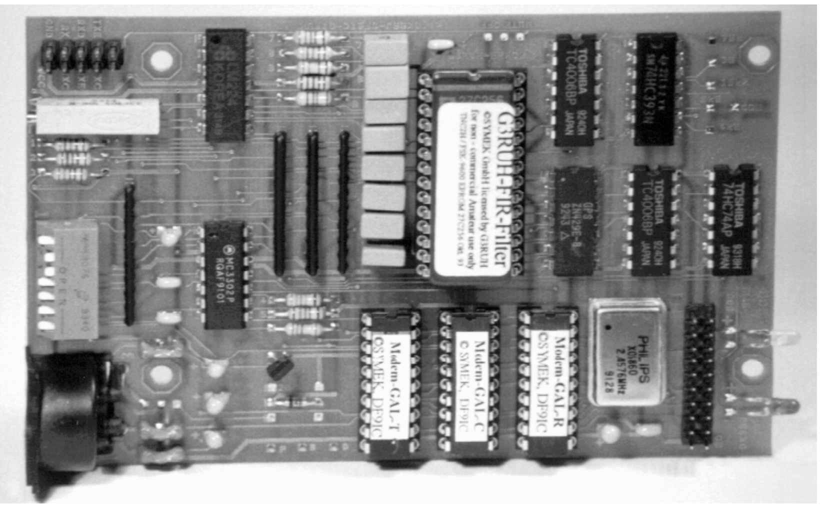
Users Manual for the Packet-Radio-Modem

FSK-9600

+ Versions for other baudrates FSK 19k2, FSK 38k4, FSK 76k8, FSK 153k6 etc.



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Production and distribution: SYMEK GmbH, Datentechnik, Ulf Kumm, DK9SJ, D-70597 Stuttgart, Johannes-Krämer-Straße 34
Phone: +49 711 -76 78 923, Fax: -76 78 924, Hotline: -76 54 911, e-mail: info @ symek.com Internet: http://symek.com

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Preface

This manual will help you to set-up your FSK9600 modem and connect it to your radio.

With this manual, the expression "FSK9600" and "9600 Baud" is used. However, all parts of the manual are valid for the various options of FSK9600 (FSK 4800, FSK 19200, FSK 38400 FSK 76800, FSK 153600 etc.)

If you need instructions how to modify a specific amateur radio transceiver for 9600 baud operation, ask us. We have a collection of many plans how to modify the transceivers. Write us an e-mail, we shall reply and attach the information requested if possible.

14. May 2005   Ulf Kumm, DK9SJ

Options for FSK9600

The FSK9600 board is tested and ready for use in the TNC3 or TNC31. For use with other packet-radio-controllers, it may be necessary to use an additional 20 wire ribbon cable. The data exchange between TNC3/31 and the modem is NRZI-formatted. If you want to use the FSK9600 with a TNC2, you need to order the option 'NRZ' because here the data format is NRZ. The difference between standard NRZI and optional NRZ version is only the programming of two of the three GALs. They are marked 'RI', 'TI' and 'C' or 'R', 'T' and 'C' for the optional NRZ version.

Most power of FSK9600 is consumed by the GALs. There are optional 'zero-power-GALs' available, which reduce the total supply current of the modem from 115 to 30 mA at 5 volt.

Technical data FSK-9600-E

Power supply:

5 volt DC, typ 115 mA. (Option low-power: 30 mA) typical values.

Dimensions:

ca. B=120, T=80, H=25 mm, masse approx. 85 grams

Radio interface:

5-pin DIN connector, same pinning as TNC2, TNC2S, TNC2H etc. Modulation (filter, scrambler) according to specifications of G3RUH, speed: 9600 baud / 9600 bit/s (optional other baudrates from 4800 to 153600 bit/s available, with special modifications up to 1,2 Mbaud.

AF-output level adjustable from 50 mV_{pp} to 2 V_{pp}, R_i: 220 Ω, DC-free. (up to 6 V DC permissible). Output is muted while reception. PTT : max. 16V 0,2A to ground, input sensitivity: 50-500 mV_{pp} at 1 MΩ, DC-free. A input limiter (0,5V_{pp}) avoids overdriving the amplifiers by short DC peaks at T/R switching.

NF-filter:

8 bit wide, 32-tap FIR-Filter in the transmitter (G3RUH-type). Active lowpass filters in TX and RX. All inputs and outputs to the radio are filtered with L-C-L filters for EMI suppression.

Modem interface (digital):

CMOS -level 5 volt. TXData, TXClock, RXData, RXClock, RTS CTS, DCD, + 5 volt,
reset, ground. Connector: 20 pin (2x10) ribbon connector.

LED display:

DCD (carrier detect), PTT (transmitter keying)

DIP-switches and trimmers:

7-pin switch for watchdog-disable, PTT-keying, bit-Error-test, selection of one of 16 filter coefficient sets. Setting of output voltage with a 20 turn trimmer.

Watchdog:

The PTT-switch is time-limited to approx. 20 seconds. In case of failure of the TNC, the PTT is released after the maximum time. For tests or special applications (digipeaters with long transmission periods) the watchdog may be disabled by a switch.

Jumpers on board:

AF-output muting on/off, baudrate 4800 / 9600 / 19200 / 38400 / 76800 Baud.

Short description

A 'modem' contains **mo**dulator and **dem**odulator circuits.

The FSK9600 converts the digital signals of a packet-radio-controller to low-frequent tones, which can be transmitted by a FM radio. Further, it decodes the tones received by a FM radio and sends them to the packet radio controller in digital form.

The modem FSK9600 generates and receives AF signals according the G3RUH-recommendations, which is usual with amateur radio on terrestrial and satellite links. all frequencies are quartz controlled, adjustments are not necessary. The audio bandwidth of the signal goes from 30 Hz to 5000 Hz (9600 bit/s. With other baudrates, the bandwidth is higher or lower according to the speed.

The transmit clock frequency (9600 Hz) is generated in the modem. The modem includes also the circuitry for transmitter-keying (PTT) and transmit-time limiter (watchdog).

Bit-rate and baudrate

In this manual, the expressions bit-rate (bit/s, bit per second) and baud (Bd) are used for determining the transmission speed. With the FSK9600 both values are equivalent, as there is exactly 1 bit transmitted with every clock cycle. In general, it is possible to transmit more than 1 bit per clock, the speed (in bit/s) is then a multiple of the clock rate.

Digital interface - 20 pin connector

Pin	Signal	Function	Pin	Signal
1	+ 5 Volt	power supply 5 volt 150 mA (from TNC)	2	Ground
3	+ 5 Volt	power supply 5 volt 150 mA (from TNC)	4	Ground
5	Reset	(not used in FSK9600)	6	Ground
7	DCD	AF carrier detect (from modem to TNC)	8	Ground
9	CTS	transmitter is keyed (from modem to TNC)	10	Ground
11	PTT	transmitter keying (from TNC to modem)	12	Ground
13	TXD	transmit data (from TNC to modem)	14	Ground
15	RXD*	receive data (from modem to TNC)	16	Ground
17	TXC	transmit clock (from modem to TNC)	18	Ground
19	RXC*	receive clock (from modem to TNC)	20	Ground

*: RXD and TXD can be encoded NRZ as well as NRZI.

Signal description digital interface

Reset (Pin 5): (modem input) normally high, is pulled low for 50 ms at power-on of TNC3. (not used in FSK9600)

DCD (Pin 7) Data Carrier Detect: (modem output) High: modem receives no carrier, low: modem has locked on a G3RUH-signal.

CTS (Pin 9) Clear to Send: (modem output) Normally high. If the modem is ready to transmit data, the signal is low. With the FSK9600, CTS output is connected to PTT input. The TNC will wait for CTS=low before data transmission starts.

PTT (Pin 11) Push to talk, or RTS (Request to send)**:** (modem input) normally high. When the transmitter is to be keyed, the TNC pulls this signal to low.

TXD (Pin 13) Transmit Data: (modem input): The data is latched at rising edge (low to high transition) of transmit clock.

RXD (Pin 15) Receive Data: (modem output): The data output changes at the falling edge and is valid at the rising edge (low to high transition) of the receive clock.

TXC (Pin 17) Transmit Clock: (modem output): The modem generates a clock frequency, which determines the transmit baudrate and the data speed between TNC and modem. Transmit data signal TXD has to be stable at the rising edge of TXC.

RXC (Pin 19) Receive Clock: (modem output): the output of the receive clock recovery circuit is sent to the TNC to synchronise the received data signal. RXD is stable at the rising edge of RXC. The frequency of RXC corresponds to the transmit clock of the remote transmitter. If the internal clock of the modem and the clock of the remote transmitter differ by some percent, the receive clock is adjusted by 1/32 clock cycle to maintain synchronism.

Connecting the FSK9600 to general TNC2

If the FSK9600 is to be used with a TNC2, the 6 signals are connected to the Z80-SIO as follows: (Pinning refers to 40 pin Z80-SIO)

SIO-Pin 9 ----------- Modem Pin 1 and 3 (+ 5 Volt)
SIO-Pin 19 ----------- Modem Pin 7 (DCD)
SIO-Pin 18 ----------- Modem Pin 9 (CTS)
SIO-Pin 17 ----------- Modem Pin 11 (RTS)
SIO-Pin 13 ----------- Modem Pin 13 (TXD)
SIO-Pin 12 ----------- Modem Pin 15(RXD)
SIO-Pin 14 ----------- Modem Pin 17 (TXC)
SIO-Pin 13 ----------- Modem Pin 19 (RXC)
SIO-Pin 31 ----------- Modem Pins 2,4,6...20 (GND)

Note: for 9600 baud operation, the system clock of the TNC2 should be 10 MHz or higher. The NRZ-option GALs of the FSK9600 must be used.

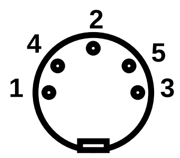
As the G3RUH-modem includes a scrambler, it would make no difference in transmit spectrum if NRZ or NRZI is used. However, to keep all systems compatible, the NRZ and NRZI versions have to be observed. Using two modems with the 'wrong' GALs would result in the same perfect communication, however other modems with the 'correct' NRZ/NRZI setting cannot read this signals.

Connecting the radio to FSK9600

Connecting a 9600 baud FSK modem to a radio requires modification of the radio in most cases. You have to find a suited point in the transmitter circuit to modulate the transmitter without significant distortion. The receiver circuit has to be tapped directly after the demodulator to get an unfiltered signal.

For connecting the radio, use a 5 pin DIN connector (180 degree pinning). The five pins are numbered as shown: (view to solder side of plug, view to front of the socket):

Pin 1: MODULATOR of radio, output of modem
Pin 2: GND ground
Pin 3: PTT transmitter keying, push-to-talk contact to ground
Pin 4: DEMODULATOR output of radio, input of modem
Pin 5: N.C.



Note: the five pins are not enumerated in turn.

Modulator (Pin 1)

Here, the modulator of the radio is connected. The maximum output voltage of the modem is up to approx. 2 Volt_{pp} and could be adjusted with the only trimmer resistor (accessible at the rear side of TNC3/31). The minimal output voltage, which could be set, is about 20 mV. Below this, the adjustment becomes somewhat fiddly. The modem has a output amplifier with a low output resistance of 220Ω.

Sometimes, the radio requires much less AF-voltage, e.g. only 10 mV for sufficient modulation. For this case, the AF voltage must be reduced by a voltage divider, which should be placed in the radio. The output of the modem should be about 1 Volt for good adjustment with the pot near middle position. This gives less susceptibility to hum and noise. Another fine place for the voltage divider is the DIN-plug.

The output voltage is coupled via a electrolytic capacitor. There should be no DC voltage applied to pin 1, which is less then 0 Volt, i.e. negative, because the output capacitor of TNC will be reversed in polarity. If the modulation input of your radio shows negative voltage, you should connect a 10µF capacitor in series, minus connection directed to the radio modulator. The transmit signal sounds like white noise, but on a oscilloscope you recognise pulses with a distance of about 0,1 ms.

IMPORTANT: the correct adjustment of the transmit AF is very important. As the radios are modulated directly (there is no AF-amplifier or modulation limiter), you may far overdrive the modulator by applying too much AF voltage. This gives the transmit signal an excessive bandwidth and the IF filter of the destination receiver will totally distort the signal. We advice to watch closely the eye diagram at the receiver and adjust then the proper modulation level. If the AF is too low, you may loose some signal-to-noise ratio, but you don't risk to distort the signal by overdriving.

Demodulator (Pin 4)

The demodulator-output of the radio is connected to this pin. The AF voltage should be 150 mV or more. The decoder works at voltages of 50 mV or more without errors, but the DCD-LED will flicker and the modem is sensitive against signal distortions.

If the output of your radio produces much more signal voltage, it should be reduced by a voltage divider, which is mounted in the radio to get 1 Volt or less. The input resistance of the modem is about 1 MΩ in parallel with the small input capacitance of the op amp.

Input voltages exceeding 1 volt are limited by the diode pair, causing excessive distortion of the signal. Make sure not to overdrive the input to avoid this.

PTT (Pin 3)

This pin is switched to ground when transmitting. With this, all common PTT-circuits of the usual radios may be operated. The switch in the TNC is a n-channel vertical MOS-field effect transistor (VMOS-FET), which is able to switch up to 60 Volts and up to 500 mA. In the 'on'-state, the resistance of the FET is typically 30 Ω or less, the cut-off current when switched off is far below 1 µA. VMOS-FETs are suited well for such applications, because the voltage across the switched-on FET is low (only a few mV). Bipolar silicon npn-transistors have usually saturation voltages, which are much higher.

With this circuit, it is only possible to switch DC-voltages up to about 20 Volts to ground. You cannot pull a line up to 12 Volt when transmitting or switch a negative voltage. For this application, you should use a switching amplifier or a reed relay (with diode clamp).

At most (handy) radios, the PTT contact and microphone is connected to the same signal pin. The AF-path for the microphone signal is decoupled by a series capacitor, the PTT-signal is fed by a series resistor of 2 to 20 kΩ in order not to short-circuit the microphone. When pressing the PTT switch, DC current may flow through this resistor, keying the transmitter. As the microphone will not be used with the 9600 Baud FSK-modem, the mic-connector of the radio may be connected directly to the PTT-pin of the modem. Then, the short circuit of the mic-modulation is no disadvantage.

GND (Pin 2)

Ground of the radio (case, 0 Volt)

Standard FSK connection cable

for transceivers with 9600 Baud FSK Capability

Since about 1994, the industry begun to produce amateur radio transceivers with the necessary inputs and outputs for 9600 Baud FSK. The transceivers of Kenwood, Azden Alinco, Yaesu, ICOM use the same connector and pinning and are easy to connect to a FSK9600. The radios have a 6 pin mini-DIN socket (same type as for PS/2 keyboards). You have to make a simple cable with a 6 pin jack on the one side and the 5 pin DIN jack on the other. Just connect the pins 1 to 1, 2 to 2, 3 to 3 and 4 to 4. Pins 5 (and 6) remain unconnected. As it is difficult to solder the tiny 6 pin jack it is better to buy a ready-made PS/2 keyboard extension cable, cut it into two pieces and attach the 5 pin DIN connector. Read the manual of the radio, how the FSK mode is to be enabled and how to adjust sensitivity. If the demodulator output voltage exceeds 0.5 volt, it is a good idea to reduce it to that level by soldering a voltage divider into the cable plug.

TRX4S, Kenwood, Yaesu, Azden etc.

TRX4S, TM733, TM455, TM251, TM451, TM-V7E, Azden PCS9600, Yaesu FT8500 etc. with 6 pin mini-DIN DATA-socket:

Modem Pin 1	*(MOD)*	*radio Pin 1*	*Data in, packet data input*
Modem Pin 2	*(GND)*	*radio Pin 2*	*Ground*
Modem Pin 3	*(PTT)*	*radio Pin 3*	*PTT, 'standby'*
Modem Pin 4	*(DEMOD)*	*radio Pin 4*	*Data out, 9600 Baud packet output*

TEKK KS960 Tnet Mini

9-pin sub-D plug (socket at the transceiver)

Modem Pin 1	*(MOD)*	*radio Pin 4*	*Transmit Data in*
Modem Pin 2	*(GND)*	*radio Pin 2*	*Ground*
Modem Pin 3	*(PTT)*	*radio Pin 3*	*PTT Line*
Modem Pin 4	*(DEMOD)*	*radio Pin 5*	*Receive Data out*

Reduce data out voltage via a 1:3 voltage divider (22 kΩ in series, 10 kΩ parallel) to 0,5 volt.

Set up of FSK9600

DIP-switches of FSK9600

Note: The modem is fixed in the TNC3 or TNC31 bottom-up. The following descriptions refer to the FSK9600 board with the component side UP! 'Arrow down' means 'switched in direction to the modem printed circuit board = direction to the upper / top side of the TNC. The enumeration of the switches is shown on the rear panel of TNC3/31: switch 7 left side, switch 1 right side.

Watchdog (switch 1)

The modem can key a transmitter only for short time. If the time limit is exceeded, the PTT is released to prevent accidental continuous transmission. This circuit is called 'watchdog'.

For full-duplex applications of for test purposes, the watchdog may be disabled:

1	2	3	4	5	6	7	Watchdog
⇓	×	×	×	×	×	×	disabled
⇑	×	×	×	×	×	×	enabled (default)

(switch up = open = high signal)

Continuous transmission, (switch 2)

With switch 2, the transmitter may be keyed permanently for test purposes. The watchdog is not active when switch 2 is ON. For normal operation, switch 2 has to be set to 'OFF'

1	2	3	4	5	6	7	PTT, transmitter keying
×	⇓	×	×	×	×	×	transmitter keyed permanently
×	⇑	×	×	×	×	×	PTT controlled by TNC (default)

(switch up = open = high signal)

As long as the transmitter is keyed, the output signal is not muted.

Bit-Error-Test (switch 3)

When the bit-error-test is enabled ("BERT") the transmitter is set to 'constant zero'. At the remote receiver, you may check if 'one'-bits are received. Those bits would show a transmission error. With the BERT-mode, you can easily set the optimum transmit filter.

NOTE: when bit-error-test is enabled, normal data transmission is NOT possible! A frequent error, as all seems to operate normal but instead of the data only a idle signal is generated.

Bit-Error-Test	1	2	3	4	5	6	7	Remark
off	×	×	⇑	×	×	×	×	normal modem mode
on	×	×	⇓	×	×	×	×	bit-error-test enabled

Setting the transmit filter characteristics (switch 4-7)

The switches 4, 5, 6 and 7 define the coefficients of the G3RUH transmit filter. The best setting can only be found by measuring the eye diagram or the bit error rate at the remote receiver and trying all 16 possible filter characteristics. In most cases, if the transceiver has no significant nonlinearity in frequency and phase response, the setting '0000' (loop-back) is best.

Filter-setting	1	2	3	4 (1)	5 (2)	6 (4)	7 (8)	Filter-type
0	×	×	×	⇓	⇓	⇓	⇓	Loop-back-setting (good for most radios)
1	×	×	×	⇑	⇓	⇓	⇓	Filter No. 1
2	×	×	×	⇓	⇑	⇓	⇓	Filter No. 2
3	×	×	×	⇑	⇑	⇓	⇓	Filter No. 3
4	×	×	×	⇓	⇓	⇑	⇓	Filter No. 4
5	×	×	×	⇑	⇓	⇑	⇓	Filter No. 5
6	×	×	×	⇓	⇑	⇑	⇓	Filter No. 6
7	×	×	×	⇑	⇑	⇑	⇓	Filter No. 7
8	×	×	×	⇓	⇓	⇓	⇑	Filter No. 8
9	×	×	×	⇑	⇓	⇓	⇑	Filter No. 9
10	×	×	×	⇓	⇑	⇓	⇑	Filter No. 10 (sometimes good)
11	×	×	×	⇑	⇑	⇓	⇑	Filter No. 11 (sometimes good)
12	×	×	×	⇓	⇓	⇑	⇑	Filter No. 12 (sometimes good)
13	×	×	×	⇑	⇓	⇑	⇑	Filter No. 13
14	×	×	×	⇓	⇑	⇑	⇑	Filter No. 14
15	×	×	×	⇑	⇑	⇑	⇑	Filter No. 15

(switch up = open 0 high ; S4=LSB, S7=MSB

Solder jumpers on FSK9600

Jumper J11 "RX-muting

When receiving, the transmitter output of the modem is muted. If the modem output has to generate a idle signal even when the PTT is not active, cut the trace on the solder side and solder a jumper to ground (marked 'OFF'). For muting, the EPROM has stored a constant 7F bias voltage programmed.

Jumpers DP, DD, DB "DCD ext"

Connecting DD and DB and orienting diode CR4 with cathode to DB (reverse to the direction shown in the schematic diagram), the FSK9600 can output a DCD-signal via pin 5 of the DIN-connector to another modem or to another device.

Connecting DD and DB and orienting CR4 with anode to DB (as schematics), the FSK9600 may receive DCD signals from another modem or circuit via Pin 5.

Connecting DD and DB and replacing CR4 by a wire jumper, the DCD of two modems can be 'ored', i.e. both modems show identical DCD signals. Result: the TNC recognises the channel 'not busy' only if both modems display 'not busy'.

Connecting DP and DB (Diode may be short circuited) the FSK9600 may output a PTT-Signal via pin 5 of the DIN-connector to another modem. (Pin 5 is pulled to ground when the modem keys the transmitter)

Connecting DD, DP and DB and replacing CR4 by a wire jumper, the FSK9600 may receive a DCD signal from and outputs a PTT signal to another modem. Both signals are 'ored'. so, the transmitter will be disabled when one of both modems detects a carrier or if one of the modem is transmitting. This setting is required to operate via combined digipeaters with e.g. 1200 + 9600 baud capability on a single frequency.

Test pins

J1 (VCC): Power + 5 Volt

J2 (GND): Ground

J3 (RXC): Receive clock from clock recovery circuit. Synchronise your scope with this signal to watch the eye diagram of the receiver.

J4 (RX): Comparator output, demodulated data signal.

J5 (RXE): Signal at the data comparator input. Connect the oscilloscope here for watching the eye-diagram.

J6 (RXD): Receive data (after de-scrambler). If the remote transmitter is in BERT mode, you should see a constant signal here. Every transition (high level double pulse) represents a transmission error. A good link should have much less than one error per second.

J7 (TXC): Transmit clock (constant 9600 Hz frequency. Trigger your scope with this clock for testing the transmit signal eye diagram.

J8 (TXE): Transmit signal unfiltered.

J9 and J10: not connected.

Special versions of FSK9600

Odd baudrates

By changing the quartz oscillator, any desired baudrate is possible. The frequency divider may be selected with the jumpers M1...M5. The analog filters have to be selected accordingly. (see below)

Paralleling the modem outputs

You cannot connect the outputs of two modems (e.g. FSK9600 and AFSK1200) in parallel. If a transceiver is to be modulated by two modems, the outputs of the modems have to be properly added with a resistor network or with an active op amp adder circuit.

Baudrates up to 76800 Baud

The FSK9600 can be configured to run speeds of 4800 to 76800 Baud if the analog filter capacitors are properly selected. With high baudrates, the EMI-filters (F3, F4) should be removed and replaced by lower capacity types. There are 7 capacitors which determine the characteristics of the transmit anti-aliasing and of the receive lowpass filter. By changing these capacitors, the FSK9600 may be used for other baudrates. For Baudrates below 4800 Baud, the quartz oscillator has to be replaced by a lower frequency type or a divider stage has to be added. The coupling capacitors have to be checked for low baudrate applications as well. The values of the capacitors are inverse proportional to the baudrate. If you like, you may adapt the time constant of the watchdog according to the baudrate. The delay of the carrier-detect circuit (C2) should be increased for low baudrates and decreased for higher speed to get a faster response of the DCD.

The FSK9600 may be used for extreme low baudrates (e.g. 110 Baud), when the lower cut-off frequency of the coupling capacitors and the radio link itself is able to transmit very low frequencies (maybe below 1 Hz). The AF spectrum will go from 1/300 up to 1/2 of the baudrate and could be transmitted as sub-audible FSK together with a FM-audio modulation.

The baudrate is determined by the quartz oscillator and the frequency divider settings and by the values of the analog filter circuit.

For special applications, the modem may be configured to get different baudrates for transmit and receive. (e.g. RX 38400, TX 9600 for satellite communication). You should check the schematic diagram for selection of filter components and additional traces. We can help you with detailed modification plans. Just write to us (info@symek.com).

The modem main clock may be selected by a wire jumper. As default, 9600 baud is programmed by a trace on the board. For other baudrates, cut this trace and solder a wire from MC to the selected pin M1, M2, M3, M4 or M5.

Baudrate	Pin	connect:	Jumper	Signal spectrum
4800 Baud	M1-MC1	● ○ ○ ○ ○ ●	4800-COM	15 Hz ... 2,5 kHz
9600 Baud	M2-MC1	○ ● ○ ○ ○ ●	9600-COM	30 Hz ... 5 kHz
19200 Baud	M3-MC1	○ ○ ● ○ ○ ●	19k2-COM	60 Hz ... 10 kHz
38400 Baud	M4-MC1	○ ○ ○ ● ○ ●	38k-COM	100 Hz ... 20 kHz
76800 Baud	M5-MC1	○ ○ ○ ○ ● ●	76k-COM	100 Hz ... 40 kHz
153600 Baud	M4-MC1	○ ○ ○ ● ○ ●	38k-COM	200 Hz ... 80 kHz

According the baudrate, the 7 capacitors of the lowpass filters have to be changed. Prefer polycarbonate capacitors or (for lower capacities) high-Q ceramic NP0 multilayer chips. Never use the brown HDK capacitors with Z5U or X7R ceramic: they have low Q and a immense temperature drift. The 1 nF EMI-filter should be changed to 100 pF types or just omitted (use 5 mm 100 Ohm resistors for replacement) or just cut the ground wire of the filters.

Dimensioning the analog filters for 4800 to 76800 Baud

Part	4800	9600	19200	38400	64000	76800
U10	2,45 MHz	**2,45 MHz**	2,45 MHz	2,45 MHz	2,048 MHz	2,45 MHz
Wire Jumper	M1	**M2**	M3	M4	M5	M5
C2	0,22 µF	**0,1 µF**	47 nF	22 nF	15 nF	12 nF
C8	1000 pF	**470 pF**	220 pF	220 pF	470 pF	470 pF
C9	6800 pF	**3300 pF**	1500 pF	470 pF	470 pF	470 pF
C10	2200 pF	**1 nF**	470 pF	470 pF	1000 pF	1000 pF
C11	2200 pF	**1000 pF**	470 pF	220 pF	150 pF	120 pF
C12	220 pF	**100 pF**	47 pF	47 pF	100 pF	100 pF
C13	220 pF	**220 pF**	220 pF	220 pF	220 pF	220 pF
C14	2200 pF	**1000 pF**	470 pF	220 pF	150 pF	120 pF
R6	56 k	**56 k**	56 k	27 k	8,2 k	8,2 k
R7	82 k	**82 k**	82 k	39 k	12 k	10 k
R8	27 k	**27 k**	27 k	15 k	3,9 k	3,3 k
R10	39 k	**39 k**	39 k	18 k	5,6 k	4,7 k
RN3 Pin 1-2	100 k	**100 k**	100 k	47 k	15 k	12 k
RN3 Pin 3-4	100 k	**100 k**	100 k	47 k	15 k	12 k
FM-Deviation	± 1,5 kHz	**± 3 kHz**	± 6 kHz	± 12 kHz	± 20 kHz	± 25 kHz
IF-Bandwidth	8 kHz	**15 kHz**	30 kHz	60 kHz	100 kHz	120 kHz

To change the resistor values of RN3 1-2 and RN3 3-4, you can replace the complete resistor network by 5 single resistors. A simpler way is to solder resistors (best: 0805 SMD types) in parallel to the network to get the desired values.

Baudrates above 76800 Baud

The FSK9600 has been used for baudrates up to 1.2 Mbaud. For baudrates above 76k, there are major modifications necessary. Especially the OP-amp is only useable for speed below 100 kbaud and has to be replaced by a faster type. For speeds above 500 kbaud, the anti-aliasing filter cannot be used and the transmit signal should be tapped directly at the D/A converter output. (ZN429 Pin 4, J8, TXE) The quartz oscillator may be changed to 9,8304 or 19,6608 MHz. A thorough test of such a special modified modem is recommended to get best results. Ask us for special hints on such modifications (info@symek.com). High speed data links with a modified FSK9600 in 1.2 Mbaud full-duplex mode are running for years with no problems.

The receive filter was developed for speeds up to 76k. For higher speeds, you have to watch the same points as with the transmitter: A lowpass filter is required, which attenuates frequencies above the half baudrate. The used filter must be linear in phase (constant group delay) within the pass band (use Bessel-type). For very high baudrates, the comparator input (RXE) may be connected directly to the radio demodulator (spurious rf from IF amplifiers must be suppressed and filtered)

For transmission and reception of signals with baudrates above 9600 baud, the standard transceivers are not suited. Those radios have been developed as speech-audio transceivers but not for high speed data applications. Best suited for up to 153 kbaud is the SYMEK-data-transceiver TRX4S. For higher speed, video transmitters (ATV) with a bandwidth from 300 Hz to 500 kHz or more are possible. Modulating the oscillator of a simple satellite-LNC (modified for 10 GHz amateur band) with 1 Mbit/s is possible, the range of such transceivers may exceed 30 km depending on the antennas. Before selecting a radio for high speed applications, calculate the influence of the TX-delay (time from keying a transmitter to stable data at the receiver). A normal FM-radio has a delay of 100 to 300 ms, which will reduce the throughput to 50% and below with 9600 baud packets. As AX.25 HDLC-controller, there exists until now only the TNC3 or TNC31 which is capable to handle such high data rates.

Modification for 153600 Baud

Solder a wire jumper M4-MC1 (as with 38400 Baud). Remove: U1, U10, RN2, RN3, R6, 7, 8, 9, 10, C8, 9, 10, 11, 12, 13, F3, F4. Solder new parts: RN3 Pin 1-2: 8,2kΩ; RN3 Pin 3-4: 8,2kΩ; RN3 Pin 5-6: 8,2kΩ; RN3 Pin 7-8: 47kΩ; RN3 Pin 9-10: open. Replace OP-Amp by faster type TL064 or equiv. Solder new parts: RN2 Pin 1-2: open; RN2 Pin 3-4: open; RN2 Pin 5-6: 1,5kΩ; RN2 Pin 7-8: 1,5kΩ; RN2 Pin 9-10: 1,5kΩ. Replace oscillator U10 by 9,8304 MHz type. Solder new parts: R6: 5,6kΩ; R7: 4,7kΩ; R8: 1,8kΩ; R9: open; R10: 2,7kΩ. Solder new parts: C8: 220 pF; C9: 220 pF; C10: 470 pF; C11: 68 pF; C12: 47 pF; C13: 100 pF; C14: 470 pF. Replace filter F4 and F3 by wire jumper with a ferrite bead. FM-deviation: approx. ±50 kHz, bandwidth of RX-IF-filter: 250-300 kHz.

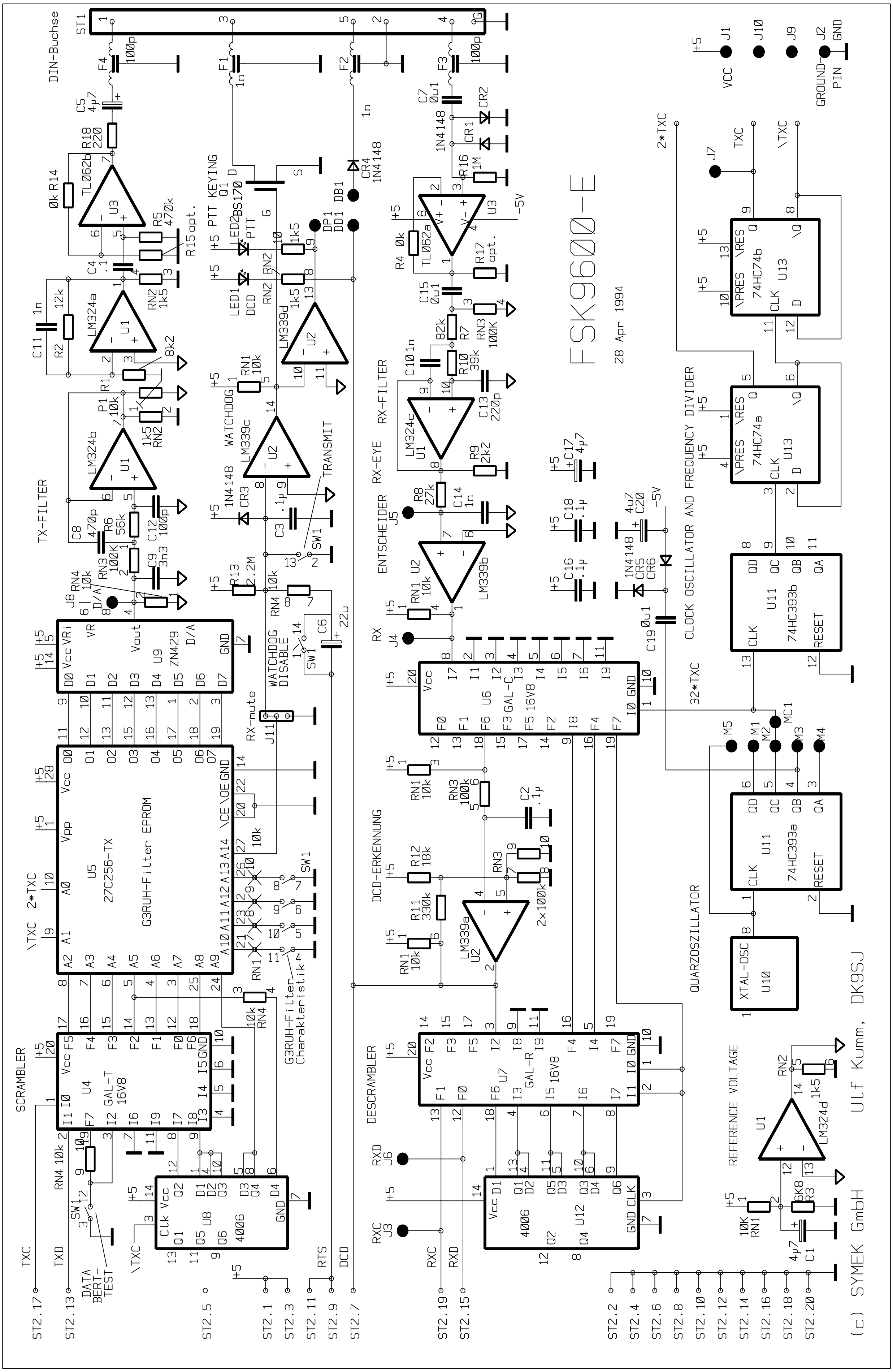
Increase of output voltage

If necessary, the output amplifier may be changed to increase output voltage. The default 1 volt should be sufficient in most cases, but adding negative feedback resistors will increase output to up to 7 volt:

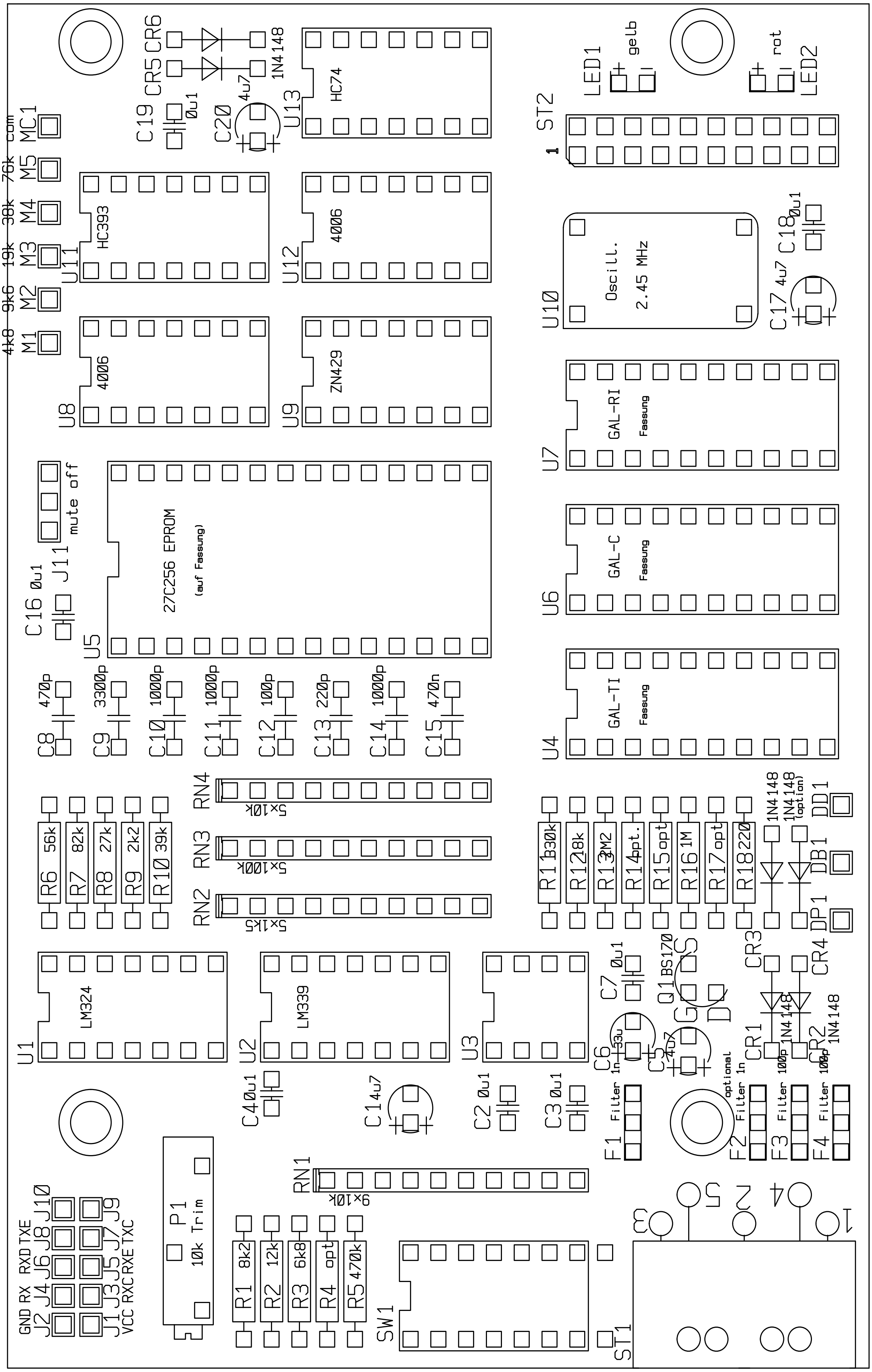
Output voltage (pp)	Gain	R14	R15
max. 2 V_{pp}	1	0 Ω (Jumper)	∞ Ω (open)
max. 7 V_{pp}	3-4	5,6 kΩ	2,2 kΩ

The trace shorting R14 has to be cut.

Schematics modem FSK9600-E



Component location modem FSK9600-E



Parts list modem FSK9600-E

U1	LM324 quad op-amp (DIL14)
U2	LM339 / MC3302 quad comparator (DIL14)
U3	TL062 dual FET-op-amp (DIL8)
U4	GAL-TI (NRZI) or GAL-T (NRZ) + socket (DIL20)
U5	27C256 G3RUH-filter-EPROM (upper=7F)+ socket (DIL28)
U6	GAL-C + socket (DIL20)
U7	GAL-RI (NRZI) or GAL-R (NRZ) + socket (DIL20)
U8, U12	MC4006 shift reg. (DIL14)
U9	ZN429 D/A converter (DIL14)
U10	Quartz oscillator 2,45760 MHz (DIL14-metal)
U11	74HCT393 double 4-stage binary counter (DIL14)
U13	74HCT74 Dual Flipflop (DIL14)
Q1	BS170 VMOS-FET plastic
F1,3,4	EMI-filter 1 nF L-C-L (F2=optional)
SW1	DIL-switch 7 (8)-polig, 'piano type'
ST2	20-pol (10x2) ribbon pin connector
C8*	470 pF 5% WIMA FKP2 (9600 Baud)
C9*	3300 pF 5% WIMA FKP2 (9600 Baud)
C10*, 11*, 14*	1000 pF 5% WIMA FKP2 (9600 Baud)
C12*	100 pF 5% WIMA FKP2 (9600 Baud)
C13*	220 pF 5% WIMA FKP2 (9600 Baud)
C15*	470 nF 10% WIMA MKP2 (9600 Baud)
P1	10 kΩ trimmer 20 turn

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The modem cannot be operated independently. So, it is a complex component and there is no need for a EMI certification (CE-sign). When the modem is to be used in systems other than TNC3 or TNC31, the EMI regulations have to be observed.

Users manual FSK-Modem FSK9600-E **printed A5 version** **Issue: 14.05.2005**

Production and distribution: SYMEK GmbH, Datentechnik, Ulf Kumm, DK9SJ http://symek.com
Address: D-70597 Stuttgart (Sonnenberg), Johannes-Krämer-Straße 34
Phone: +49 711 76 78 923, Fax: +49 711 76 78 924, Hotline: +49 711 76 54 911, e-mail: info @ symek.com