000m			
		5W transmitter power		-	≈2000m			
	Converter			-			X	
	Single receiver			X			-	
	Diversity receiver			-	X			
Data conversion	Resolution			12bit				
	Dynamic range			72dB				
	Signal to noise ratio (SNR)			≈65dB				
	System accuracy			0.2% at 0Hz				
Sample rates	Analog channels	System bit rate		40kbit/s	160kbit/s	320kbit/s	640kbit/s	1280kbit/s
		Total sample rate		2.5kS/S	10kS/s	20kS/s	40kS/s	80kS/s
		8 channels	Channel sample rate	312.5S/s	1.25kS/s	2.5kS/s	5kS/s	10kS/s
			Channel bandwidth	100Hz	400Hz	800Hz	1.6kHz	3.2kHz
			Channel time delay	22.4ms	5.6ms	2.8ms	1.4ms	0.7ms
		16 channels	Channel sample rate	156.25S/s	625S/s	1.25kS/s	2.5kS/s	5kS/s
			Channel bandwidth	50Hz	200Hz	400Hz	800Hz	1.6kHz
			Channel time delay	44.8ms	11.2ms	5.6ms	2.8ms	1.4ms
		24/32 channels	Channel sample rate	78.125S/s	312.5S/s	625S/s	1.25kS/s	2.5kS/s
			Channel bandwidth	25Hz	100Hz	200Hz	400Hz	800Hz
			Channel time delay	89.6ms	22.4ms	11.2ms	5.6ms	2.8ms
		40/48/56/64 channels	Channel sample rate	39.0625S/s	156.25S/s	312.5S/s	625S/s	1.25kS/s
			Channel bandwidth	12.5Hz	50Hz	100Hz	200Hz	400Hz
			Channel time delay	179.2ms	44.8ms	22.4ms	11.2ms	5.6ms
		72/80/88/96/ 104/112/120/128 channels	Channel sample rate	%	78.125S/s	156.25S/s	312.5S/s	625S/s
			Channel bandwidth		25Hz	50Hz	100Hz	200Hz
			Channel time delay		89.6ms	44.8ms	22.4ms	11.2ms
		Required transmitter/receiver pair		TEL-40k	TEL-MHz(-NoDiv), TEL-GHz		TEL-GHz	

				D7-PCM4-320	DA-PCM HS
PCM recorder	**Type**			**D7-PCM4-320**	**DA-PCM HS**
	Tape deck	**Tape**		DAT-tape width 3,81 mm	
		Track width		13.6 µm	
		Tape speed		8.15 mm/s	
		Density		61kbit/inch	
		Bit rate		1.536 Mbit/s or 192 kByte/s	
		Storage capacity	**2h recording**	1.38 Gbyte	
			3h recording	2.07 Gbyte	
	Channels			4	1
	Digital inputs	**Number**		4	2
		Name		Digital In 1-4	PCM In, Clock In
		Logic		TTL	
		Input impedance		100kΩ	
		Bit rate	**1-channel mode**	0 - 320kbit/s	160, 320, 640 and 1280kbit/s
			2-channel mode	0 - 160kbit/s	-
			4-channel mode	0 - 80kbit/s	-
	Digital outputs	**Number**		4	2
		Name		Digital Out 1-4	PCM Out, Clock Out
		Logic		TTL	
		Output impedance		130Ω, 5mA	
		Remaining jitter	**1-channel mode**	0.7 µs	<1%
			2-channel mode	1.4 µs	-
			4-channel mode	2.8 µs	-
	Voice channel			8bit, 100-3000Hz	
	Remote control	**Level**		3 - 30V	
		Pulse width		min. 2s	
	Power supply	**Input voltage**		10-18V or 18-30V DC	10-30V DC
		Consumption		≈4W	≈3W
	Recording time			max. 3h	
	Error correction			double encoded Reed-Solomon	
	Bit error			$< 10^{-10}$	
	Dimensions without shock absorber			160x90x75mm	160x90x70mm
	Weight (without shock absorber)			≈1050g	≈950g
AC/DC Power supply	**Input**	**Voltage**		100-240V AC	
		Frequency		47-63Hz	
	Output	**Voltage**		12V DC	
		Current		2A	
		Power		24W	
Environment conditions	**Types**			**All components**	
	Operating temperature range			-5 °C to +45 °C	
	Storage temperature range			-20 °C to +60 °C	
	Humidity			20 - 80% non condensed	
	Vibration			5g Mil Standard 810C, Curve C	
	Shock			10g in all directions	

Technical specifications are subject to change without notice !