APPLICATION NOTE

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Philips FM/IF systems for GMSK/GFSK receivers

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ABSTRACT

To assist Philips Semiconductors customers in digital cellular and wireless/PCS system design, a Philips FM/IF system-based GMSK/GFSK demoboard has been developed based on CT-2 specifications. This application note presents a detailed description of this board including circuits, design information, and measured BER performance. The circuit diagram, component list, and board layout are also included.

INTRODUCTION

In order to meet the rapidly increasing demand for mobile radio and wireless/PCS services, digital cellular and digital wireless systems have become the new generation of mobile communications for higher capacity. It is a new challenge for engineers to find IC solutions for these digital wireless applications.

In worldwide digital cellular, wireless/PCS standards, GMSK/GFSK modulation techniques have been widely employed as illustrated in Table 1. In order to assist the applications of Philips ICs in these digital systems, a Philips FM/IF system-based GMSK/GFSK demoboard has been developed. The purpose of this application note is to provide a detailed description of this board, to help customers achieve the best performance using Philips SA626, and also to provide suggestions for the applications of other Philips FM/IF systems.

Table 1. A Summary of Digital Cellular and Cordless Standards

Standard	Access	Modulation	Bit Rate	Ch. Spacing
IS-54	TDMA	π/4-DQPSK	48 kb/s	30 kHz
GSM	TDMA	GMSK	270 kb/s	200 kHz
CT-2	TDMA	GFSK	72 kb/s	100 kHz
DECT	TDMA	GFSK	1.152 Mb/s	1.728 MHz

This application note is organized as follows:

- Introduction.
- Review of GMSK/GFSK modulation: advantages of GMSK/GFSK modulation techniques and implementation methods.
- Overview of the demoboard: general block diagram and detailed description of each part of the board.
- BER measurements: measurement set-up, procedures, and measured results.
- Questions & Answers.

REVIEW OF GMSK/GFSK MODULATION

GMSK(Gaussian Minimum Shift Keying) is a premodulation Gaussian filtered binary digital frequency modulation scheme with modulation index of 0.5. The following features make GMSK very suitable for digital cellular and wireless applications.

1. Constant envelope: this allows the operation of Class-C RF power amplifiers to achieve higher system power efficiency.
2. Narrow power spectrum: narrow mainlobe and low spectral tails keep the adjacent channel interference to low levels and achieve higher spectral efficiency.
3. Coherent/non-coherent detection capabilities.
4. Good BER performance.

GMSK modulation can be implemented in two ways. The most straightforward way is to transmit the data stream through a Gaussian low-pass filter and apply the resultant wave form to a voltage controlled oscillator (VCO) as shown in Figure 1. The output of the VCO is then a frequency modulated signal with a Gaussian response. The advantage of this scheme is the simplicity, but it is difficult to keep an exact modulation index of 0.5 with this scheme. Therefore, VCO implemented GMSK is usually used in non-coherent detection systems such as DECT and CT2.

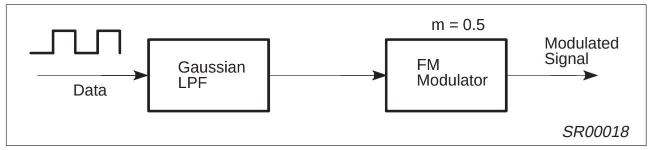

Figure 1. VCO Implemented GMSK Modulator

GMSK signals can also be generated using a quadrature modulation structure. Consider the phase modulated signal given by:

$$s(t) = \cos[\omega_C t + \phi(t)] \quad \text{(EQ. 1)}$$

This can be expanded into its in-phase and quadrature components,

$$s(t) = \cos[\phi(t)]\ \cos(\omega_C t) - \sin[\phi(t)]\ \sin(\omega_C t) \quad \text{(EQ. 2)}$$

The quadrature modulator is based on Equation (2). The implementation of such a GMSK modulator is shown in Figure 2. The incoming data is used to address two separate ROMs which contain the sampled versions of all possible phase trajectories within a given interval. After D/A conversion, the output of each ROM is applied to the I/Q modulator. The output is the GMSK modulated signal. This implementation scheme provides an exact modulation index of 0.5, which allows coherent detection.

GFSK (Gaussian Frequency Shift Keying) is also a premodulation Gaussian filtered digital FM scheme, but without the restriction of modulation index to be 0.5. The block diagram of GFSK modulator is the same as shown in Figure 1, but the modulation index can be specified according to the applications.

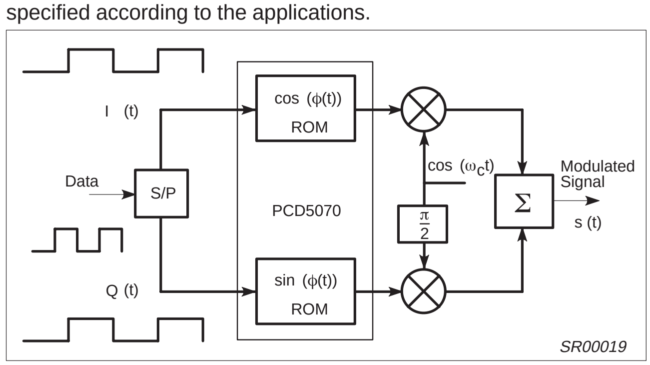

Figure 2. I/Q Implemented GMSK Modulator

GMSK signals can be demodulated in three ways: 1.) FM discriminator detection, 2.) differential detection, and 3.) coherent detection. The coherent detection scheme has the best BER performance, but is only suitable for I/Q structure based GMSK systems (Ref 6.). The differential detection method has BER degradation even with complex implementation (Ref 7.). The limit/frequency discriminator structure is the simplest scheme suitable for both GMSK and GFSK applications. Therefore, the FM discriminator technique is widely used for GMSK/GFSK demodulation in digital cellular/PCS applications. Figure 3 presents the block diagram of an FM discriminator GMSK/GFSK demodulator.

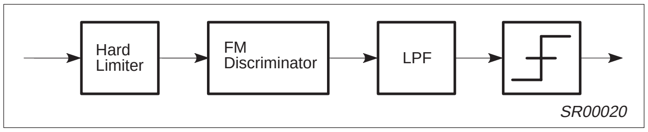

Figure 3. Limit/Frequency Discriminator GMSK/GFSK Demodulator

OVERVIEW OF THE GMSK/GFSK DEMOBOARD

Figure 4 is the block diagram of a VCO/FM discriminator based GMSK/GFSK modem (modulator/demodulator), which also illustrates the structure of the Philips GMSK/GFSK demoboard. The demoboard contains the entire demodulator as well as the Gaussian low-pass filter (LPF) for the modulator. The input data stream is first premodulation filtered by the Gaussian LPF, then the filtered base band wave form is applied to an FM signal generator with specific modulation index. The output is then the GMSK/GFSK modulated signal. After the limit/frequency discriminator detection, a Gaussian LPF is employed to eliminate noise. The output of the threshold detector is the regenerated binary data, which can be sent to a data error analyzer to evaluate the BER performance.

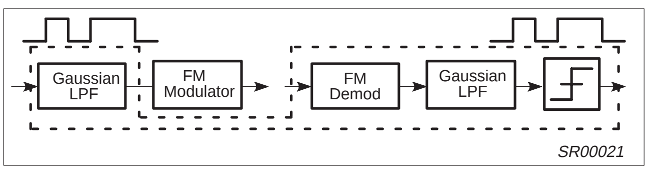

Figure 4. VCO/FM Discriminator GMSK/GFSK Modem (dotted line for the demoboard)

Gaussian LPF

On the demoboard, a 4th-order Gaussian LPF is implemented for both premodulation filtering and post demodulation filtering. The response function of this 4th-order filter can be expressed as (Ref 4.):

$$H(s) = \frac{\omega_1^2}{S^2 + 2\zeta_1\omega_1 S + \omega_1^2} \cdot \frac{\omega_2^2}{S^2 + 2\zeta_2\omega_2 S + \omega_2^2} \qquad \text{(EQ. 3)}$$

By looking up the Gaussian LPF poles table[4], with 3dB bandwidth normalized to unity, we have:

$$\omega_1 = 1.9086, \quad \zeta_1 = 0.7441; \quad \omega_2 = 1.6768, \quad \zeta_2 = 0.9720$$

This 4th-order Gaussian LPF is implemented with switched capacitor filters. The reason for using this scheme is that the LPF's 3dB bandwidth can be controlled by an external clock which allows generating GMSK signals with different BTb. To realize a 4th-order LPF, two stages of LMF100 are cascaded and operated at mode-3[5]. Figure 5 shows the circuit diagram for this mode.

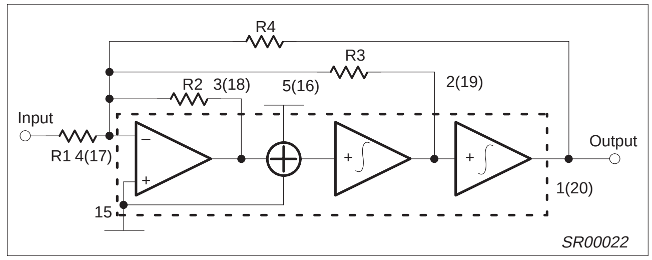

Figure 5. Circuit Diagram of LPF with LMF100 at Mode-3

For mode-3 LPF applications, the following formulas can be used to calculate the resistor values [5]:

$$H_{LP}(s) = \frac{H_{OLP}\omega_0}{S^2 + S\omega_0/Q + \omega_0} \qquad \text{(EQ. 4)}$$

$$\text{where, } H_{OLP} = -\frac{R_4}{R_1} \qquad \text{(EQ. 5)}$$

$$\omega_0 = \left(\frac{f_{CLK}}{100}\right) \cdot \sqrt{\frac{R_2}{R_4}} \qquad \text{(EQ. 6)}$$

$$Q = \left(\frac{R_3}{R_2}\right) \cdot \frac{\sqrt{R_2}}{R_4} \qquad \text{(EQ. 7)}$$

Example:

Step 1. Decide the gain and choose R value:
For unity gain, we have
H_{OLP} = - R_4/R_1 = -1, i.e. $R_4 = R_1$.
For the first stage, we choose a convenient value for input resistance: $R_{14} = R_{11} = 22k\Omega$

Step 2. Calculate R_{12}:
Compare (3) with (4), we have:

$$\omega_1 = \left(\frac{f_{CLK}}{100}\right) \cdot \sqrt{\frac{R_{12}}{R_{14}}} \qquad \text{(EQ. 8)}$$

By choosing f_{clk} = 100 times the 3dB bandwidth, we have

$$\omega_1 = \sqrt{\frac{R_{12}}{R_{14}}} \rightarrow R_{12} = 80.14k\Omega$$

Step 3. Calculate R_{13}:
From the comparison of (3) and (4), we also have,

$$Q_1 = \frac{1}{(2\zeta_1)} = \left(\frac{R_{13}}{R_{12}}\right) \cdot \sqrt{\frac{R_{12}}{R_{14}}} = \frac{1}{(2 \cdot 0.7441)} \qquad \text{(EQ. 9)}$$

$R_{13} = 28.22k\Omega$

For the second stage, the resistor values can be calculated by the same procedures. For this example, they are:

$R_{24} = R_{21} = 22k\Omega$
$R_{22} = 61.86k\Omega$
$R_{23} = 18.98k\Omega$

To obtain a good Gaussian LPF, the resistor values have to be adjusted with all input/output circuits connected. Baseband eye-diagrams and modulated power spectrum could be the references for the adjustment. The final values for this example are shown in the circuit diagram.

FM/IF System

The Philips low-voltage high performance monolithic FM/IF system, SA626, is employed for demodulation on the GMSK/GFSK demoboard. SA626 was designed specially for wide bandwidth portable communications applications, incorporating with a mixer/oscillator, two limiting intermediate frequency amplifiers, quadrature detector, and audio and RSSI op amps. The RF section is similar to the famous SA605. The audio and RSSI outputs have amplifiers. With power down mode, SA626 will function down to 2.7V. Figure 6 is the block diagram of SA626. Detailed information can be found in the data book and application note [1, 2, 3].

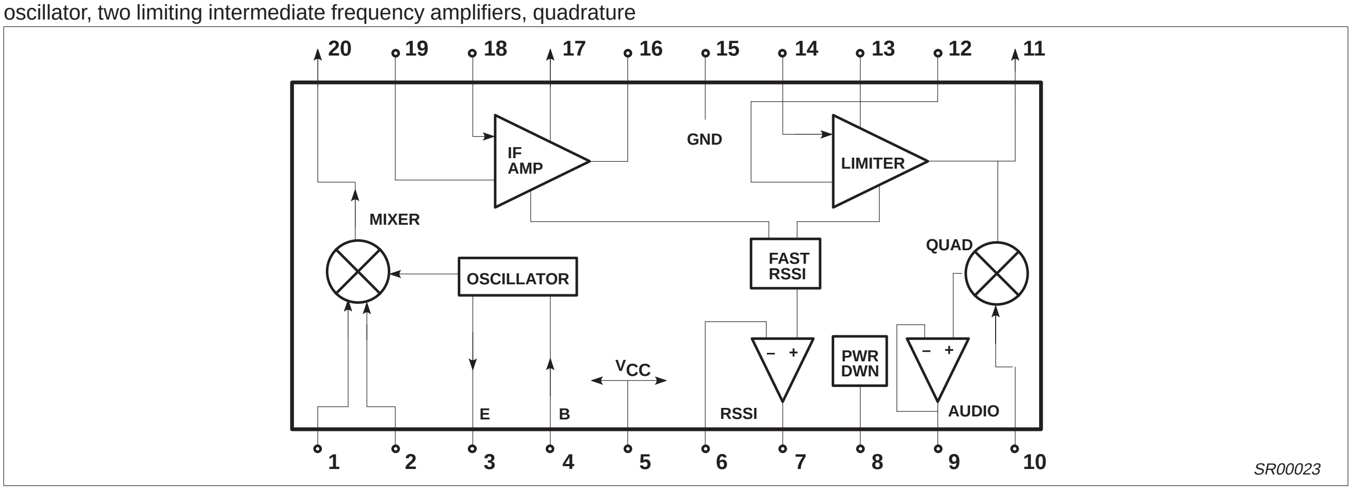

Figure 6. Block Diagram of the FM/IF System SA626

The GMSK/GFSK demoboard is designed for an RF frequency of 45MHz, LO frequency of 55.7 MHz, and intermediate frequency of 10.7MHz. For different RF frequency applications, the step-by-step matching circuits design procedure is presented in Ref. 1.

Although this demoboard is designed with SA626 based on CT-2 specifications, Philips also provides FM/IF solutions for many other GMSK/GFSK systems. SA626 is specially designed for wide bandwidth applications. For lower data rate applications such as CDPD (19.2 kb/s), SA605/625 family is recommended. For DECT and other high data rate applications, SA636 and SA639 are the recommended solutions. Data (audio) output bandwidth is the main limiting factor for high data rate applications. Table 2 presents a summary of the major characteristics of Philips FM/IF systems. The suggested maximum data rate for each part is an approximation based on the baseband eye pattern. Higher data rate could be operated with some modifications or if more BER degradation is allowed.

Table 2. Major Characteristics of the FM/IF Systems

	SA602/604	SA605	SA625	SA626	SA636	SA639*
V_{CC}	4.5 - 8V	4.5 - 8V	4.5 - 8V	2.7 - 5.5V	2.7 - 5.5V	2.7 - 5.5V
I_{CC}	2.4/3.3mA @ 6V	5.7mA @ 6V	5.7mA @ 6V	6.5mA @ 3V	6.5mA @ 3V	8.3mA @ 3V
SINAD	-120dBm/.22µV (RF: 45MHz, IF: 455kHz, 1kHz tone, 8kHz Dev.)	-120dBm/.22µV (RF: 45MHz, IF: 455kHz, 1kHz tone, 8kHz Dev.)	-120dBm/.22µV (RF: 45MHz, IF: 455kHz, 1kHz tone, 8kHz Dev.)	-112dBm/.54µV (RF: 240MHz, IF: 10.7MHz, 1kHz tone, 70kHz Dev.)	-111dBm/.54µV (RF: 240MHz, IF: 10.7MHz, 1kHz tone, 125kHz Dev.)	-111dBm/.54µV (RF: 240MHz, IF: 10.7MHz, 576kHz tone, 288kHz Dev.)
Features	Audio & Data pins IF BW of 25MHz Matching for standard 455kHz IF filters	Audio & Data pins IF BW of 25MHz Matching for 455kHz IF filters	Pin compatible with SA605 Fast RSSI IF BW of 25MHz Matching for 455kHz IF filters	Power down mode Low voltage Fast RSSI IF BW of 25MHz Int. RSSI & Audio op amp Matching for 10.7MHz IF filters	Power down mode Low voltage Fast RSSI IF BW of 25MHz Int. RSSI op amp Wideband data out Matching for 10.7MHz IF filters	Power down mode Low voltage Fast RSSI IF BW of 25MHz Int. RSSI op amp Wideband data out Post detection amp Matching for 10.7MHz IF filters
Data Rate**	100kb/s	100kb/s	100kb/s	300kb/s	1.5Mb/s	2Mb/s
NOTES	* Objective specifications. ** Approximated maximum data rate. With some modifications, higher data rate might be operated.					

Threshold Detector and Data Regeneration

A 2-level threshold detector with sampling time adjustment circuits is implemented for data regeneration as shown in the circuit diagram. The output base band signal (eye-diagrams) from SA626 is first fed into a comparator (LM311) to generate a TTL logic signal which is then sampled with the data clock at the transmitting bit rate. The phase of the data clock can be adjusted manually through a monostable multivibrator (74HC123) to achieve the optimal sampling time. The demoboard is initially adjusted for a bit rate of 72 kb/s. If a different data rate is used, the sampling time has to be re-adjusted.

The symbol timing recovery (STR) circuit is not implemented on this demoboard. The transmitting data clock should be either hard-wire connected from the transmitter, or obtained from a separate STR circuit for operation. The measured performance presented in this paper is conducted with hard-wire connected data clock. However, BER degradation caused by STR should be no more than 1dB (Ref 8.).

PERFORMANCE MEASUREMENTS

The performance of this GMSK/GFSK demoboard including receiver sensitivity and BER is experimentally evaluated. BER performance is evaluated based on CT-2 specifications. Measurement procedures and the measured results are presented in this section.

Measurement Set-up

Figure 7 illustrates the measurement set-up with the GMSK/GFSK demoboard. A data error analyzer is employed to generate a pseudo random binary sequence (PRBS) with length of 10^9 -1 at a data rate of 72kb/s. This data sequence is sent to the Gaussian LPF on the board for premodulation filtering. The output Gaussian filtered base band signal is then applied to an FM signal generator as the modulating signal. To generate a GMSK modulated signal (modulation index = 0.5) at a bit rate of 72kb/s, frequency deviation of the FM signal generator needs to be set at 18kHz. The output from the generator is then a GMSK modulated signal (at 45MHz). Another signal generator is employed to provide an LO signal at 55.7MHz for the FM/IF system detection.

After FM discriminator detection, the output base band signal is fed into another Gaussian LPF on the board to eliminate noise. The 3dB bandwidth of both Gaussian LPFs is controlled by an external clock. This clock should be a square wave signal with TTL level. By controlling the frequency of this clock, different BTb can be achieved for certain bit rate. To have BTb equal 0.5 with bit rate of 72kb/s, the clock signal is set at 3.6MHz (100 times the required 3dB bandwidth). The output from the LPF is then sent to the threshold detector for data regeneration. The data clock signal is taken directly from the data error analyzer. The sampling time can be controlled by adjusting VR2 in the circuit diagram. The recovered data sequence is fed back to the Data Error Analyzer for BER measurement.

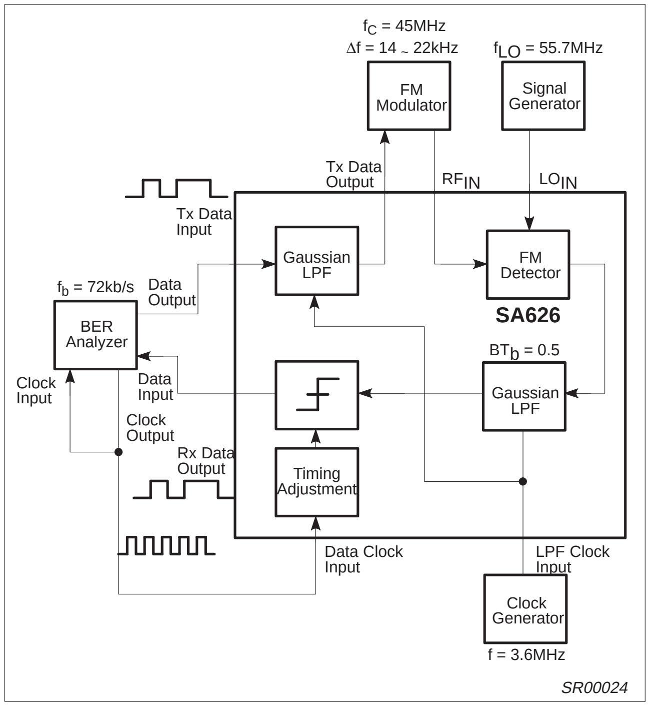

Figure 7. Measurement Set-Up with the GMSK/GFSK Board

Measurement Procedure and Results

1. **Measure SINAD at the audio output of SA626:** use the same set-up as described above, but set RF = 45MHz, fm = 1kHz, Δf = 8kHz; LO = 55.7MHz, -10dBm; the measured typical sensitivity for 12dB SINAD should be about -110dBm. (See Ref 1. for detailed SINAD measurement.)
2. **Check "LPF clock input":** this clock should be a TTL level signal with the frequency of 100 times the desired 3dB bandwidth of the LPF. For the data rate of 72kb/s and BTb = 0.5 LPF, the clock frequency is 3.6MHz (100 × 36kHz).
3. **Check "Tx data input":** 72kb/s baseband NRZ signal.
4. **Measure "Tx data output":** Gaussian low-pass filtered baseband eye-diagram as shown in Figure 8.
5. **Check "data clock input":** 72kHz clock signal.
6. **Adjust sampling position:** by adjusting VR2, set the rising edge of the clock at Pin 11 of Unit 4 (74HC74) to be at the center of the eye-diagram at Pin 2 of Unit 6 (LM311) in the circuit diagram.
7. **Measure BER with high RF level:** set RF input signal level at -80dBm and -90dBm, LO signal level at -10dBm: error free.
8. **Measure BER vs. RF input level curve:** RF level: -94 ~ -104 dBm, LO level: -10dBm, at each point, at least 100 errors have to be measured. Figure 9 presents the measured BER as a reference.

QUESTIONS & ANSWERS

Q. For the SINAD measurement, is it necessary to connect the whole system?

A. Even though only part of the system is used to measure SINAD, it is recommended to connect the whole system because the RF part should be tested under the operating conditions.

Q. Why is the DC current (I_{CC}) very large when I measure the SINAD on SA626?
A. Check the power supplies. Make sure both +5V and -5V are connected all the time even though only +5V is needed for SA626.

Q. Is it possible that SINAD is good, but BER is not good?
A. Yes, because there are other factors affecting BER .

Q. Is it possible that SINAD is bad, but BER is good?
A. No. Good SINAD is a necessary condition to achieve good BER.

Q. What are the main factors affecting BER?
A. They are:

1. Tx LPF
2. FM deviation and RF signal level
3. RF part sensitivity
4. Rx LPF
5. Threshold detector
6. Sampling time

Q. There are two “Rx Data Output” ports. Which one should be used?
A. Two “Rx Data Output” ports are designed to provide convenience for different measurement conditions. Either one can be used if the BER analyzer has the $Q/\overline{Q}$ detection capability.

Q. What needs to be done for higher RF frequency applications?
A. First, RF and LO input matching circuits have to be redesigned at the desired frequency. Second, the layout of RF and LO input circuits might also need to be re-designed. The inputs should be further away from each other and in different directions (not in parallel with each other) to provide better isolation.

REFERENCES:

1. “AN1994: Reviewing key areas when designing with the SA605”, *RF/Wireless Communications*, Data Handbook, Philips Semiconductors, 1994.
2. “AN1996: Demodulation at 10.7 MHz IF with SA/SA605/625*”, RF/Wireless Communications*, Data Handbook, Philips Semiconductors, 1994.
3. “Low voltage high performance mixer FM IF system with high speed RSSI,” (SA626 data sheet), *RF/Wireless Communications*, Data Handbook, Philips Semiconductors, 1994.
4. C. S. Lindquist, *Active Network Design with Signal Filtering Applications,* Steward & Sons, 1977.
5. *Linear Data Book,* National Semiconductor.
6. “GMSK modulation for digital mobile radio telephony”, K. Murota and K. Hirade, *IEEE Transactions on Communications*, July 1981.
7. “Low complexity GMSK modulator for integrated circuit implementation”, S. Grath and C. J. Burkley, *Proceedings of IEEE VTC’90*.
8. K. Feher, *Digital Communications, Satellite/Earth Station Engineering,* Prentice Hall, 1983.

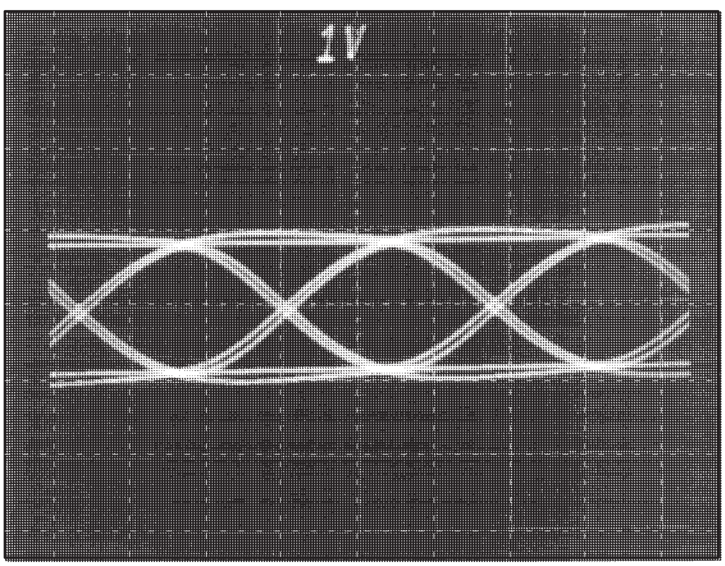

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Figure 8. Baseband Eye-Diagram at the Output of Tx Gaussian LPF

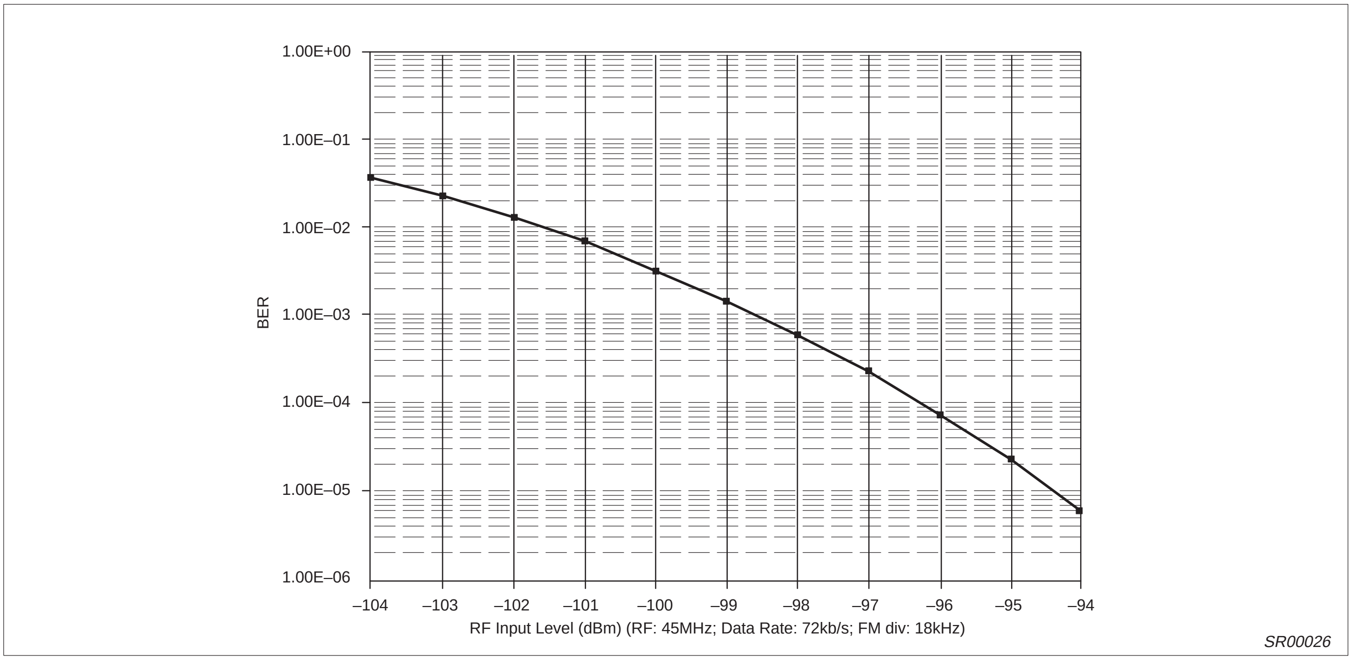

Figure 9. BER of the GMSK/GFSK Demoboard

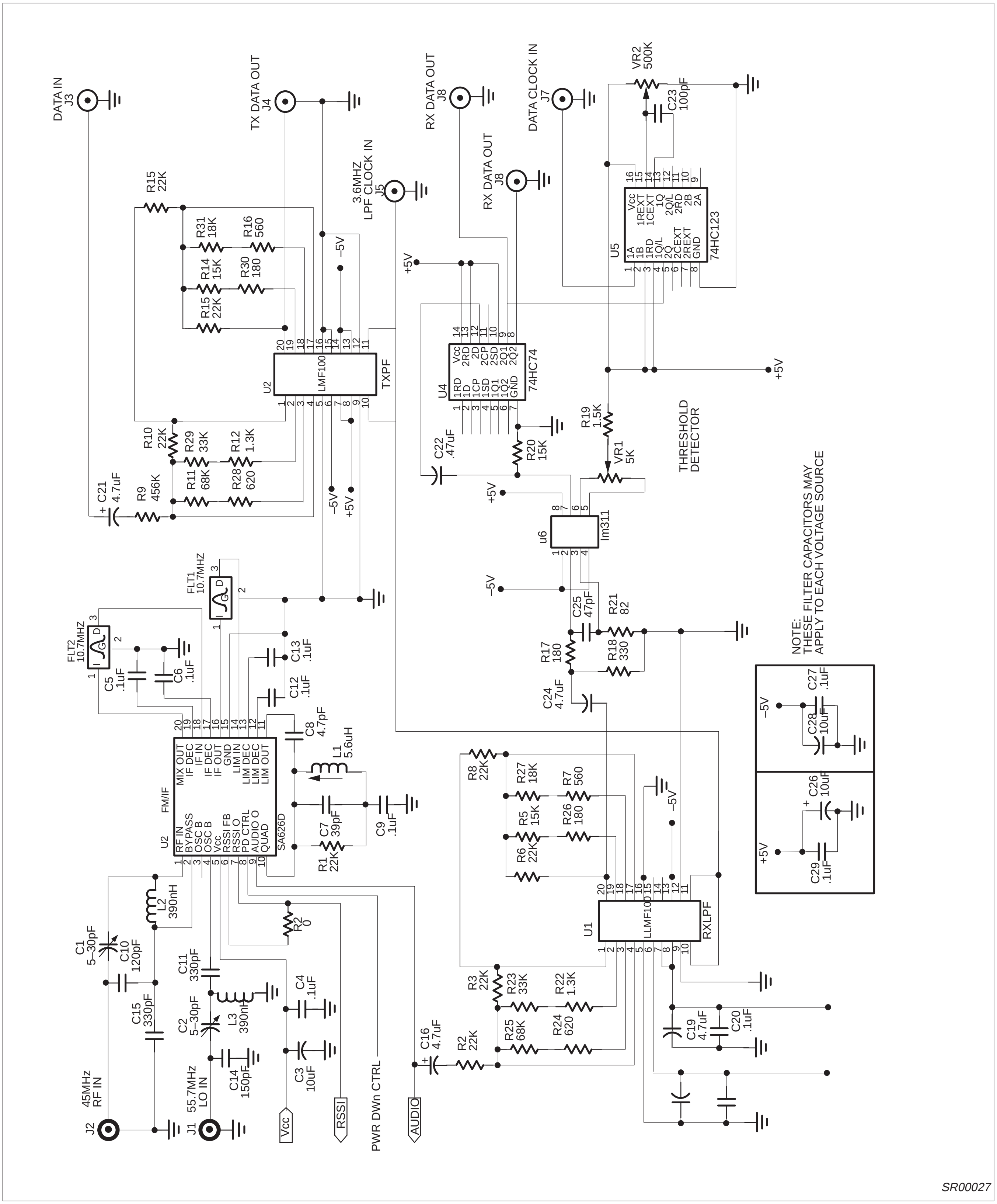

Figure 10. **Circuit Diagram of the GMSK/GFSK Demoboard**

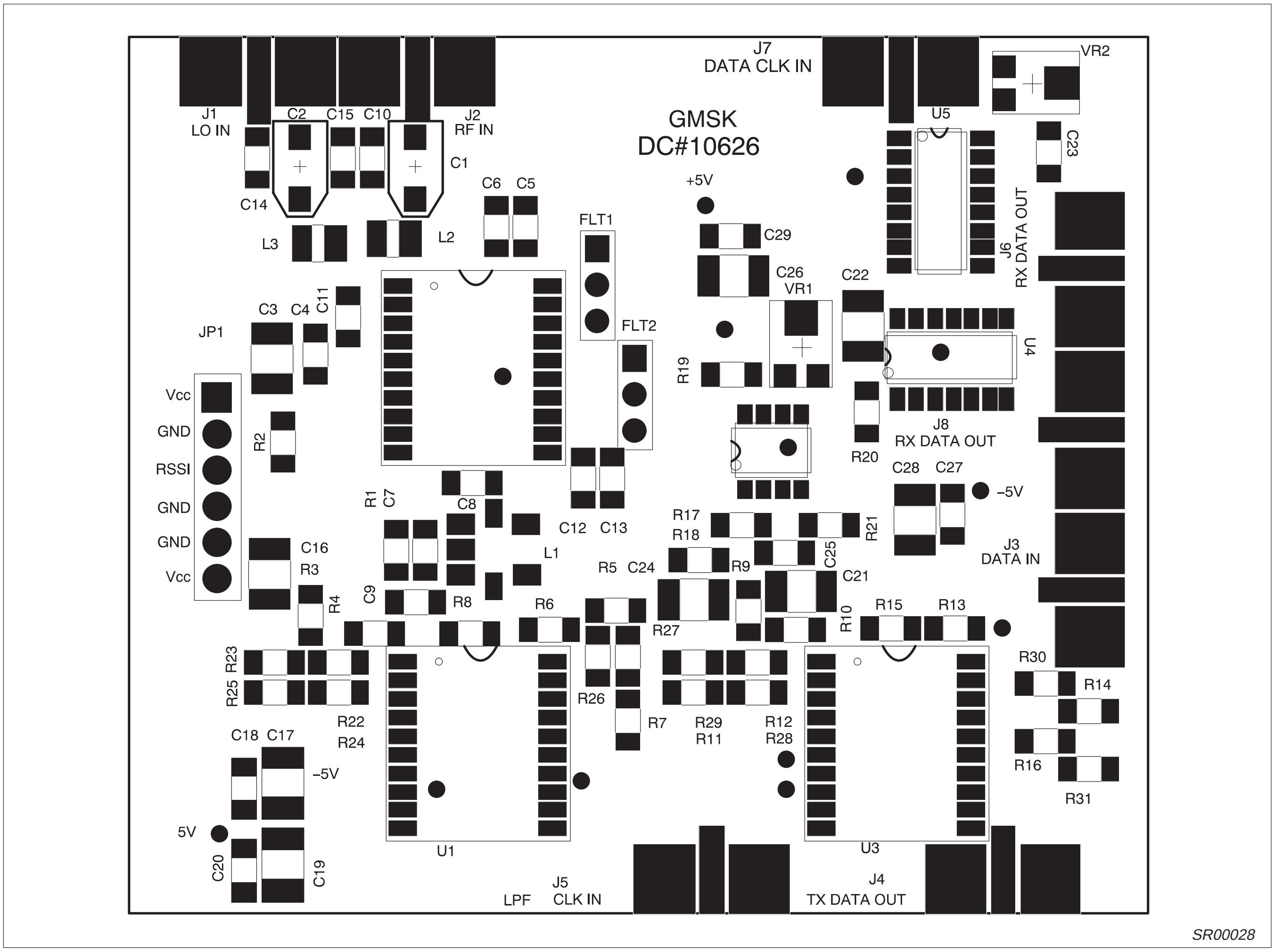

Figure 11. GMSK/GFSK Demoboard Components Layout

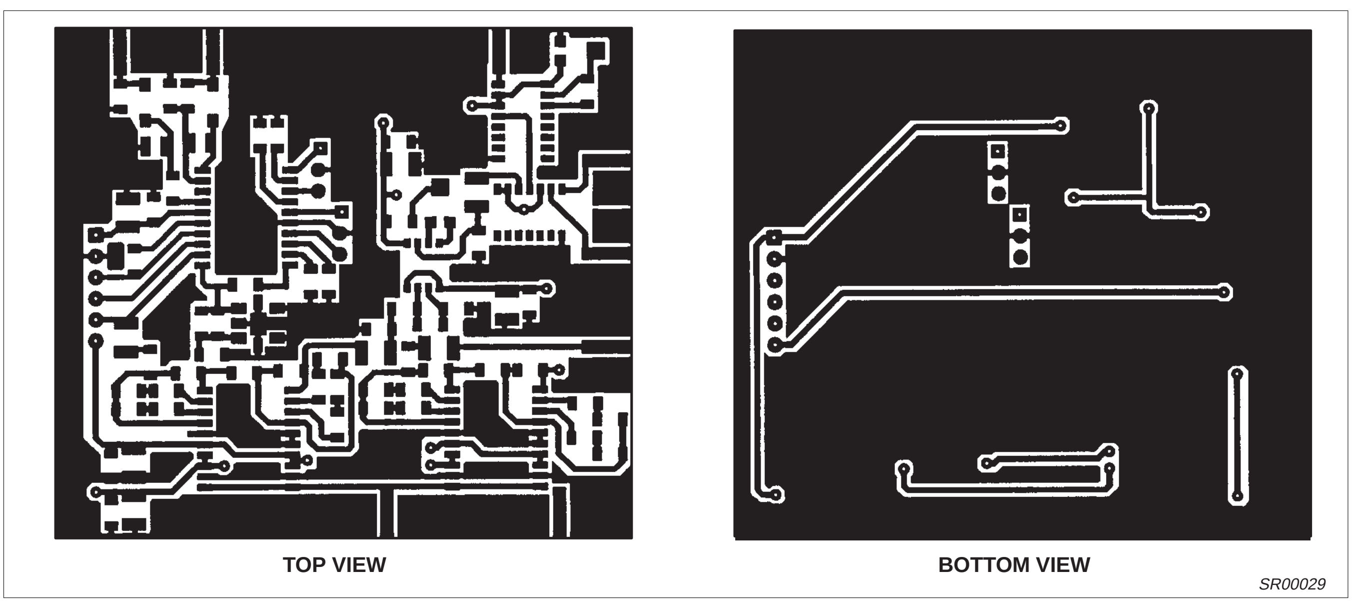

Figure 12. GMSK/GFSK Demoboard Layout

Table 3. Customer Application Component List for GMSK/GFSK Demoboard

Qty.	Part Value	Volt	Part Reference	Part Description	Vendor	Mfg	Part Number
Surface Mount Capacitors							
1	4.7pF	50V	C8	Cap. cer. 1206 NPO ±0.25pF	Garrett	Rohm	MCH315A4R7CK
1	39pF	50V	C7	Cap. cer. 1206 NPO ±5%	Garrett	Rohm	MCH315A390JK
1	47pF	50V	C25	Cap. cer. 1206 NPO ±5%	Garrett	Rohm	MCH315A470JK
1	100pF	50V	C23	Cer. chip cap 1206 NPO ±5%	Garrett	Philips	1206CG101J9BB0
1	120pF	50V	C10	Cer. chip cap 1206 NPO ±5%	Garrett	Philips	1206CG121J9BB0
1	150pF	50V	C14	Cer. chip cap 1206 NPO ±5%	Garrett	Philips	1206CG151J9BB0
2	330pF	50V	C11, C15	Cer. chip cap 1206 NPO ±5%	Garrett	Philips	1206CG331J9BB0
8	0.1μF	50V	C4, C5, C6, C9, C12, C13, C18, C20	Cer. chip cap 1206 X7R ±10%	Garrett	Philips	1206R104K9BB0
1	0.47μF	35V	C22	Tant. chip cap B 3528 ±10%	Garrett	Philips	49MC474B035KOAS
3	4.7μF	10V	C16, C21, C24	Tant. chip cap B 3528 ±10%	Garrett	Philips	49MC475B010KOAS
3	10μF	10V	C3, C17, C19	Tant. chip cap B 3528 ±10%	Jaco	AVX	TAJB106K016R
	Option		C26, C27, C28, C29				
Surface Mount Variable Capacitors							
2	5-30pF		C1, C2	Trimmer capacitor	Kent Elect	Kyocera	CTZ3S-30C-W1
Surface Mount Resistors							
1	0Ω		R2	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW000E
1	82Ω		R21	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW820E
3	180Ω		R17, R26, R30	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW181E
1	330Ω		R18	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW331E
2	560Ω		R7, R16	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW561E
2	620Ω		R24, R28	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW621E
2	1.3kΩ		R12, R22	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW132E
1	1.5kΩ		R19	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW152E
3	15kΩ		R5, R14, R20	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW153E
2	18kΩ		R27, R31	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW183E
1	20kΩ		R1	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW203E
7	22kΩ		R3, R4, R6, R8, R10, R13, R15	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW223E
2	33kΩ		R23, R29	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW333E
1	56kΩ		R9	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW563E
1	68kΩ		R11, R25	Res. chip 1206 1/8W ±5%	Garrett	Rohm	MCR18JW683E
Surface Mount Variable Resistors							
1	5kΩ		VR1	SM RES TRIM, 1 TRN ±20% J-H	Garrett	Philips	ST-4TA502
1	500kΩ		VR2	SM RES TRIM, 1 TRN ±20% J-H	Garrett	Philips	ST-4TA504
Surface Mount Inductors							
2	0.39μH		L2, L3	Chip Inductors-1800CS series	Coilcraft	Coilcraft	1800CS-391
Surface Mount Variable Inductors							
1	5.6μH		L1	Adjustable SM Inductor 5CCD type	Digikey	TOKO	TKS2251
Filters							
2	10.7MHz		FLT1, FLT2	10.7MHz IF filter 110kHz±30kHz	Murata	Murata	SFE10.7MHY-A
Surface Mount Integrated Circuits							
2			U1, U3	Switched capacitor filter	Hamilton	National	LMF100CIWM
1			U2	Low voltage mixer FM IF high RSSI	Philips	Philips	SA626D
1			U4	Dual D-type flip-flop	Philips	Philips	74HC74
1			U5	Dual re-triggerable monostable	Philips	Philips	74HC123
1			U6	Voltage comparator	Philips	Philips	LM311
Miscellaneous							
8			J1, J2, J3, J4, J5, J6, J7, J8	SMA gold connector	Newark	EF Johnson	142-0701-801
1			JP1	6-pins header straight	Mouser	Molex-Waldem	538-22-05-2061
1				Printed circuit board	Philips	Philips	GMSK/DC#10626
78 Total Parts							