Trouble Shooting Guide T20, Advanced

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1 General

The T20s is a dual band phone and has the same size as T28s, but a new industrial design with:

- **Test program integrated in the Signalling software.**
- WAP (Wireless Application Protocol), that is a specification designed to adapt Internet content to be viewed in a mobile phone display.;
- Hierarchical phonebook for group numbers according to personal profile;
- A radically improved talk and standby times.
- A connector at the bottom of the phone makes it possible to connect various accessories like chargers and hands-free units.

2 Logic

2.1 General

The purpose of the logic part is to control and monitor the transmission and reception functions of the mobile phone and maintain contact with the mobile phone system. The logic therefore has links with all the relevant parts of the radio. Its functions, with reference to the radio, include selection of radio channel and control of the transmitter power. It also generates the base-band modulation after burst building, encryption, channel coding and demodulates the received base-band signal including equalisation, decryption and channel decoding.

Its functions, with reference to the audio parts, include opening and closing of speech paths and volume control of the earphone, Speech codec and PCM A/D and D/A are also performed here, together with the appropriate audio frequency filtering.

The external tasks of the logic part include monitoring and control of links with the control unit and power supply and also the communication to the SIM and external units connected to the external connector.

2.2 Power supply

A battery must always be attached to get the phone powered up.
The battery voltage is fed through the battery connector on the Printed Circuit Board. Then it is linked through the Printed Circuit Board to N700, which contains the regulators for the baseband and radio part.

The different voltages are:

VBATT (3.6V) is the unregulated battery voltage.
VDIG (2.75V) is used for D600 baseband pads and for the mixed mode circuit N800.
VCORE (1.8V) is used to supply the D600 core and the memories.
VRAD (2.75V) is used to supply the radio circuits.
VRTC (2.75V) is used to supply the RTC block in D600. The regulator for this voltage is always powered up when a battery is connected and cannot be switched off.
SIMVCC (3 or 5V) is used to supply the SIM. A DC/DC converter in N700 generates SIMVCC. It steps up the VDIG voltage to 3 or 5V.

An error flag output, PWRRST, is generated by N700 that warns for low battery voltage. When N700 detects a VBATT level out of limits, the signal PWRRST goes low. This will cause a reset to D600. N700 will turn off the regulators and power down the phone.

The signal PWRRST is also, the power reset to D600 at power up. PWRRST will be changed from low to high when the voltages from the regulators inside N700 have stabilized.

2.3 On/Off function

A battery must always be attached to get the phone powered up. The phone can be started from the keyboard, from the system connector or from the clock alarm.

2.3.1 Switching On the phone with On/Off key

When the ON/OFF button is pressed, the signal ONSWa is connected to ground through V610. This will cause N700 to check the VBATT level. If VBATT is within limits N700 will power up the regulators and the serial interface. By doing this, the rest of the phone is powered up.

One of the first things the CPU has to do at power up is to keep the regulators powered up. By sending a command on the I^2C interface from D600 to N700 that is done. After that the ON/OFF button can be released.

2.3.2 Switching On the phone from the system connector

The phone can also be started from the system connector by pulling the ONSRQn signal to low level, if the signal SERVICEIn is set to low (VPPFLASH on system connector high). This signal is connected to the ONSWb pin on N700. When ONSWb is pulled to low level, N700 will check the VBATT level and power up the regulators in the same way as when starting the phone with the ON/OFF button.

2.3.3 Auto turn on

The CPU will automatically switch on, if a charger is connected. N700 will sense the voltage difference between DCIO and VBATT created by the connected charger. If VBATT is within limits (>3.3V) N700 will power up the regulators. If VBATT is too low, a current generator inside N700 will charge the battery with a small current (trickle charge), and when VBATT reaches the lower limit, the regulators and the phone will power up.

2.3.4 Alarm

The phone is switched on at Alarm from the RTC. A signal, ONSWAn is set to high directly from the RTC block with no influence from the CPU, which in this state has no power. This will cause N700 to check the VBATT level. If VBATT is within limits N700 will power up the regulators and the serial interface. By doing this, the rest of the phone is powered up.

One of the first things the CPU has to do at power up is to keep the regulators powered up. By sending a command on the I^2C interface from D600 to N700 that is done.

2.3.5 Switching Off the phone

By pressing the ON/OFF button KEYROW 0 is grounded through V610. D600 senses the signal and the Software can turn off the regulators inside N700 by using the serial I^2C interface.

2.4 Charging

A simplified circuit diagram for the regulation of the charging current is shown below.

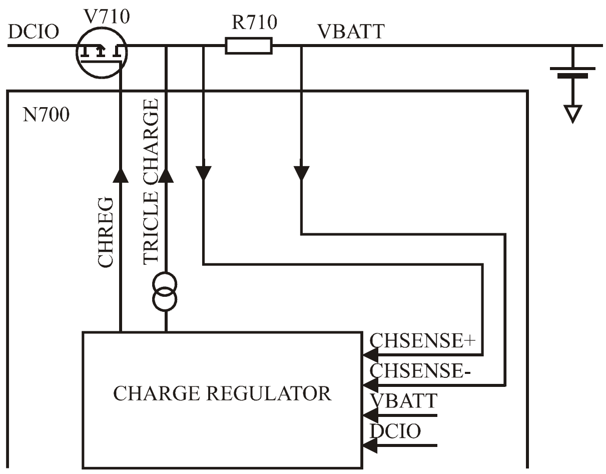


Fig. 2.1

The charge regulation is placed in N700. The charging starts when a charger is connected to DCIO (system connector). N700 detects DCIO and checks if battery voltage VBATT is within its limits.
If the battery voltage is too low, the regulator starts charging with a built-in constant current generator in N700. A small current, called *Trickle Charge* is fed from DCIO through CHSENSE+ and R710 to VBATT.
When N700 detects that the battery voltage is within its limits, the ordinary charging starts. N700 regulates the charge current linear with the signal CHREG and the transistor V710 with consideration of the battery voltage and the charge current. Information about the charge current is achieved by measuring the potential drop over the resistor R710 with the signals CHSENSE+ and CHSENSE-.

In the first phase of the charging, the battery is charged with constant current (~300mA for Li-Polymer Ultra Slim Battery). When the battery voltage has increased to a defined voltage the charging changes to constant voltage. The battery voltage is kept constant and the charge current decreases. When the charge current decreases below a defined level, it is showed in the display that the battery is fully charged.
The charge regulation has over voltage and over current protection whenever DCIO is connected. When any of these limits are reached the transistor V710 shall be turned off immediately. If the over voltage limit is reached N700 shall turn off.

2.5 Battery

The phone is powered from a rechargeable LiIon or LiPolymer battery with different options on capacity. The nominal voltage is 3,6V and the battery is easy to replace.
The new Lithium cells used for 3V platform can explode or react aggressively if they are not charged according to specification. For that reason the battery pack includes a safety system which automatically switches off charging or discharging if stated limits are exceeded. The battery pack also includes a microprocessor used for battery identification.

2.6 Real Time Clock

The real time clock is a part of the D600 chip. A 32.768 kHz crystal (B600) is placed close to the inputs on D600. The RTC block is supplied with a separate voltage, VRTC (2.75V). A regulator in N700 generates it.
The RTC is always powered as long as the main battery is connected. On the output of the regulator one backup capacitor(C720) is connected. This capacitor will give power enough to keep the RTC alive at least 6 hours after the main battery has been disconnected. The backup capacitor is a coin type rated 2.5V.

2.7 Keyboard scanning

The function of the keyboard is build of nine signals connected as a matrix with five rows and four columns. The rows are called KEYROW 0 – 4 (CMOS inputs with internal pull-ups) and the columns KEYCOL 0 – 3 (open drain outputs). Each crossing between a row and a column can be used as an identification of a key.

The rows are fed by a voltage directly from the processor, giving the rows a voltage of 2.75V. When pressing one of the keys of the keyboard turns one of the KEYROW 0 – 4 low. By doing so the processor knows that a key is pressed and the software should start the scanning of the keyboard to identify which key is being pressed.
If the scanning cannot find an active column it means that the No key or the flip switch is activated. Checking witch KEYROW is being used can separate the keys. The No button grounds KEYROW 0 and the flip switch grounds KEYROW 4.

2.7.1 Flip Switch

For the flip switch a hall device is used. A hall device is a Magneto-electric Conversion Switch with an open collector output. When a magnetic field with the right polarization is applied on the hall device, it lowers its output.
The processor switches the supply voltage to the hall device with the signal HALL by the transistors V630 and V631. This is done to decrease the current consumption.
When the flip is closed (a magnet is placed into the flip), a magnetic field is applied on the hall device. In the next supply voltage pulse, the hall device lowers its output and grounds KEYROW1. The software starts the scanning of the keyboard and identifies that the flip is closed.

It is possible to measure at the flip switch with an oscilloscope.

2.8 LCD Voltage Regulation

For best performance concerning viewing angle and contrast ratio, the VLCD voltage to the LCD has to be regulated quite precisely. D600 is used for this purpose.

The display is controlled by the processor with serial data through an I^2C-bus (Inter IC). The I^2C-bus consists of two lines, I2CDAT for data and I2CCLK for clocking.

To get as good readability as possible of the display in different angles and to get clear contrast, the display has to be regulated exactly. The contrast is controlled by a voltage, VLCD. It is achieved with two PWM signals, Pulse Width Modulation, from the processor and some discrete components.

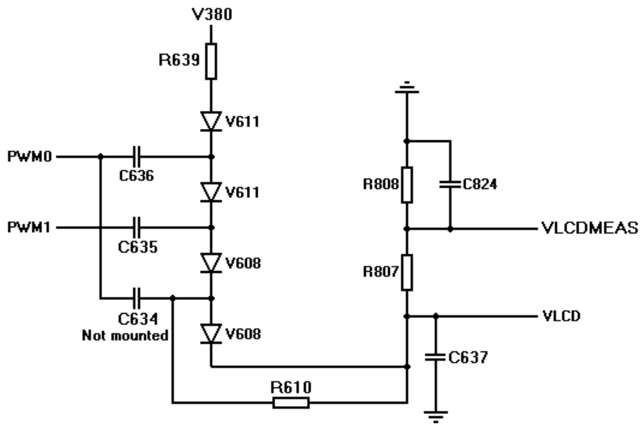


Fig. 2.2

2.9 Illumination

The keyboard illumination is made up of an electroluminescent lamp (EL-lamp). The EL-lamp requires high voltage to work, which is generated by N750. It generates an AC output of up to 170Vpp and 250Hz over the EL-lamp.

N750 is controlled by the two digital CMOS signals: EL-HIGH (PWM1) and EL-LOW (PWM2). Both signals are generated directly in D600. In this way, no external components are needed between D600 and N750.

N750 consists of a DC/DC boost converter and a current limited H-bridge.
A high voltage switching transistor and diode is included in boost converter. The converter will be operating in burst mode to conserve power. A high level on EL-HIGH (PWM1) turns the switching transistor on. When the booster output voltage has reached its upper limit, a built in voltage limiter turns off the switch transistor.

By increasing/decreasing the duty cycle on EL-HIGH, the output voltage to the EL-lamp can be increased/decreased. In this way, the brightness of the film can be changed.

An H-bridge and the signal EL-LOW transform the high voltage generated by the boost converter into an AC-voltage over the EL-lamp. The capacitor in the lamp is charged when EL-LOW is high and discharged when EL-LOW is low. The outputs from the bridge are current limited and will generate triangular voltages to minimise audible noise.
The drive of the output stage is set by resistor R750 connected between the REF pin and GND.

Principle waveforms are shown below.

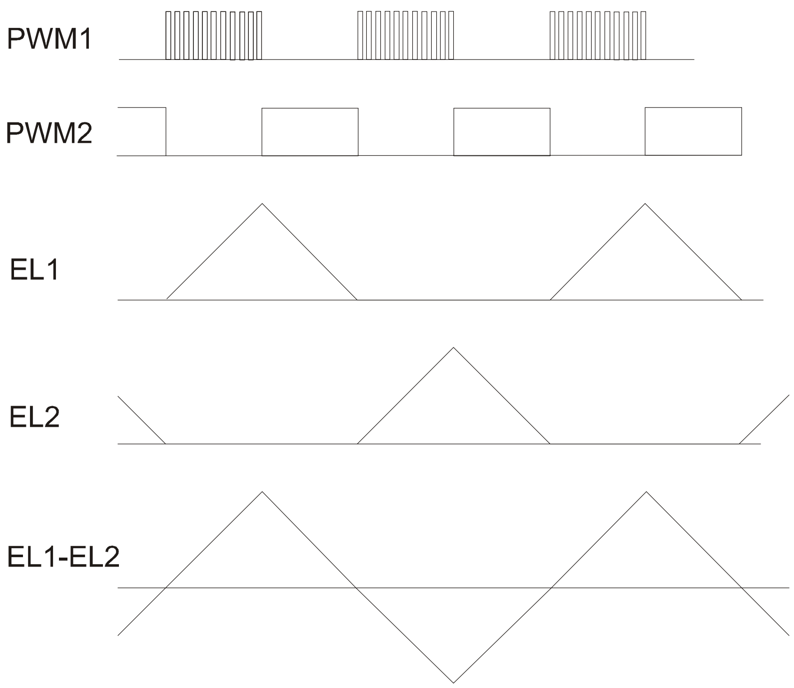


Fig. 2.3

2.10 Buzzer and top indicator

The buzzer is supplied with voltage directly from VBATT. The sound pressure in the buzzer will drop as the battery voltage goes down. This can be Software-controlled by adjusting the duty cycle.

The buzzer is controlled from D600 by the signal BUZZ. Transistor V606 switches the current through the buzzer.

The top LED is supplied by VDIG. Both the red and green LED are directly driven by output ports on D600, no external transistors are used.

2.11 Audio

A general block diagram for the GSM phone is shown in *Fig. 2.4* below.

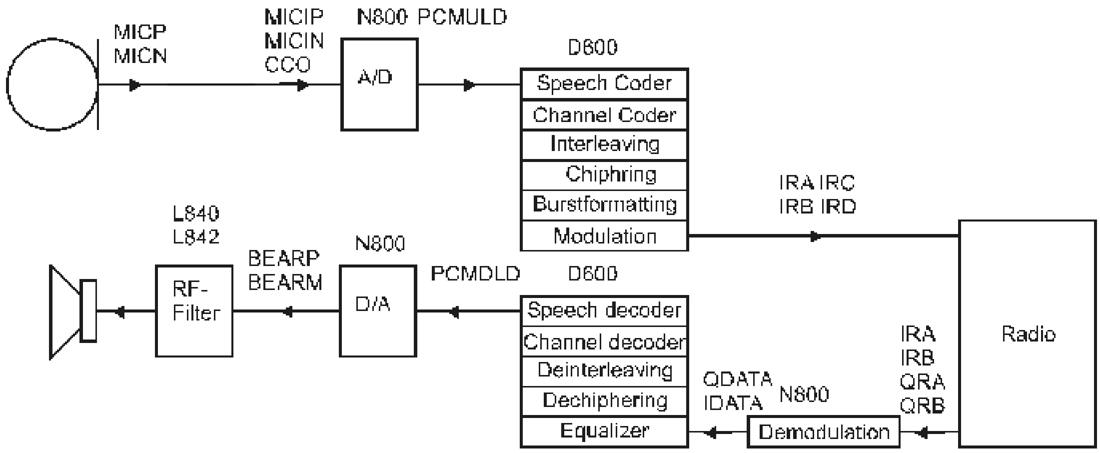


Fig. 2.4

It shows the data flow (speech) through the GSM phone. It also indicates the different hardware parts involved in the transmission.

D600 controls the data flow. This is the central unit containing the microprocessor, DSP, internal RAM and the interfaces to external circuits and units, external memories and the radio. It also performs a lot of the signal processing not done in the other circuits.

N800 communicates with D600 by means of the I^2C interface. Settings, readings and control of N800 are made on this interface.

2.11.1 Tx audio

The microphone is an electret condenser microphone of noise cancelling (bi-directional) type. It is delivered with flexible printed circuit that contains a RF rejection filter and a sensitivity adjustment filter. The microphone and the flexible printed circuit are mounted in the flip.

The microphone is biased by a reference signal, CCO, from N800, which is filtered on the circuit board and inside N800.. In the microphone path is also a high pass filter, designed to cut frequencies below approximately 300 Hz.

The speech signal from the microphone is fed to the inputs MICIP and MICIN of N800. The signal is very low, nominally 5- 10mV$_{rms}$ and must be amplified. The amplifier in N800 is adjustable to compensate the different sensitivity in different microphones. A calibration is performed when the phone is manufactured.
There also is an input for external audio that can be used either as an alternative high-level source of speech or a low level source from an external microphone.
The amplified signal is digitized to a 16 bit-PCM signal, filtered and fed to D600 as the signal PCMULD.
It is sliced into 20 ms pieces and thereafter speech coded in the DSP (part of D600) to reduce the bit rate.
Further data processing is carried out in D600 that includes channel coding, interleaving, ciphering and burst formatting. The data is then sent to the radio as digital modulation signals MODQN, MODQP, MODIN and MODIP.

2.11.2 Rx audio

The signals IRA, IRB, QRA and QRB from the radio are hard limited phase modulated and differential signals that contain all the data received. These signals are demodulated by a fast phase digitizer in N800. The phase information is then fed to D600 as QDATA and IDATA.
The received bursts are then further processed in D600 mainly in the same way as in the TX path but in reversed order and with reversed functions, that is deciphering, deinterleaving and channel decoding.
The first step in D600 is however an equaliser that performs a Viterbi algorithm to create a channel model. After all eight half bursts have been received and deciphered, they are reassembled into a 456 bit message. The sequence is decoded to detect and correct errors during the transmission. The decoder uses soft information (probability that a bit is true) from the equaliser to improve error correction.
Finally the bit stream is speech decoded in the DSP (part of D600) and fed to N800 with the signal PCMDLD. The signal is PCM decoded and then fed to a digital volume control and a digital filter. The signal is AD converted and passes an adjustable amplifier. It is used to compensate the different sensitivity in different earphones. A calibration is performed when the phone is manufactured. Finally the audio signal is fed differentially to the earphone with the signals BEARP and BEARM trough a RF-filter to the earphone connector.

2.12 SIM

The logic in the phone uses a supply voltage of 2.75V witch means that all digital signals also have that level. The SIM card uses 3 or 5V supply voltage and data signals. The phone uses a SIM interface between the CPU and the SIM card.
The SIM interface consists of a DC/DC converter and a Level Shifter.
The DC/DC converter sources 3 or 5 V to the SIMVCC output and to the level shifter. The DC/DC converter operates switched and is built in N700. C735 is used for switching and C734 is used to filter the SIMVCC. The DC/DC converter is activated together with the level shifter.
The level shifter is used to increase the voltage level for the signals SIMCLK, SIMDAT and SIMRST from 2.75 to 3 or 5V.

When the phone is started the CPU tries to start the SIM card with 3V signals. If the SIM does not respond the CPU tries with 5V. Because of that the phone T20s has the possibility to work with both 3 and 5V SIM card.

2.13 Memories

The flash memory for the CPU is D610.

It is possible to use flash memories and perform on board programming. The erasing and programming of the flash is then completely software controlled. The software communicates with external equipment through a serial link. During erasing and programming the software runs in RAM which is built in, in the CPU.

To perform programming of the flash, a special hardlock together with the loader software is needed.

To increase the programming time VPP can be supplied. VPP is applied to the system connector on the terminal VPPFLASH. This pin is also used to disable the watchdog function in D600.

2.13.1 CPU flash memory, D610

The flash memory D610 holds the signalling software, temporary data and non-volatile parameters.

The flash memory section is a block architecture memory that includes block selective erasures, automated write and erase operations. The memory is organized as 2048k*16 and is divided into separately erasable blocks.
A part of the memory is used as an emulated EEPROM area. This is called the NVM (Non Volatile Memory) area.
In the same package as the flash memory a SRAM is stacked on top of the FLASH chip. This SRAM is 8-bits wide and is used for temporary data storage during execution. No program code can be executed in this memory. The size of the SRAM is 256k*8.

The flash memory and the SRAM memory are connected to the common address and data bus. For control, the signals ROMCS (ROM Chip Select), RAMCS (RAM Chip Select), OE and WE are used.

2.14 External connectors

External units are connected to the transceiver by means of an 11-pin connector on the bottom of the phone. The pin numbering is starting from the right when looking on the system connector with the front/flip up.

The table below shows pin placement on external connector for accessories.

Pin	Signal	Function
1	DCIO	DC + pole for charging phone battery and external accessory powering.
2	GND	Digital GND and DC return.
3	VPPFLASH	Flash memory Vpp/Service.
4	GND	Audio signal GND, 0 V reference.
5	CFMS/PHFS	Accessory Control From Mobile Station serial (ACB) communication/ Portable Hands Free Sense.
6	CTMS	Accessory Control To Mobile Station serial (ACB) communication.
7	DFMS	Data From Mobile Station, serial bus communication.
8	DTMS	Data To Mobile Station, serial bus communication/ External accessory Power on
9	ONSRQn	Mobile station ON REQuest/ Clear To Send
10	AFMS/RTS	Audio from Mobile station/ Ready To Send
11	ATMS	Audio to Mobile station

A connector for an external antenna is available at the back of the phone. A separate mechanical switch in the antenna connector selects if the normal antenna or an external antenna shall be used. The external antenna connector (the hot pin) is disconnected from the antenna or antenna signal and grounded until an external antenna is connected. When an external antenna is connected, then the main antenna is also disconnected.

The DCIO channel connects an external charger to the mobile phone as well as provides supply to some external accessories, connected to the phone. The DCIO channel is a shunt device, which does not provide the current path for the large battery charge current. This path is provided by a circuit board track external to the device.

The VPPFLASH is used to provide programming voltage to the flash memory in the phone. It is used only at production and service. The signal is also used to provide the internal SERVICE signal, which is used to inhibit the watchdog in the transceiver.

CFMS signal is used to send serial data from the mobile phone to external data equipment as accessories. It is also used as an input to sense the presence of some accessories that do not use the serial data link. As default the signal is kept high by the pull-up resistor. In normal mode the signal is an input to the phone. In active mode the signal is an output.

CTMS signal is used to receive serial data from external equipment as accessories. As default the signal is kept low by the pull-down resistor. The signal is always an input signal.

DFMS signal is used to send serial data from the mobile phone to external data equipment as accessories. This signal is always output from the phone.

DTMS signal is used to receive serial data from external equipment as accessories. As default the signal is kept low by pull-down resistor. The signal is always an input signal.

ONSRQn It is used for external accessory to power on the phone by grounding this signal. The other condition is that the signal SERVICEIn is set to low (VPPFLASH on system connector high).

ATMS is analogue input for external audio signal. The signal has 2V DC bias for direct connection of an electret microphone. It can also be driven from an external AC-coupled amplifier.

AFMS is analogue output for external audio. The output is AC-coupled to its amplifier. The load can be an earpiece or a power amplifier.

MICP and MICN are differential input for electret microphone. The build in RF-filter is effective in common-mode as well as single mode.

3 Radio

3.1 General

A general block diagram for the radio part of the GSM telephone is shown below.

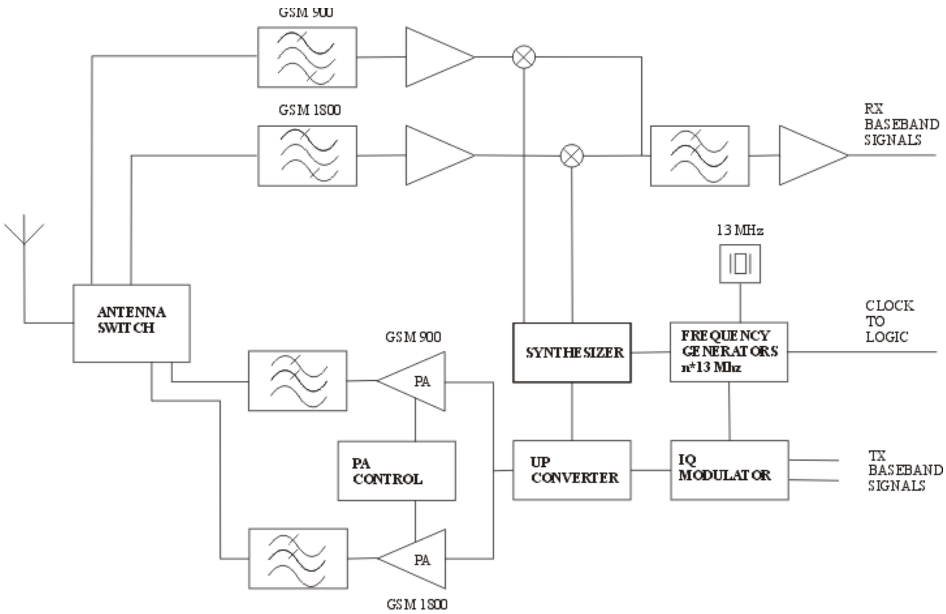


Fig. 3.1

The radio is constructed to select the wanted channel and convert that RF signal to a signal, which can be handled by the logic. This has to be done without transmitting spuriouses disturbing other radio traffic and fulfilling the requirements in presence of disturbing RF signals. In order to minimize current consumption all parts in the radio are only powered up during the needed timeslot.
There are several signals from the logic controlling the radio and its frequency generators.

There is a dual band antenna switch module, aimed for GSM 900 and GSM 1800. The band selection is accomplished by software control. Only one band can be activated in a certain timeslot. The switches are used to select the connection of either the receiver or the transmitter to the antenna.

The main synthesiser is able to operate as a local oscillator for the 900, and 1800 band. The main synthesiser has the dual function of down-converting the wanted RX channel to base band and to down-convert the TX-signal to the TX-IF, which is necessary for the up-converting loop. It is a standard synthesiser working with the channel distance, 200 kHz as reference. Due to the fast switching nature of the GSM signal, special care has been taken to achieve fast switching between channels.

One linear regulator (VRAD) is used to supply the radio with an output voltage of 2.75 V.

3.2 Receiver

The RF signal is fed to the radio through the antenna connector W100. A separate mechanical switch in the antenna connector selects if the normal antenna or an external antenna shall be used. The external antenna connector (the hot pin) is disconnected from the antenna or antenna signal and grounded until an external antenna is connected. When an external antenna is connected, then the main antenna is also disconnected.
After the antenna connector the signal passes the antenna switch. The antenna switch N200 separates the two different bands with the control signals: VTXVCOLB, VTXVCOHB and ANTSW.

The table below shows how the antenna switch is controlled.

Mode	VTXVCO LB	VTXVCO HB	ANTSW
GSM Tx	H	L	L
DCS Tx	L	H	L
GSM Rx	H	L	H
DCS Rx	L	H	H

After the antenna switch there are two different signal paths, one for each band. The signal path consists of a bandpass filter (Z200, Z201) and a BALUN (N201). For GSM 900 Z200 works both as filter and BALUN. It converts the RF signal to a differential signal. Balanced signals are used for minimising noise and other disturbance from, for example supply voltages. When the RF signal has passed one of the three receiver paths it goes to N234.

N234 contains all receive and transmit functions required for a GSM 900/1800 cellular phone. First amplification of the selected band is performed. The band selection control signal BSEL is used to select low or high band operation .

The wanted channel is down-mixed with the quadrature local oscillator signal to a base band signal. The baseband signals are IRA, IRB, QRA and QRB. These signals carry speech and system information. The amplitude still is proportional to the received signal, i.e. if the signal from the antenna becomes higher the I and Q signals also will be stronger.
The I and Q signals are then buffered and lowpass filtered before they are fed to the ADC in N800. The two bands use the same filter and amplifier for the I and Q signals.
The I and Q signals are digitised in N800. The output is presented as two bitstreams IDAT and QDAT. The information goes to the CPU that handles the data. The CPU gets the transmitted speech/system data and information about RSSI.

3.3 Transmitter

3.3.1 Tx synthesiser

The Tx synthesiser in this phone works as an ordinary phase locked loop (PLL). It consists of a VCO, prescaler, phase detector, charge pump and a loop filter.

The Tx VCO generates a RF signal, which is fed to the PA and later to the antenna.
To control the frequency in the synthesiser the RF signal also is fed back to the PLL. In the prescaler, which has the possibility to divide the RF signal with different divide ratios the RF signal is divided to 52 MHz(GSM) and 91MHz(DCS).
The phase detector compares the divided RF signal with the reference frequency at 13 MHz from the crystal oscillator (XO). The phase detector works both on the up going and down going flanks of the reference frequency.

If there is a phase difference in the detector, the charge pump will change the current in the loop filter. The output current from the charge pump CPo is converted to a voltage VTUNE in the loop filter. VTUNE is the control voltage for the Tx VCO, i.e. VTUNE controls the frequency of the Tx VCO output signal. More current from the charge pump will generate a higher VTUNE voltage and a higher frequency out from the Tx VCO.

D600 sends information about different settings to the synthesiser with the signals: SYNSTR, SYNDAT and SYNCLK.

There are some principle differences in this synthesiser compared with older designs:

- There are not any intermediate frequencies (IF) in the transmitter chain.

3.3.2 Power control

The phone T20s uses the PA module N400 for both GSM 900 and GSM 1800. Selection is done with help from the control signal BSEL.

The PA control built in N700 shall regulate the output power of an external PA module. An external reference signal POWLEV is used to control the output power. The reference signal POWLEV is a calibrated voltage from N800 that tells the PA control in N700 which power level that is wanted. The PA control compares the output power with the reference value. Information about the output power is received through measuring the current consumption of the PA module. This is done through measuring the voltage drop over R400. The result of the regulation is a DC voltage, which is fed to the PA module from the output PAREG. Higher voltage on PAREG gives higher output power.

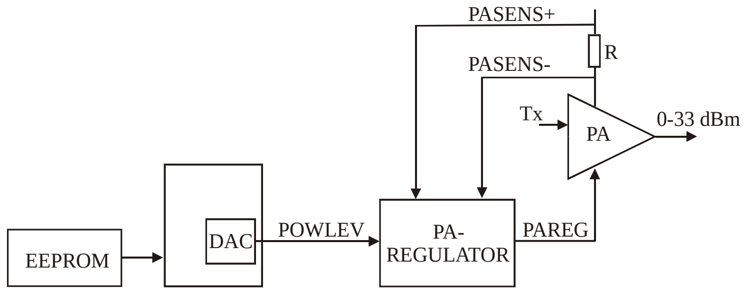


Fig. 3.1

3.4 VCXO

The phone has got a reference crystal of 13 MHz which signal is used for both the radio and the logic.

The frequency fault of both the transmitter and the receiver must be within the valid limits. The phone needs the possibility to control the frequency of the reference crystal to be able to maintain the limits during different circumstances. This is possible since the reference crystal is a Voltage Controlled Crystal Oscillator (VCXO).

The crystal B320, the capacitors C321, C322 and the varicap diode V322 are forming an oscillating circuit (see Radio schematics "Synthesiser and modulation"). By changing the DC voltage on the varicap diode its capacitance changes which changes the frequency of the oscillating circuit. The control voltage for the varicap diode VCXOCONT comes from a DAC in N800.

The range of the DAC is between 0 and 3FF Hex, that is equivalent to a control voltage between 0 and 2.5 V.

The logic uses the clock signal MCLK as master clock and for the synchronisation of the digital circuits of the logic.

The 13 MHz crystal is being trimmed in “tune VCXO”, in the calibration.

4 Measurement, Calibration and Troubleshooting

Parameter	GSM 900		GSM 1800
	GSM	EGSM	
Uplink	890 – 915 MHz	880 – 915 MHz	1710 – 1785 MHz
Downlink	935 – 960 MHz	925 – 960 MHz	1805 – 1880 MHz
Duplex distance	45 MHz		95 MHz
Carrier separation	200 kHz		200 kHz
RF carriers	124	174	374
Physical channels	992	1392	2992

4.1 Measurements on the logic

The table below shows some conditions that the phone has to fulfil to be flashed.

Signal	Measured on	Value
VDIG	C703	2.8 V
VRAD	C501	2.8 V
VCORE	C702	1.8 V
PWRRSTn	TP701	0 V
SERVICE	V600:3	2.8 V
MCLK	C680	350 mV / 13 MHz

4.2 Logic calibration

4.2.1 ADC-calibration

For the processor to be able to control the phone in a correct way it has to know the current battery voltage. The processor cannot use analogue information, therefore it has to be converted from analogue to digital configuration. The VBATT voltage input is CHsense-. The voltage is then AD-converted in N700 before the value of VBATT is sent to D600 through the I2CDAT-bus as an 8-bit serial data word.

To make the measurement of the battery voltage precise it is necessary to perform a calibration. The calibration is performed on two voltages, 3.2 V and 4.1 V in EFRA. The corresponding ADC-values are stored in EEPROM. The ADC-values for other battery voltages are produced by interpolation of the two calibrated voltages.

4.2.2 Bdata-Calibration

The purpose of BDATA-calibration is to check the function and connection of the BDATA signal and calibrate current generator for BDATA.

The calibration is performed in EFRA.

NOTE! The calibration assumes that there is a 100 kΩ resistor is mounted between BDATA and GND at the fixture.

4.2.3 Current calibration

The information about the charging current is achieved by measuring the potential drop over the resistor R710. The current flow is measured in the ADC and is converted to I2C data that is transferred to D600. For detailed description, see chapter *Charging*.

To be able to control the charging in a correct and safe way, the CPU needs the possibility to measure the charge current exactly. That requires a calibration. The calibration is performed on two different currents in EFRA. The corresponding ADC-values are stored in EEPROM. The ADC-values for other charge currents are produced by interpolation of the two measured currents.

After performed Current Calibration verification of the charging function should be done according to 4.2 (with signal software in the phone).

4.3 Verification of the charging function

Attach a battery to the phone. The voltage of the battery should be high enough to start the phone, otherwise the verification will take too much time.

Cut a cable from a battery charger to make a charging test cable.

Connect the charging test cable to a power supply that shows the current consumption. Make sure the positive side from the power supply connects to DCIO (Another method is to use a regular battery charger with an ampere-meter connected in series).

Set the power supply to 5.0V and the current limit to 650 mA.

If the phone starts, shows charging and the current consumption is 100-350 mA (usually ~300mA), the charging function is probably working correctly.

4.4 Audio in EFRA

The figure below shows a simplified schematic over the paths of the audio signals when measuring.

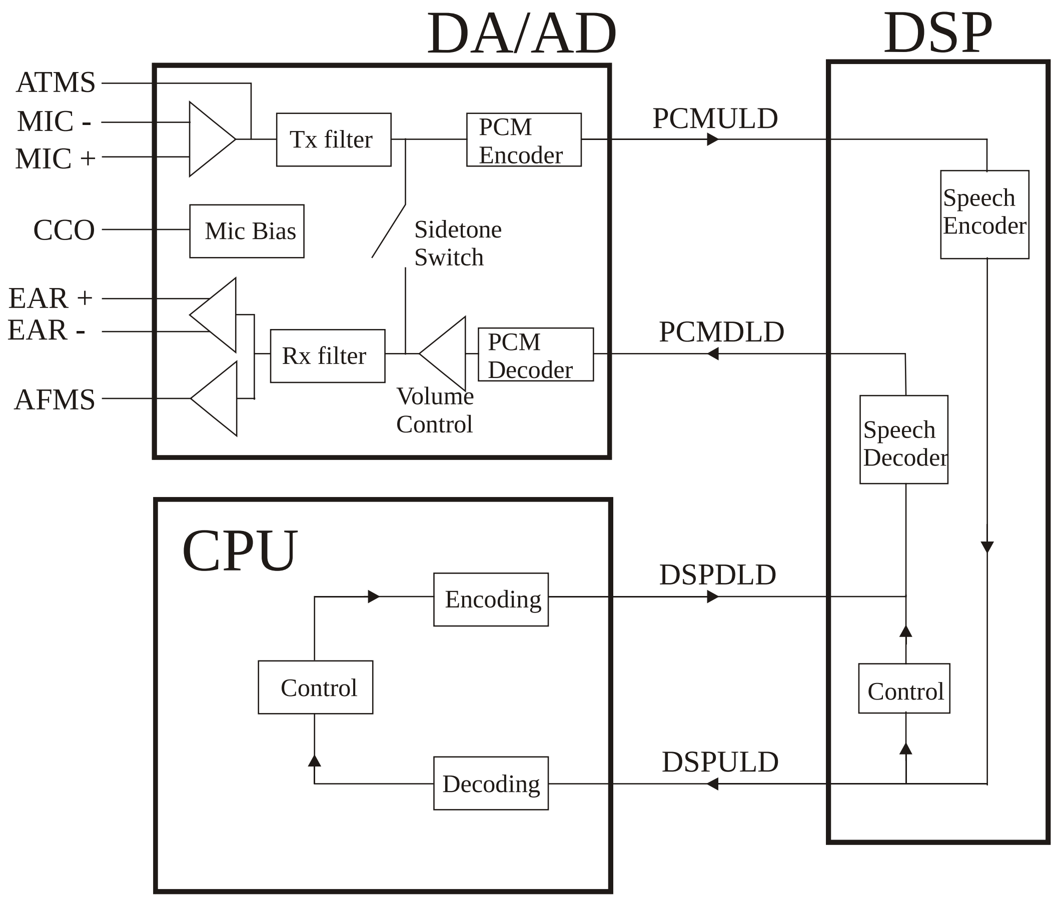


Fig. 4.1

In the trouble shooting part of EFRA there are several ways to test the audio function. There are five different ways to connect an audio signal.

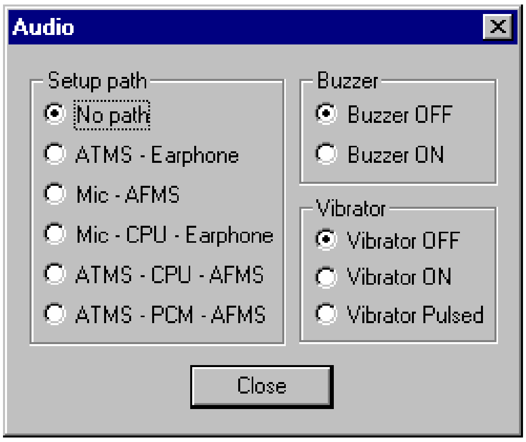


Fig. 4.2

ATMS – Earphone: The input signal is taken from the ATMS pin of the system connector. The signal passes a Tx filter (band pass 300- 3400 Hz) and connects through the side tone switch to the Rx part. In the RX part the signal passes a Rx filter (band pass 300- 3400 Hz) and is amplified, then it is connected to the earphone through BEARP and BEARM.

Mic – AFMS: The input signal is taken from the microphone pads. The signal is amplified, passes a Tx filter (band pass 300- 3400 Hz) and connects through the side tone switch to the Rx part. In the RX part the signal passes a Rx filter (band pass 300- 3400 Hz), then it is amplified and connected to the AFMSS pin of the system connector.

ATMS – PCM – AFMS: The input signal is taken from the ATMS pin of the system connector. The signal passes a Tx filter (band pass 300- 3400 Hz) and is AD converted in N800. The data is sent as PCM code through PCMULD to D900 where the signal is speech coded. The signal is fed back in reverse order, speech decoded in D900, send back through PCMDLD to be DA converted in a PCM decoder and filtered in N800. The signal is amplified and then connected to the AMFSS pin of the system connector.

ATMS – CPU – AFMS: The input signal is taken from the ATMS pin of the system connector. The signal passes a Tx filter (band pass 300- 3400 Hz) and is AD converted in N800. The data is sent as PCM code through PCMULD to D900 where the signal is speech coded. The speech coded information is sent to the processor through DSPULD for further coding. The signal is fed back in reverse order. It is decoded in the processor, sent back to D900 trough DSPDLD for speech decoding. Then it is sent to N800, through PCMDLD, for DA conversion in the PCM decoder. The signal is filtered and amplified, then connected to the AMFSS pin of the system connector.

Mic – CPU – Earphone: The input signal is taken from the microphone pads. The signal is amplified, passes a Tx filter (band pass 300- 3400 Hz) and is then AD converted in N800. The data is sent as PCM code through PCMULD to D900 where the signal is speech coded. The speech coded information is sent to the processor through DSPULD for further coding. The signal is fed back in reverse order. It is decoded in the processor, sent back to D900 trough DSPDLD for speech decoding. Then it is sent to N800, through PCMDLD, for DA conversion in the PCM decoder. The signal is filtered and amplified, then connected to the earphones trough BEARP and BEARM.

4.5 Receiver

4.5.1 Rssi

In the mobile phone, the received RF-signal strength is measured and indicated by a function called **RSSI, Received Signal Strength Indicator.**

When switching the mobile phone “ON” it starts searching the surrounding radio channels ARFCN at the geographical site. Receiving a lot of information on the broadcast channels it will be directed by the network to “Camp on a cell”. The surrounding Base Stations (BBS) are at the same time stored in the MS memory as Base Transceiver Stations Identity Codes (BSIC) for further usage. Up to 30 BSIC can be available, depending on the network. The MS memory capacity is 32 positions for BSIC.

Once the MS is camped on the strongest available carrier it starts performing the RSSI measurements on the surrounding cells from the list of identified BSS-carriers in its memory. The measurements are averaging from all the base stations by sampling 5 times on each carrier and then stored in the memory together with the corresponding BSIC. This list of identified carriers and signal strength is updated by repeated measurements.

For the speech quality and the MS to Base distance it is important that the reported RF-signal measurements are correct and calibrated towards known values. If the reported value is too high it results in late Handovers and bad readability due to the limits are set out of reach for the MS. The opposite, too low values, provokes the switch to make unnecessary Handovers, increased traffic load and perhaps dropped calls by forced release.

The received signal carries information both in the phase and the amplitude. The phase contains the digital information about the message and it is detected later in a phase digitizer for further processing in the main program as speech data and signalling.

The information about the amplitude corresponds to the strength of the received RF-signal, i.e. the RF-level at the antenna input of the receiver.

The modulated RX-signal is mixed down to a baseband signal in the receiver block in N234 and fed to the logic with the signals IRA, IRB, QRA and QRB. The signals carry speech and system information. Information about received signal strength is get from the I and Q signals amplitude. The I and Q signals are digitised in a fast ADC in N800. The output is presented as two bitstreams IDAT and QDAT. The information goes to the CPU that handles the data. The CPU gets the transmitted speech/system data and information about RSSI, Received Signal Strength Indicator.

To measure the received signal strength accurate enough the RSSI had to be calibrated. This procedure calibrates an absolute RF level on the antenna to a corresponding RSSI value. This value together with a pre-defined slope figure is then used to calculate the RSSI value of an arbitrary received antenna power.
Calibration is performed when the phone is manufactured and has to be done if a component that affects the RSSI measurement is replaced. The calibration shall be done in EFRA at a middle channel for each band. The input signal has to be GMSK modulated, –68 dBm strong and receiver in switched mode.

4.5.2 Rx level

The phone receives a signal from the base station, the signal is mixed down to 67.7 kHz. The received signal is measured with an ADC. A high input signal gives a high value out from the ADC. The phone is calibrated for input signals between -110 dBm and -40 dBm. The phone compares the measured value and sends back the information about the signal strength to the base station. The base station calculates the Rx-level value by comparing the systems lowest signal strength according to the GSM-specification (-110 dBm) with the value of signal strength that the phone sends back.

110 - (the absolute value of the signal strength from the phone) = Rx level

E.g.: The phone measures the signal strength to -102 dBm.

Rx level = 110-102 = 8

When there is a Rx-level fault, the calculated value in the EEPROM does not correspond with the input signal, i.e. the phone experience the signal to be stronger or weaker then its real value.

NOTE! If there is problem with Rx-level / Rx Quality in the Go/No-Go test on a certain ARFCN e.g. Ch. 1, it can be caused by interference from a BSS in the area. Find out which channels are in use and configure TCH on the Go/No-Go test according to this.

4.5.3 Rx quality

The base-station sends out a pattern of bits, which the phone loops back to the base-station. The base-station then compares the original pattern with the one the phone sent back and calculates a percentage on the difference. This percentage is used to measure the Rx Quality. The calculation is performed during a call. For EGSM 900, GSM 900 and GSM 1900 at -102 dBm Rx-signal and the highest power level at low, middle and high channel. For GSM 1800 at -100 dBm Rx-signal and the highest power level at low, middle and high channel. Rx Quality should be 0-2 steps. If it is higher on any of the channels then it is almost always a receiving problem.

NOTE! If there is problem with Rx-level / Rx Quality in the Go/No Go test on a certain ARFCN e.g. Ch. 1, it can be caused by interference from a BSS in the area. Find out which channels are in use and configure TCH on the Go/No Go test according to this.

4.5.4 Measurements in the receiver

The measurements below are done in EFRA with the receiver set to Static mode with test program in the phone. The measurements are no absolute values. Differences can appear because of component tolerances, different probes and instruments.

DC voltages

Signal	Measured on	Value
VDIG	C703	2.8 V

Signal	Measured on	Value
VRAD	C501	2.8 V
RXON	PIN 14(N234)	2.8 V

Mode	VTXVCO LB	VTXVCO HB	ANTSW
GSM 900 - Rx	H	L	H
GSM 1800-Rx	L	H	H

RF signals

Measured with -50 dBm GMSK modulated signal, mid channel.

GSM 900

13 MHz at B320 : 650 mV_{p-p} / 5 dBm

Signal loss in components in the receiver path:

N200 pin 9 - pin 2 : 0 dBm

Z200 pin 2 - pin 4, 6 : 3 dBm

Signal	Measured on	Value
IRA	C220	250 mV_{p-p}
IRB	C220	250 mV_{p-p}
QRA	C221	250 mV_{p-p}
QRB	C221	250 mV_{p-p}

GSM 1800

13 MHz at B320 : 650 mV_{p-p} / 5 dBm

Signal loss in components in the receiver path:

N200 pin 16 - pin 2 : 2 dBm

Z201 pin 2 -pin 5 : 2 dBm

N201 pin 2 - pin 6, 4 : 2 dBm

Signal	Measured on	Value
IRA	C117	250 mV_{p-p}
IRB	C117	250 mV_{p-p}
QRA	C118	250 mV_{p-p}
QRB	C118	250 mV_{p-p}

4.6 Transmitter

4.6.1 Output power

Output power is a part of the measurement in the Go/No Go test that checks which output power the transmitter gives at different channels and different power levels. The measurement is done on three channels (Low, Middle and High) and on three power levels (Low, Middle and High). See tables below.

Channel definition

Channel	Channels in EGSM900	Channels in GSM1800
Low	975-980	512-517
Middle	35-40	697-702
High	120-124	880-885

Power level definition

Power level	Power levels in EGSM900	Power levels in GSM1800
Low	19	15
Middle	10-14	6-10
High	5	0

Output power EGSM

Power level	Output power (dBm)	Tolerance (dBm)
5	32.5	±2
15	13	±3
19	5	±5

Output power GSM1800

Power level	Output power (dBm)	Tolerance (dBm)
0	30	±2
10	10	±4
15	0	+5

4.6.2 Burst timing

The GSM system uses TDMA (Time Division Multiple Access). The radio spectrum is divided into both frequency band and time slots. The frequency band for EGSM 900 is divided in 174 frequencies, GSM 1800 is divided in 374 frequencies and GSM 1900 is divided in 299 frequencies. The frequency bands has got eight time slots (channels) per frequency. All information (speech and system information) is encoded and transmitted as a burst in a time slot. Since several channels are sharing the same frequency it is vital for every burst to start and end at the correct time. The GSM specification describes the amplitude/time relation for the bursts.
The figure below shows the amplitude limits for Power level 5 GSM 900, during one burst.

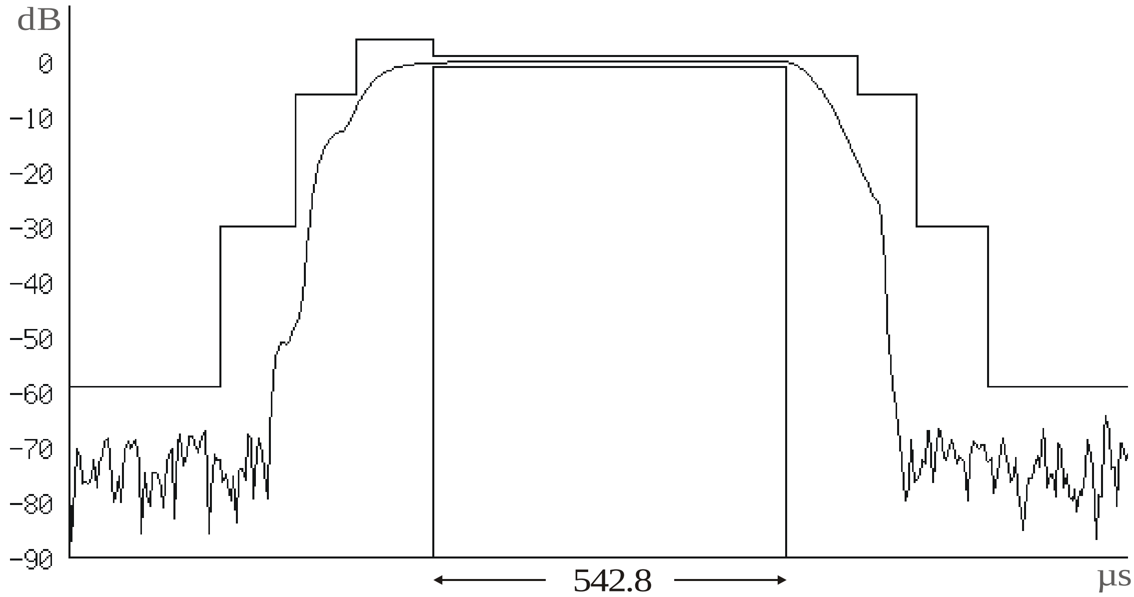


Fig. 4.3

Burst timing is a part of the measurement in the Go/ No Go- test. You can get a good look of the burst by checking the amplitude of the burst at some time spots of the raise and fall slope of the burst (Figure above). This lets you know if the burst is within the limit. The tables below shows the limits of the timing for all power levels in GSM 900 and GSM 1800/GSM 1900.

EGSM 900

Parameter	Powerlevel	Min value	Max value	Unit
Power at – 10µs	5	-	-6	dBc
Power at – 18µs	5	-	-30	dBc
Power at – 10µs	9	-	-6	dBc
Power at – 18µs	9	-	-30	dBc
Power at – 10µs	19	-	-1	dBc
Power at – 18µs	19	-	-30	dBc
Power at – 18µs	19	-	-17	dBm

GSM 1800

Parameter	Powerlevel	Min value	Max value	Unit
Power at – 10µs	0	-	-6	dBc
Power at – 18µs	0	-	-30	dBc
Power at – 10µs	9	-	-6	dBc
Power at – 18µs	9	-	-30	dBc
Power at – 10µs	15	-	-1	dBc
Power at – 18µs	15	-	-30	dBc
Power at – 18µs	15	-	-20	dBm

4.6.3 Phase and frequency error

Phase and frequency error is a measurement in the Go/No Go – test where you check how big the phase and frequency variations of the transmitter are during a connected call.

The phase and frequency fault is measured during 20 bursts.

For GSM 900 use power level 5 and low channel.

For GSM 1800 and GSM 1900 use power level 0 and low channel.

The phase fault is presented as RMS and peak. RMS is the average value during the 20 bursts and peak is the largest phase divergence measured at anyone of the 20 bursts.

4.6.4 Measurements in the transmitter

The measurements below are done in EFRA with the transmitter set to Switched mode with test program in the phone. The measurements are no absolute values. Different values can appear because of component tolerances, different probes and instruments.

DC voltages

Signal	Measured on	Value
VDIG	C703	2.8 V
VRAD	C501	2.8 V
TXON	C364	2.8 V*

*Measured with an oscilloscope.

Mode	VTXVCO LB	VTXVCO HB	ANTSW
GSM 900 - Tx	H	L	L
GSM 1800 - Tx	L	H	L

RF signals

Measured switched at high power level, mid channel.

GSM 900

13 MHz at B320 : 650 mV_{p-p} / 5 dBm

Signal level in the transmitter signal path:

W100:1	: 33 dBm
N200:2	: 33 dBm
N200:7	: 33 dBm
N400 pin 4	: 25 dBm
N400 pin 1	: 13 dBm
N351 pin 12	: 9 dBm

GSM 1800

13 MHz at B320 : 650 mV_{p-p} / 5 dBm

Signal level in the transmitter signal path:

W100:1	: 33 dBm
N200:2	: 33 dBm
N200:13	: 33 dBm
N400 pin 6	: 25 dBm
N400 pin 9	: 13 dBm
N351 pin 14	: 9 dBm

4.6.5 Spectrum switched mode

Description

In the GSM system the mobile phone transmitter output RF- signal is time-shared. This implies the transmitter to be started exactly at a controlled point of time to reach a specific RF-power level within a very short and clearly defined period of time (< 28 µS). This RF-power levelshift, called *upramp*, must be as smooth and linear as possible during the transition from low to high.

The transmitter RF-power level as a function of time, can be seen in *Fig. 4.4*:

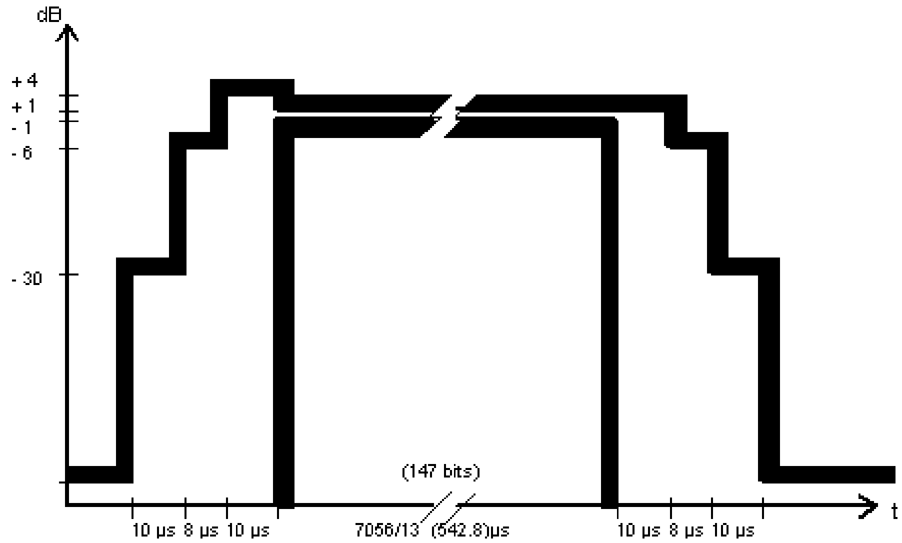


Fig. 4.4

When the transmitter is up at the decided RF-power level, it is ready to send the message in a digital burst format. Some of the messages are system information only; some are digital speech frames, but mostly both types in the same data packet. During this time interval, the spectral propagation must be limited within a specified bandwidth for the system. Time mask for *normal duration burst* 147 bits is 542.8 µS.

After hopefully a completed message time-lapse, the transmitter shall be stopped exactly at a controlled point of time, to return to RF-off level again, within a very short and clearly defined period of time (<28µS). The transmitter RF-power level downshift is called *downramp* and also this must be as smooth and linear as possible during the transition from high to low, in order to limit the spectral propagation.

According to the principle of TDMA and the bursty nature of the signal, the output *RF spectrum* results from two effects:

- The RF-power levelshift at *upramp* and *downramp* or **Spectrum due to Switching transients**.
- The *digital modulation* process or **Spectrum due to the Modulation and wide band noise**.

The actual RF-spectrum

When the mobile phone has a call in progress, the transceiver is switching between receive and transmit, to follow the physical channel. Around the carrier ARFCN the transmitter produces a RF-spectrum with an amplitude and bandwidth depending on the TX RF-power and the two effects: of switching and modulation. The spectrum is spread over a wide frequency band, but is technically limited by the equipment design and must conform within the GSM spectrum mask.
To verify that, the mobile phone is tested on both sides of the carrier ARFCN, over the frequency band at integer multiples of the channel separation 200 kHz. This test is rather complicated, time consuming and it is mandatory for design and production to fulfil the requirements for type approval. But for testing at normal maintenance and repair, it is permitted to reduce the test and simplify at a reasonable level.

With a Spectrum Analyser it is possible to catch a narrow sample of the spectrum as a time waveform due to a transmitted burst. By repeating that sample for a long raw of consecutive bursts it will be possible to measure the average of the spectrum components selected, in a time-gated measurement.
The example of such a time waveform is seen in *Fig. 4.5*.

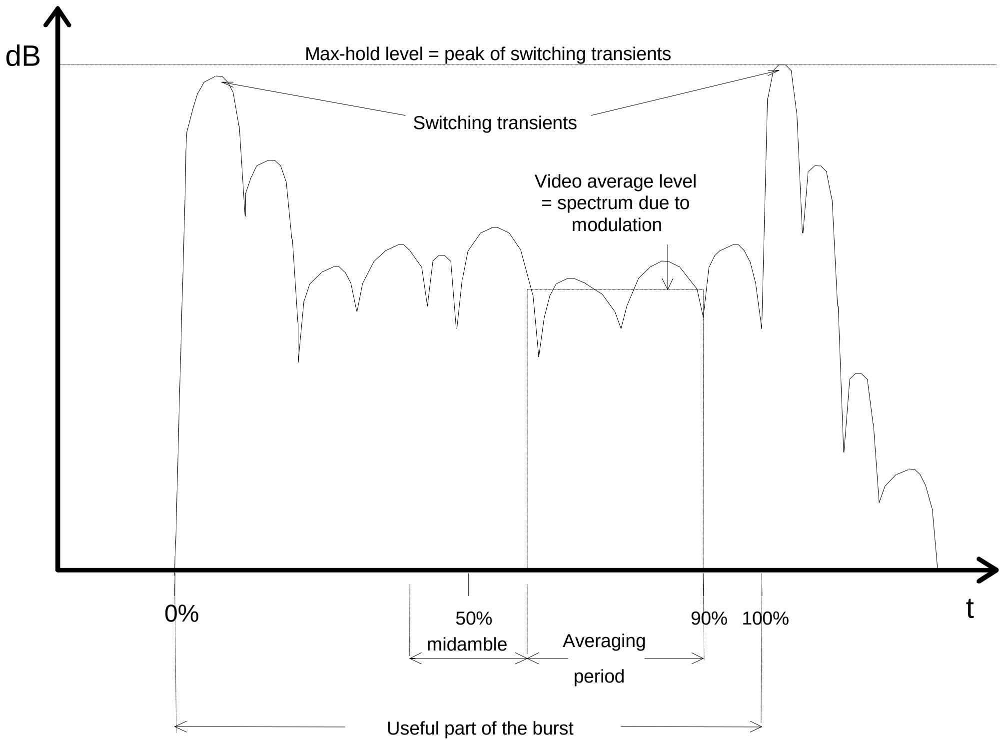


Fig. 4.5

In this time are visible waveform spectrum components from both the *switching* and the *modulation*. Looking at the time axis we know that the transmitter is started before the useful burst at the *upramp*. At that part of the waveform the spectrum is still affected by the upramp and a peak of switching transients is visible. The beginning of the time waveform is therefor not good for measuring the modulation spectrum.

In the middle of the burst there is a *training sequence*, usually called *midamble*, with an equal bit pattern in every normal burst. This part is not interesting for modulation measurements either.

The part of the waveform that follows after the *midamble*, called the *Averaging period* is the part decided to be measured as the *Spectrum due to the Modulation and wide band noise* by definition in the GSM spec. This period is finished at 90%, before the end of the burst. This is to avoid interference from switching transients at the *downramp*.

At the end of the time waveform again spectrum components from the switching is present, because the time gated measurement has got a STOP point at the end of the *downramp* period.

Spectrum due to switching
(and Intermediate Power Level)

In the GSM-system, all communication between the base station and the phone, is done switched, in shape of bursts. The burst is a squared output power pulse with step up- and down ramping. Every time the voltage of the squared pulse changes rapidly there will be formed a number of over tones. The over tones have got different frequencies and amplitudes. The amount of over tones and what amplitude they have got depends on how steep the up- and down ramping are, the steeper up- and down ramping, the higher amplitude and frequency of the over tone. The over tones form a spectrum that is called ”Spectrum due to switching”.

To be able to get lower amplitudes for the over tones in the Spectrum due to switching, the up- and down ramping do not change momentarily from zero-to-max/max-to-zero. Instead, this is done with two help steps. These two help steps are called *Low* and *High Intermediate Power level*.
The figure below shows what the control signal from the POWLEV-DAC should look like.

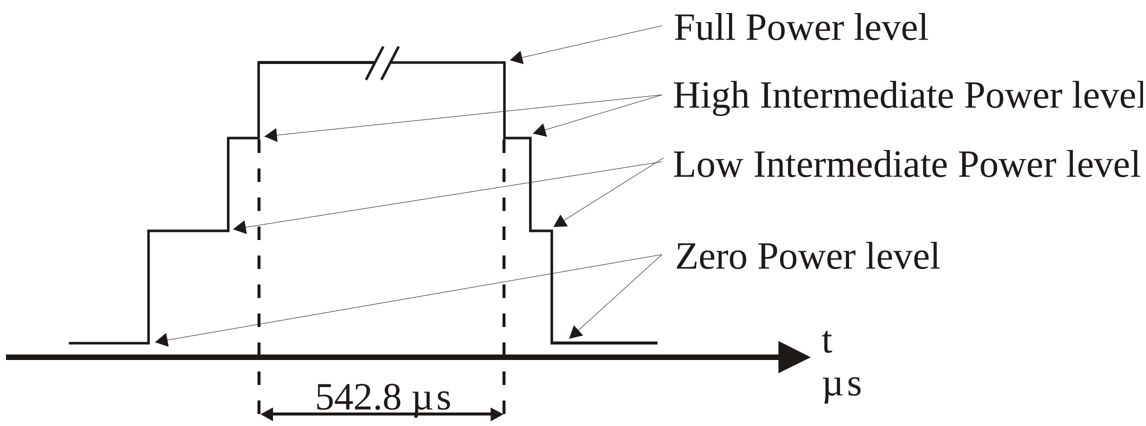


Fig.4.6

The control voltage then passes through an exponential amplifier and a Bessel low pass filters where the transient disturbance is reduced. This gives a control voltage without the straight, vertical edges and the sharp corners that produces the over tones. The Zero Power level is a voltage level from the DAC that assures no output power at all.

Spectrum due to the modulation and wide band noise

The telephone is connected to test equipment: Fixture, Computer with a test program, Communication Tester or a Spectrum Analyser and a Powersource. The TX is started at high power level PL 5 in switched mode on an ARFCN in the Mid ARFCN range. At the same time the RX is switched OFF.

A specific designed base band signal for testing is generated by the test program and injected to the TX- modulator. The signal, only used for testing has a digital pattern combined from a Pseudo Random Bit Sequence (PRBS) and Training Sequence (TSC 0). These are combined in a burst with the two data fields filled with PRBS and TSC 0 as the midamble. The signal pattern is designed to give a modulation spectrum, good for testing, that optimally uses the channel bandwidth.

A gated measurement is performed with the Spectrum Analyser set to capture the whole useful part of the burst, i.e. from 0% to 100% in *Fig. 4.5*. No matter of the interference from switching transients. Assumed to be negligible.

Each carrier is measured at the time. Beginning with the ARFCN here called Fc. An average of the modulation power content in the spectrum on Fc is taken from 3 repeated bursts. The result will be used as a reference level.

Two more measurements will be done at the adjacent RF-channels + 400 kHz and – 400 kHz apart from the Fc. But still the Fc as the active modulated carrier. Equally an average of the modulation power content in the spectrum on the adjacent RF-channel is taken from 3 repeated bursts on each of the two RF-channels at the time. The two results from Fc+400 kHz and Fc–400 kHz are compared to the result from Fc as a reference RF–power level in dBm.

When compared to the reference, each of the two adjacent RF-channels gets a lower value, calculated as a difference in dBc down from the Fc. The smallest difference is the valid measurement result. (Easiest to achieve, but closest to the limit).

This is the measurement result of **Spectrum due to the Modulation and wide band noise** and will be examined according to the requirements specification in the doc 1524 TEST DATA written and approved by the Ericsson Testengineering and based on the GSM specification.

The requirement is that the absolute RF levels in dBm and the levels in dBc relative to Fc, from all three results must not exceed the limit of a modulation spectrum mask decided in the GSM spec. Any crossing of this limit is considered as a failure.

It is very difficult to make an exact transient spectrum measurement on a trouble-shooting site since there are a lot of disturbances in the air. It can be a difference of a few dBm compared to the measurement in EFRA.

You can also check the transient spectra with an Anritsu.
Start the transmitter in switched mode and go to “Tx measure/Output RF spectrum”.
“Switching Transients Lower” (-400 kHz) and “Switching Transients Upper” (+400 kHz) must be inside the limits.

Parameter	Measured	Min	Typ	Max	Units	Comment
Fc+400kHz				-19	dBm	
Fc- 400kHz				-19	dBm	

GSM1800:

Same as for EGSM900, but do not forget to change to GSM1800 and Power level 0 in the test program, also change CF at the spectrum analyser. The Power level must be inside the limits.

Parameter	Measured	Min	Typ	Max	Units	Comment
Fc+400kHz				-22	dBm	
Fc- 400kHz				-22	dBm	

4.6.6 How to measure the spectrum due to switching

EGSM900:

Power up the board and start it in the test program.

Start the transmitter in switched mode at channel 64 and power level 5.

Before performing a transient spectrum measurement you have to make sure that the spectrum analyser has got the correct amplitude compensation. To do this you use a phone with a known output power and start the transmitter in switched mode at power level 5. Then you compensate the spectrum analyser until the correct output power is achieved. Proper settings for this could be: CF – 902.8 MHz, SPAN – 0 MHz, RBW – 300 kHz, VBW – 100 kHz and SWEEP – 0.8ms.)

One method to measure the transient spectrum is to use the following settings on the spectrum analyser: CF – 903.2 MHz, SPAN – 0 MHz, RBW – 30 kHz, VBW – 100 kHz and SWEEP – 6 ms. Measure the highest level of the signal. The easiest way to do it is to use ”single sweep” to freeze the picture and ”peak search” to find the highest level. The spectrum should look like the figure below.

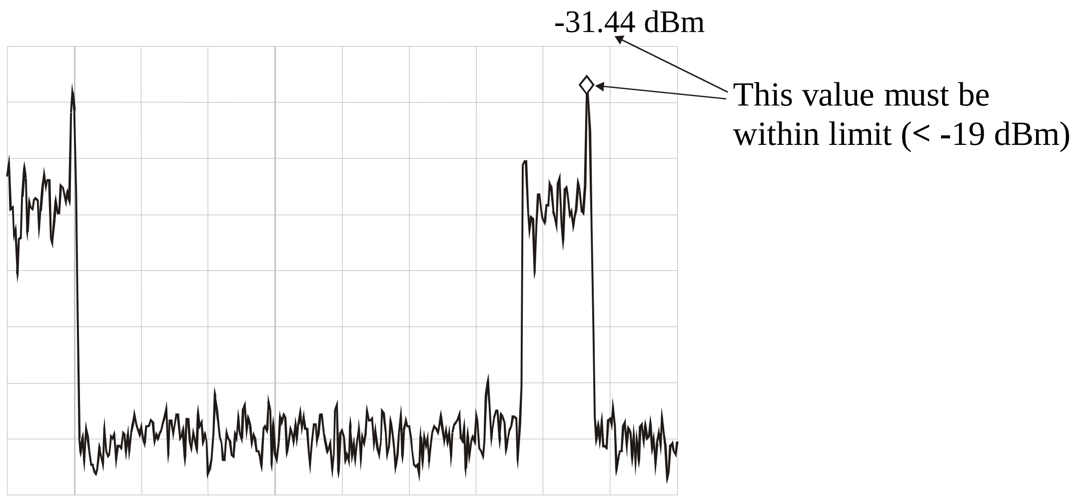


Fig 4.7

For the example in the picture we have measured the transient spectrum at channel 64 + 400 kHz. Do the same measurement at channel 64 - 400 kHz, by changing CF at the spectrum analyser to 902,4 MHz. The power level must be inside the limits.

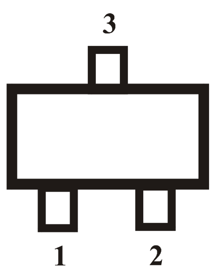
It is very difficult to make an exact transient spectrum measurement on a trouble-shooting site since there are a lot of disturbances in the air. There can be a difference of a few dBm compared to the measurement in EFRA.

You can also check the transient spectra with an Anritsu. Start the transmitter in switched mode and go to “**TX measure/Output RF spectrum**”. “**Switching Transients Lower**” (-400 kHz) and “**Switching Transients Upper**” (+400 kHz). The power must be inside the limits.

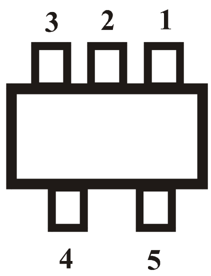
GSM1800:

Same as for EGSM900, but do not forget to change to EGSM900/GSM1800 and Power level 0 in the test program, also change CF at the spectrum analyser. The Power level must be inside the limits.

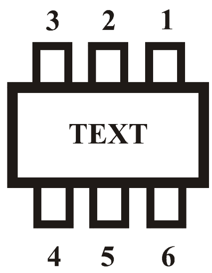
4.7 Pin Placing



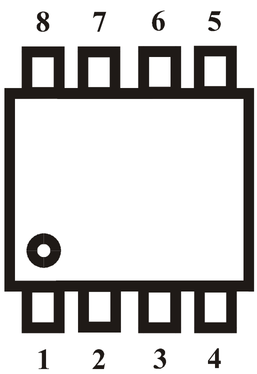
Double diode or single transistor



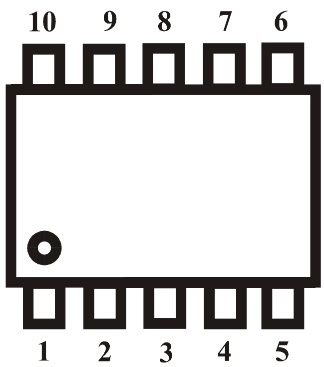
Voltage regulator



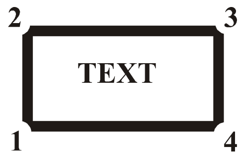
Double transistor



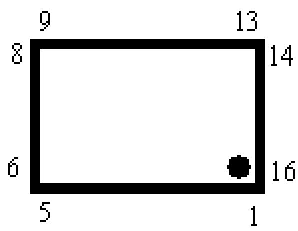
Eight pin circuit



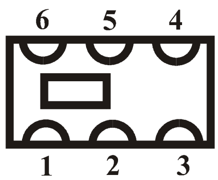
Ten pin circuit



Crystal 13 MHz



Antenna switch N200



BALUN

PA module, N400

5 Revision History

Rev.	Date	Changes / Comments
B	2001-02-15	
C	2001-03-20	First page updated with information that the guide also is applicable for T20e/ec.