Wireless Components

Application Note of DVB-T(COFDM) Tuner with Broadband Multimedia IC, TUA6034

Version 2
(Revised including DVB-T Field Test and Half NIM with TDA6192T)

Applications of IC, TUA6034 :
Specially Suitable for Digital Broadcasting Standards
like DVB-T, DVB-C, ISDB-T, ATSC, etc.

Overview of the DVB-T Tuner

Single Conversion Tuner For European DVB-T application

With Infineon Components of

TUA 6034 Single Chip Mixer-Oscillator-PLL IC

BF 2030W self biasing MOSFETs

BB565, BB659C and BB 689 Varactor Diodes

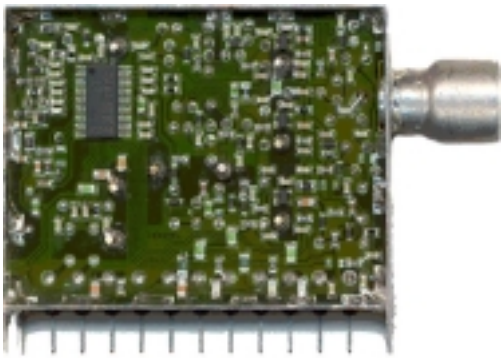
This very small sized single conversion tuner designed for DVB-T(COFDM) front-end in the frequency range from 45 to 865 MHz can be used with minimum modification for all digital broadcasting reception. The tuner was developed as a real 3 band tuner concept, designed without switching diodes based on the Infineon 3 band tuner IC, **TUA6034** which has 3 mixer, 3 oscillators, separated SAW driver input, PLL and balanced crystal oscillator for optimum digital front-end performance. The IC is particularly suitable for COFDM applications like DVB-T and ISDB-T that requires stringent close-in phase noise. The IC provides a balanced SAW filter driver output that is designed to drive a SAW filter directly.

The tuner is optimized for IF bandwidth = 8MHz and IF center frequency = 36.125MHz.
The frequency ranges of the tuner is as follows :

VHF I	**: 51.025 - 157.025 MHz**
VHF II	**:164.025 - 442.025 MHz**
UHF	**:450.025 - 859.025 MHz**

All the passive and active components except air coils, 1 choke coil are SMD components. The PCB is single-clad and the dimensions are 49.5 x 38.5 mm. The pin layout and the outline dimensions are designed according to the world standard tuner description, which is the current standard size of analog tuners in the market.

Semiconductors:



1 X 

TUA 6034

3 X  **BF 2030W**

7 X  **BB 565**

4 X  **BB 659C**

4 X  **BB 689**

2 x MOSFET in case of using a new Double -MOSFET
1 X BF2030W(UHF), 1 X BG3130(VHF)

Contents

1. Tuner Design

1.1. Circuit Concept

The RF input signal is splitted by a simple high pass filter combined with IF & CB(Citizen Band) traps. Instead of band switching with PIN diodes a very simple triplexer circuit is used. With a high inductive coupling the antenna impedance is transformed to the tuned input circuits. The pre-selected signal is then amplified by the high gain self biased MOSFET **BF2030W**. One **BG3130, double-MOSFET** can be used for both VHF bands. In the following tuned bandpass filter stage, the channel is selected and unwanted signals like adjacent channels and image frequency are rejected . Tracking traps of prestages and capacitive image frequency compensations of band filters reject especially image frequencies.

The conversion to IF is done in the one chip tuner-PLL IC, TUA 6034. **TUA6034** is a real 3 band tuner IC which has all the active parts for the 3 mixers, 3 oscillators, an IF driver stage, the complete PLL functions including 4 PNP ports & 1 NPN port(ADC input) for the band switching, and a wideband AGC detector for internal tuner AGC. Combined with the optimized loop filter, 4 programmable charge pump currents, the balanced crystal oscillator, and the voltage controlled oscillators which have superb characteristics thanks to Infineon's B6HF technology , the tuner can achieve distinguished phase noise performance suitable for all digital applications. The balanced IF output signal of the **TUA6034** is designed to drive directly a SAW filter in the following IF stage.

The tuner consumes less than 90 mA currents or 0.45 Watt power. This can be a big advantage for portable or handheld appliances.

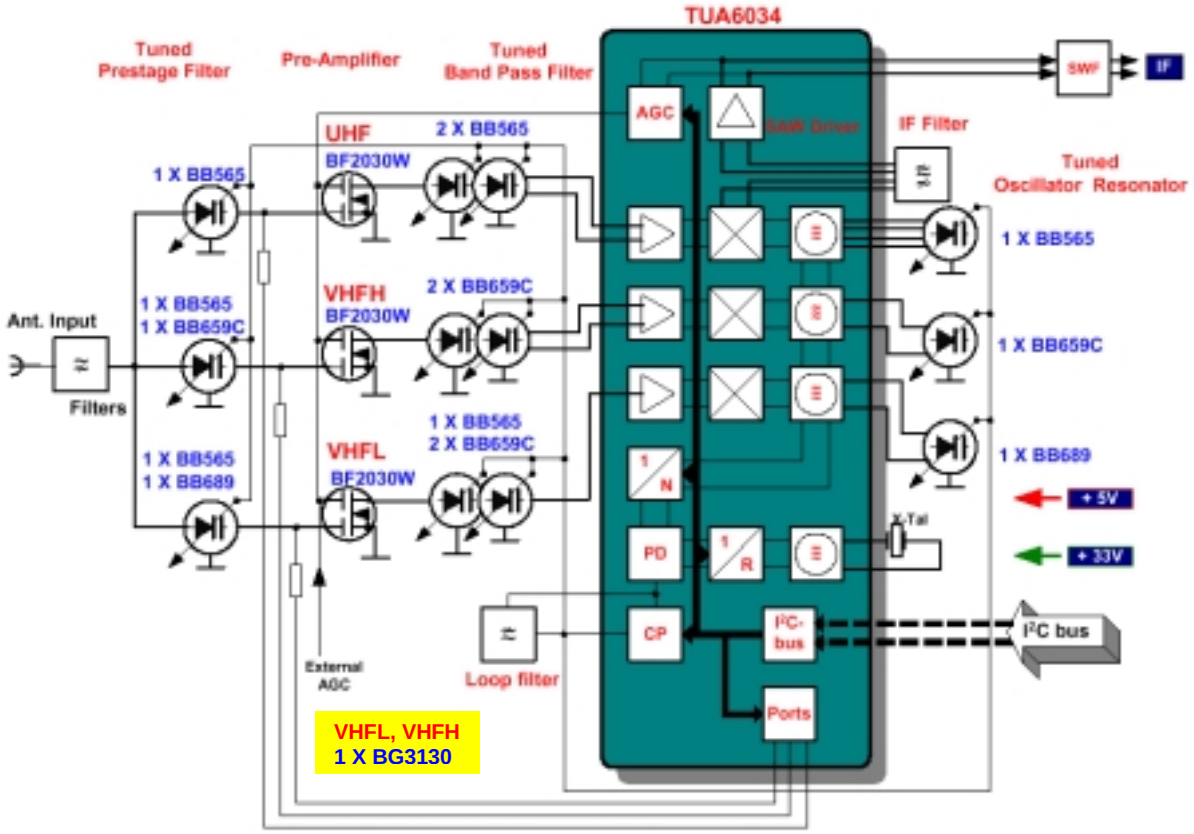


Fig 1. Circuit Concept Diagram of DVB-T Tuner

For the detailed circuit description please refer to Appendix.

1.2. UHF RF Block

With the wide range ultra linear varactor diode **BB565** it has become possible to design an UHF band without coupling diodes and without compensating coils for extending the frequency ratio in the tuned filters. To get a good tracking without a coupling diode between the input filter and the MOSFET the point of coupling is set between the tuning diode and the series capacitor, and not at the high end of the resonant circuit.

The bandpass stage is an inductive low end coupling filter, which concurrently provides the transformation from unbalanced to balanced. Also thanks to the matched image filters on both prestage and band pass filter stage, better than 65dB image rejection can be achieved over the whole UHF band. By means of simple gate 1 switching through PNP ports, pre-amplifiers are selected.

1.3. VHFH RF Block

For VHFH band, high quality ratio-extended varactor diode, **BB659C** is used. To compensate gain, one additional coupling diode, **BB565** is placed on the prestage of VHFH.

The RF bandpass filter is unbalanced on the primary side, and balanced on the secondary side just like UHF band pass filter. The coupling between filters is realized via a printed inductor. The mixer input circuit is optimized to protect the mixer from overloading. Image rejection filters work as those of UHF block.

1.4. VHFL RF Block

For the wide VHFL frequency range a tuning diode with an extended capacitance ratio is required. **BB689** is a tuning diode, which was developed to cover the wide frequency range of Hyperband tuner and at the same time shows a low series resistance. 2 X **BB565** are used for coupling to achieve improved RF characteristics.

The RF band pass filter is unbalanced, and is also coupled asymmetrically to the high ohmic VHFL mixer, which has no negative effects due to the relatively low frequencies involved.

After the RF Block circuit design it is preferable to do block simulations to confirm its frequency dependent characteristics. Fig.2 is one of such simulation results.

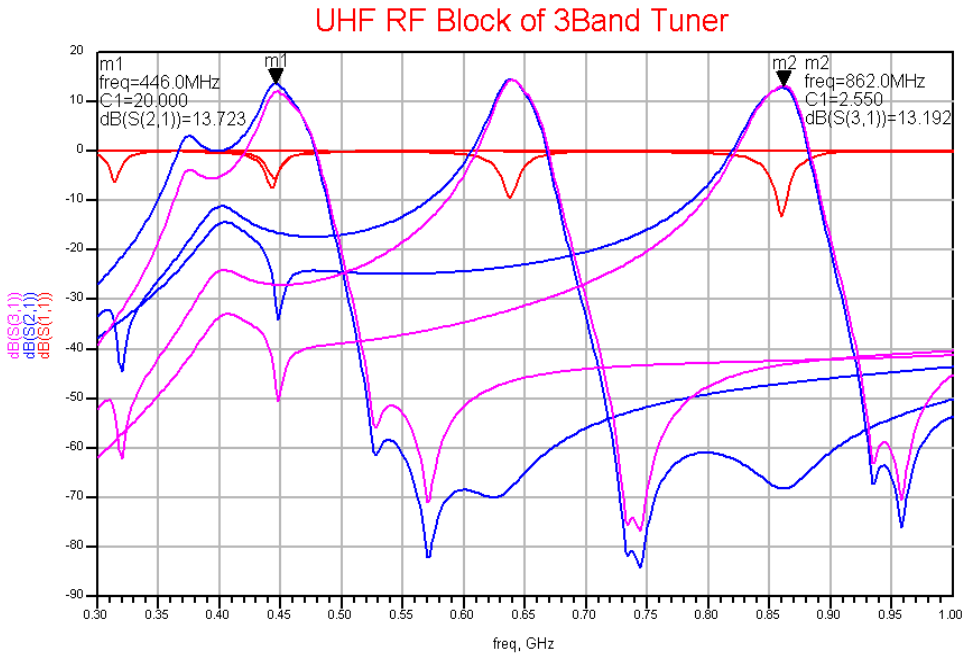


Fig 2. One of the Simulation Results of DVB-T Tuner RF Blocks

1.5. Oscillator Resonator, PLL Loop Filter and Phase Noise

The Oscillator tank circuits were carefully optimized for oscillator range, stability and phase noise. The layout is also optimized to prevent any kind of unwanted parasitic oscillations, Capacitors of the resonators could be temperature-compensated if necessary. N750 type is recommended for this purpose.

One of the most important considerations to design a good DVB-T tuner is how to down-convert input RF signals to IF frequency with minimized phase noise. The DVB-T standards provides for two modes of operation, a 2K mode with 1705 subcarriers, and an 8K mode with 6817 subcarriers for OFDM(Orthogonal Frequency Division Multiplexing) transmission[1]. An OFDM signal as in Fig.3 contains multiple subcarriers, each of which is a smaller percentage of the total frequency bandwidth than in a single carrier system. As a result, phase noise is a smaller percentage of the bandwidth in a single-carrier system. For this reason, phase noise degrades the performance of an OFDM system more than in a single carrier system.

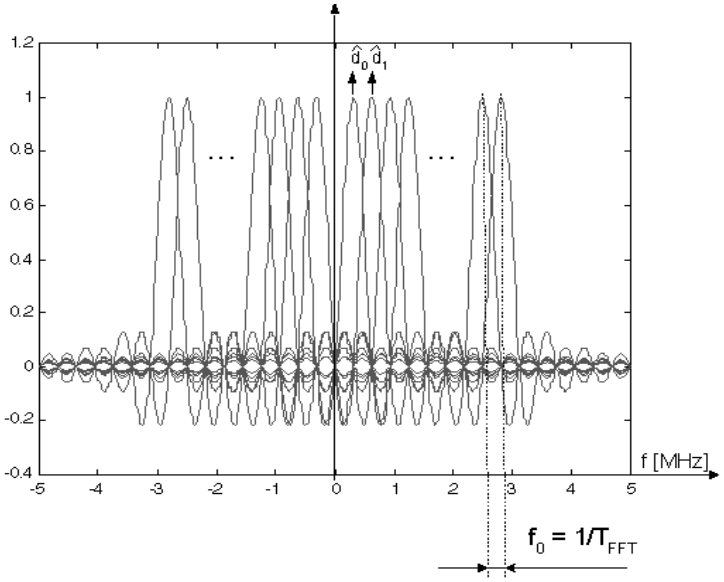


Fig 3. Typical Spectrum of the simple OFDM signal

Phase noise influences two important system performances : One is receiver selectivity by reciprocal mixing in Fig.4, and the other is receiver sensitivity or SNR[2], which decides BER(Bit-Error-Rate) of the digital system combined with other noise sources like prestage noise figures, image noise, etc.

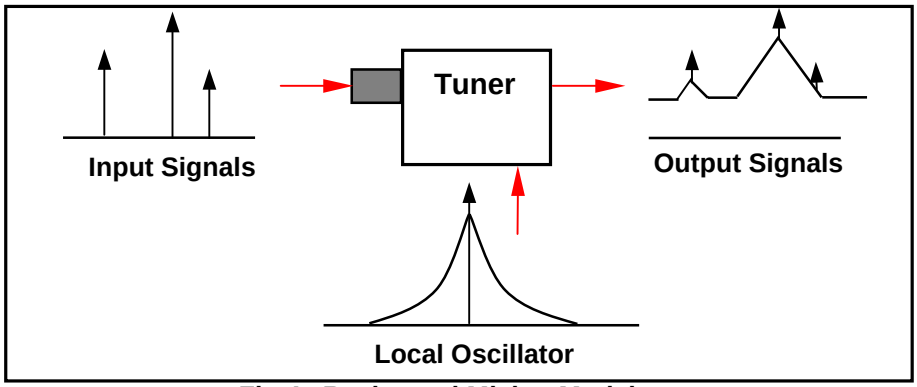


Fig 4. Reciprocal Mixing Model

[1]. *ETSI EN 300 744 V1.2.1*

[2]. *Muschallik, C., Influence of RF oscillators on an OFDM signal, IEEE Transactions on Consumer Electronics, vol.41,No.3, pp.602-603*

To design optimum resonators for the IC, the well-known Leeson's equation[3] should always be reflected. Even though there is an improved phase noise model[4] for better phase noise analysis and

$$L(fm) = 10\log\left[\frac{1}{2}\left[\left(\frac{fo}{2QLfm}\right)^2 + 1\right]\left(\frac{fc}{fm} + 1\right)\left(\frac{FkT}{Ps}\right)\right] \qquad (1)$$

prediction, Leeson's equation is still a basis of all those new approaches.

L(fm) is ratio of noise power in a 1-Hz bandwidth in units of dBc/Hz. fo is the frequency of oscillation. fc is the flicker noise corner. F is the noise figure of oscillator. Ps is the carrier power. K is Boltzmann's constant, 1.38x10^{-23} J/K. T is Kelvin temperature. $Q_L$is loaded Q factor.

Infineon Technologies B6HF bipolar process with a transit frequency (f_T) of 25 GHz to produce **TUA6034** can satisfy a low intrinsic F requirement of oscillator. The external applications of the oscillator should be carefully designed not to degrade Q with regard to stable oscillation.

The critical role of loop filter is to remove the reference spurs produced by the phase detection process, which is fundamentally a sampled system in digital implementations. Since the control voltage directly modulates the frequency of the VCO, any AC components of tuning voltage results in a frequency modulation of the oscillator. If these components are periodic, they produce stationary side-bands like reference spurs. Because of the wide tuning range of the tuner, the tuning sensitivity of tuner can go up to 35MHz/V, so even a few millivolts of noise on the tuning lines will generate noticeable spectral interference.

The oscillator's output now has the benefits of phase locking such as improved stability and phase noise and this is another crucial function of PLL. By determining a proper loop bandwidth, optimum phase noise characteristics of the reference oscillator and the local oscillator can be utilized. For a given loop bandwidth, a higher order filter provides more attenuation of out-of-band spectral components. However, the higher the order, the more poles there are, and it means it gets harder to make the loop stable. The loop bandwidth and loop filter components should be carefully selected to achieve optimal phase noise and to reject reference spurs. 4 extended modes of charge pump currents also must be appropriately chosen and used for best phase noise performance of different frequency ranges. For this tuner design DVB-T recommended fref=166.667KHz is used for all loop filter calculations and measurements.

A 3rd order passive loop filer is chosen for the tuner design. The following are simplified procedures to decide the loop filter components.

1. *Define the basic synthesizer requirements ; oscillator frequency ranges, f_{ref}, maximum frequency step, f_{BW}(Loop Bandwidth, Hz) with deep consideration of in-out band phase noise.*
2. *Identify Kvco(VCO sensitivity, Hz/V) and Icp(charge pump current, A).*
3. *Calculate F_{step} = f_{vco_max} - f_{vco_min}, to optimize for f_{vco_max}*
4. *Calculate N = f_{vco_max} / f_{ref}, to optimize for f_{vco_max}.*
5. *Calculate natural frequency, F_n ; ζ = damping factor*

$$Fn = \frac{2\times f_{BW}}{2\pi\times(\zeta + \frac{1}{4\times\zeta})} \quad Hz \qquad (2)$$

6. *Calculate C68 ;*

$$C68 = \frac{I_{cp}\times K_{vco}}{N\times(2\pi\times F_n)^2} \quad Farad \qquad (3)$$

[3]. *G.Vendelin, A.Pavio, U.Rohde, Microwave Circuit Design using Linear & Nonlinear Techniques, John Wiley & Sons, New York, 1992, pp.385-491.*

[4]. *Hajimiri, A., & Lee, T.H., A genaral theory of phase noise in electrical oscillators, IEEE journal of solid-state circuits, Vol.33, No.2, pp.179-194.*

7. *Calculate R39, and its phase noise contribution. This completes the main part of the loop filter.*

$$R39 = 2 \times \zeta \times \sqrt{\frac{N}{I_{cp} \times K_{vco} \times C68}} \quad ohm \qquad (4)$$

$$L_{\Phi}(fm) = 20\log\left(\frac{K_{vco}\sqrt{2k \times T \times R39}}{fm}\right) \quad dBc/Hz \qquad (5)[5]$$

8. *Calculate C65, which is used to damp transients from the charge pump and should be at least 20 times smaller than C69, i.e.,* $C69 \le \frac{C68}{20}$

9. *Calculate R40 & C24 within these limits and the phase noise contribution of R40 by Eq.(5).*

$$\tau 1 = C68 \times R39, \tau 2 = C24 \times R40, \qquad 0.01 < \frac{\tau 2}{\tau 1} < 0.1$$

A bigger time constant results in somewhat better filtering action, but tends to be associated with lower stability.

10. *In order to have the confidence in the stability of the loop, an open loop analysis is performed to estimate the gain and phase margin. By closed loop analysis we can obtain the frequency response & transient response of the loop. We use a mathmatic tool to analyse these parameters though a spreadsheet program is enogh for the above calculations.*

Typically the crystal oscillator used for the reference has very good phase noise that then levels off near 10KHz offset at around -150dBc/Hz. The free running oscillator to be phase locked typically has much higher close in noise but continues down to around -120dBc/Hz beyond 1MHz. At some offset the reference noise multiplied up to the output frequency becomes higher than the oscillator's free running noise. This is the point where normally the loop bandwidth is set. Inside the loop the oscillator noise is improved by the reference, yet outside the loop is not degraded by the reference. Because of the wide tuning range of the tuner oscillator the loop bandwidth should be very carefully chosen with deep consideration of these noise contribution mechanism.

The phase noise level within the loop bandwidth can be approximated by

$$Close\_in\_phase\_noise = (1Hz\_normalized\_phase\_noise\_floor) + 20\log N + 10\log f_{ref} \qquad (6)$$

There are other sources of phase noise that need to be considered when designing the tuner. One of the most common sources of noise is the power supply to the IC. This can be caused in many ways, but most commonly are due to supply ripple and electric or magnetic coupling to +5V line. Correct PCB layout and good AC blocking are critical to ensure good noise performance. The highest level signal line in the tuner is the IF output line, and all those sensitive blocks like oscillator, loop filter and long DC lines should be well-protected from coupling by IF lines.

1.6. IF Block

TUA6034 has separated mixer outputs and SAW driver inputs to realize an IF filter of band pass filter structure that helps much better adjacent channel rejection. Especially in simulcasting signal environment as in Fig.5, it is a big advantage combined with **internal AGC** of TUA6034 to efficiently suppress strong adjacent PAL signals. The tuner provides a balanced IF output to drive directly a **SAW** filter.

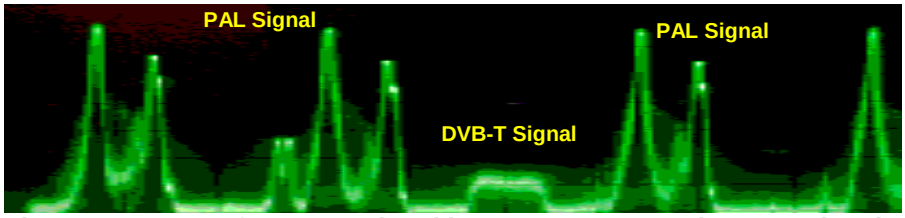


Fig 5. Spectrum of a DVB-T signal between strong analog PAL signals

[5]. *G.Vendelin, A.Pavio, U.Rohde, Microwave Circuit Design using Linear & Nonlinear Techniques, John Wiley & Sons, New York, 1992, pp.436.*

2. PCB

Single-clad, 1.5 mm thickness FR4 PCB is used for the tuner design. However, Double-clad PCB will give more chances to achieve better performance.

3. TUA 6034, One-Chip Multimedia Tuner IC

3.1 Highlights

The core of the tuner is the one-chip mixer oscillator-PLL IC TUA 6034.

The following are some of the outstanding features:

Features

- **Suitable for DVB-C, DVB-T, ISDB-T and ATSC**
- Wideband AGC detector for internal tuner AGC
  - 5 programmable take-over points
  - 2 programmable time constants
- **Low Phase Noise**
- **Full ESD protection**
- **Mixer/Oscillator**
  - High impedance mixer input (common emitter) for LOW band
  - Low impedance mixer input (common base) for MID band
  - Low impedance mixer input (common base) for HIGH band
  - 2 pin oscillator for LOW band
  - 2 pin oscillator for MID band
  - 4 pin oscillator for HIGH band
- **IF-Amplifier**
  - IF preamplifier with symmetrical 75Ω output impedance able to drive a SAW filter
- **PLL**
  - 4 independent I^2C addresses
  - I^2C bus protocol compatible with 3.3 V and 5V micro-controllers up to 400 kHz
  - Short lock-in time
  - High voltage VCO tuning output
  - 4 PNP ports, 1 NPN port/ADC input
  - Internal LOW/MID/HIGH band switch
  - Lock-in flag
  - 6 Programmable reference divider ratio (24, 28, 32, 64, 80, 128)
  - 4 Programmable charge pump current (50, 125, 250, 650uA)
- **TSSOP-38 and VQFN-40 Package on demand in CY2002**

3.2 Block diagram

In the block diagram the internal structure of the IC is shown in Fig.5.

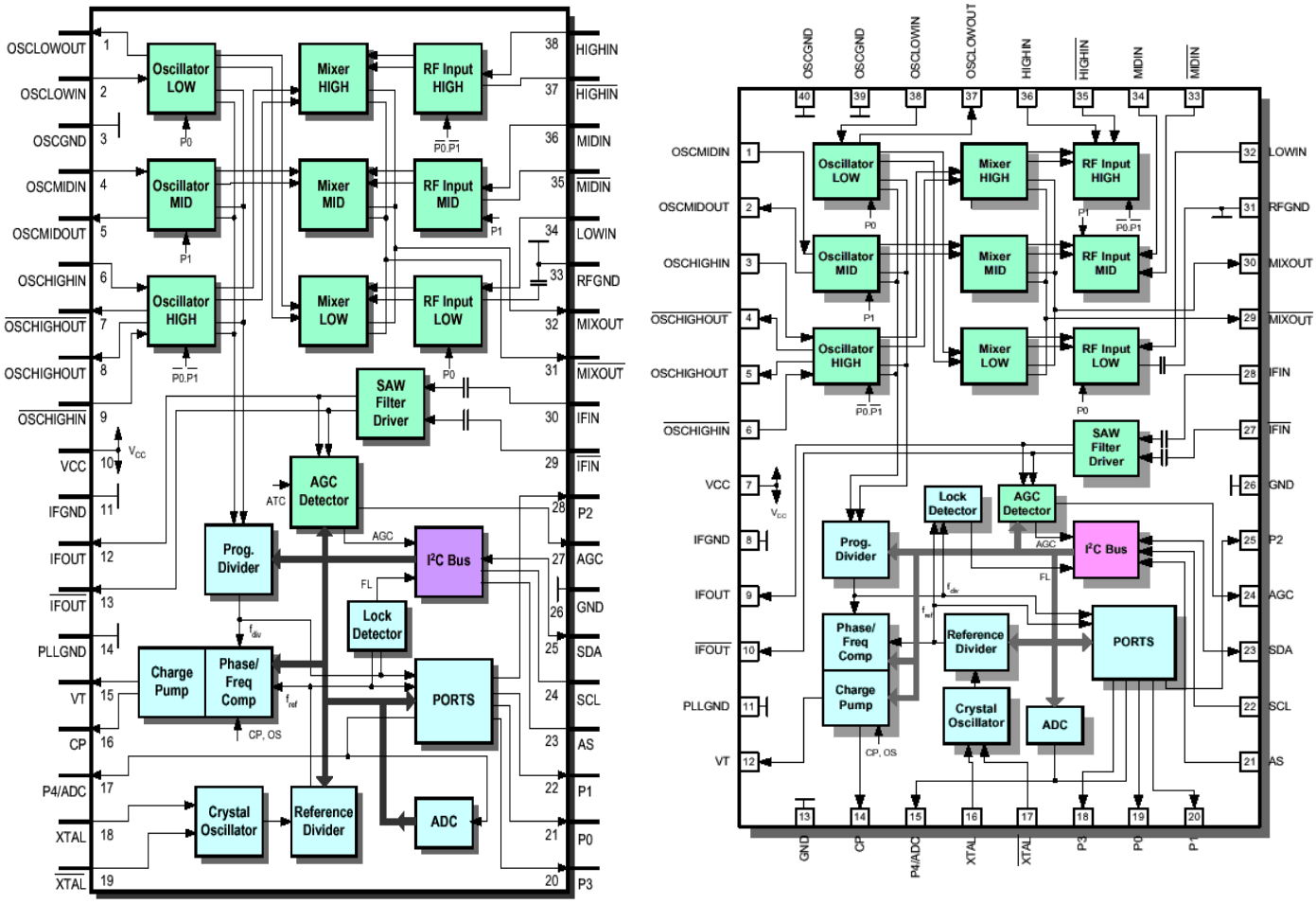


Figure 5. Block Diagram of TUA6034, TSSOP-38 and VQFN-40 package

TUA6034 combines a mixer-oscillator block with a digitally programmable phase locked loop (PLL) for use in broad-multimedia frontend applications. The mixer-oscillator block includes three balanced mixers (one mixer with an unbalanced high-impedance input and two mixers with a balanced low-impedance input), two 2-pin asymmetrical oscillators for the LOW and the MID band, one 4-pin symmetrical oscillator for the HIGH band, an IF amplifier, a reference voltage, and a band switch. Mixer outputs and IF amplifier inputs are separated to make it possible to realize a band pass IF filter to suppress adjacent channels efficiently.

The PLL block with four independently selectable chip addresses forms a digitally programmable phase locked loop. With a 4 MHz balanced reference quartz oscillator, the PLL permits precise setting of the frequency of the tuner oscillator up to 1024 MHz in increments, f_{ref} of 31.25, 50, 62.5, 125, 142,86 or 166.667 kHz. The tuning process is controlled by a microprocessor via I²C bus. The device has 5 output ports; one of them (P4) can also be used as ADC input port. A flag is set when the loop is locked. The lock flag can be read by the processor via the I²C bus. By means of 4 programmable charge pump current, 50, 125, 250, 650uA tuner designers can choose an adequate charge pump current depending on their own loop filter design, frequency usage, and in-out band phase noise requirement.

4. Alignment

4.1 Alignment set-up

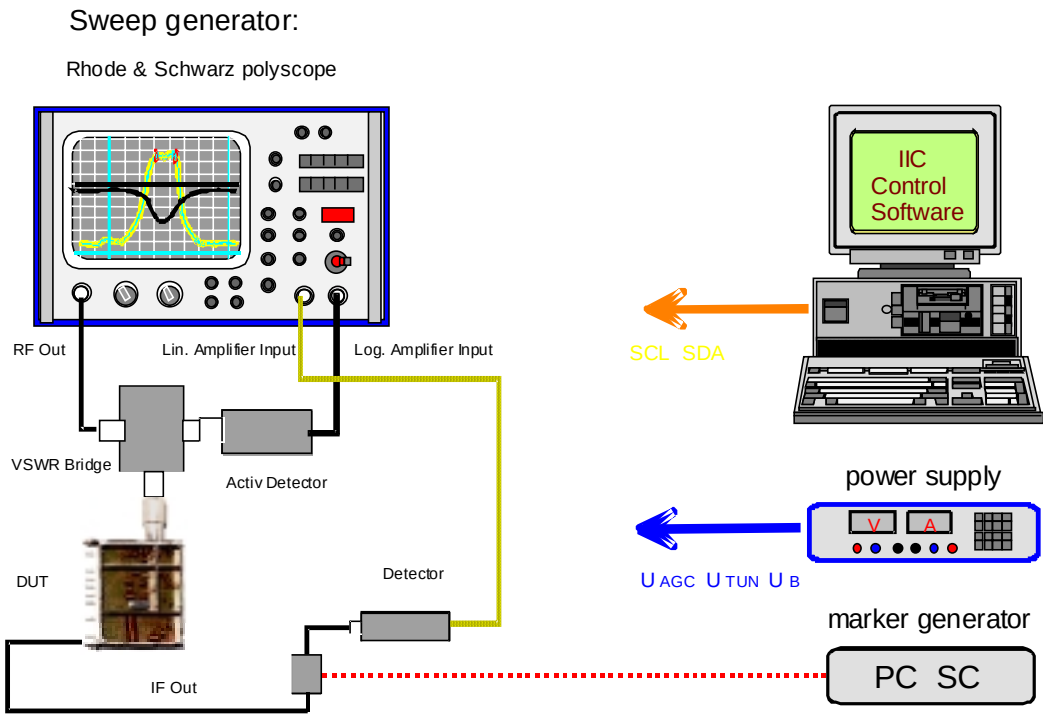
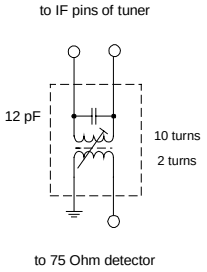


Figure 7. Tuner Alignment Setup

This is an example of analog tuner alignment setup. The same setup can be used to align RF performance of DVB-T tuner. IF center frequency of 36.125MHz will be used for the overall alignment, and 3 points of IF frequencies, 32.125, 36.125 & 40.125MHz should be monitored to align in-channel characteristics. Instead of a Polyscope we can use any type of network analyzer which has a conversion loss measurement function. With such a general-purpose network analyzer the system bandwidth and sampling points of the instrument should be adjusted for best resolution.

The sweep generator is connected via a return loss bridge to the antenna input of the tuner. Because of the balanced SAW driver output the 75 Ω detector has to be connected via a dummy balun simulating the SAW filter input impedance to the tuner output.

This dummy balun is also used for the measurements in the test set-up.



For digital tuner alignment only IF center frequency of 36.125(36) MHz can be used all through the alignment and measurement. The tuner is designed to cover IF bandwidth of 8MHz between 32MHz ~ 40MHz.

The tuning voltage of each band should not fall below 0.7 V for lowest frequency and 28 V for highest frequency.

4.2 Alignment Procedures

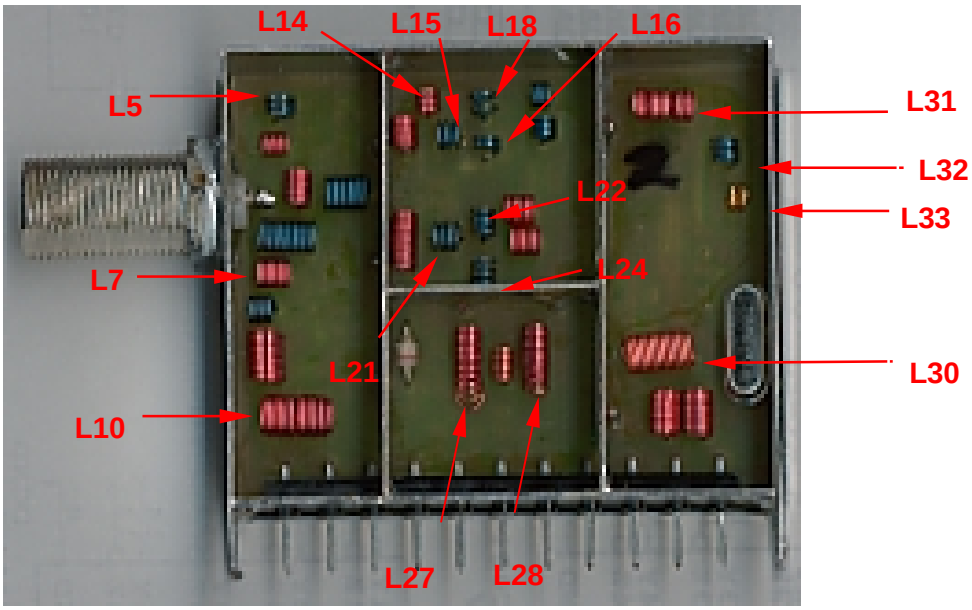


Figure 8. Picture of The Tuner After Alignment

Presented on BOM, some coils should be pre-formed before starting alignment to align easily. Also all the coils must be checked whether they are in the right form, not distorted abruptly.

1. Current consumption & Vt of the tuner must be monitored all through the alignment to check the proper operation of the IC. If the current consumption is over 100mA, the IC must seem to be damaged. IF_{center} = 36.125MHz.
2. UHF alignment :
   - Set the tuner to the highest channel of UHF band, frequency = 859.025MHz and then adjust L33 to have Vt = 22.5 ± 0.3V.
   - Adjust L5 for VSWR.
   - For RF curve & tilt adjust L15 first, and depending on the result, adjust L16 & L18. For highend fine-tuning, adjust L14 a little bit. If the pre-formation of L16, L18 is O.K, we need to touch only L15 & L14.
   - Sweep the whole band or selected channels, and do a fine tune once again if necessary.
3. VHFH alignment :
   - Set the tuner to the highest channel of VHFH band, frequency = 442.025MHz and then adjust L32 to have Vt = 22.5 ± 0.3V.
   - Adjust L7 for VSWR.
   - For RF curve & tilt adjust L21 first, and depending on the result, adjust L22 & L24 a little bit.
   - Sweep the whole band or selected channels, and do a fine tune once again if necessary.
4. VHFL alignment :
   - Set the tuner to the highest channel of VHFL band, frequency = 157.025MHz and then adjust L31 To have Vt = 25.7 ± 0.3V.
   - Adjust L10 for VSWR.
   - For RF curve & tilt adjust L27(Main) & L28 a little bit.
   - Sweep the whole band or selected channels, and do a fine tune once again if necessary.
5. Fine-tune L30 for best IF curve and tilt in case air coil is used for IF filter.

5. Measurement Results

5.1 Electrical Characteristics of the Tuner

Unless otherwise specified all data were measured in conditions of supply voltage of 5 V ± 5%, AGC voltage of 4.5 V ± 5%, ambient temperature of 25 º C ± 5%, f_{ref} of 166.667KHz.

Parameter		Min	Typ	Max	Unit
Frequency range					
VHFL	**51.025 ~ 157.025 MHz**				
VHFH	**164.025 ~ 442.025 MHz**				
UHF	**450.025 ~ 859.025 MHz**				
IF center frequency			36.125		MHz
Frequency margin at low and high ends of each band		1.5			
Supply voltages and currents					
Supply voltage +5 V Pin		4.5	5	5.5	V
Supply voltage VD Pin (with PLL)		30	33	35	
Supply current +5 V Pin				90	mA
Supply current Pin VD Pin (with PLL)				1,8	
Input connector: IEC					
RF Characteristics					
Input impedance Output impedance with IF dummy			75 75		Ω
VSWR at nominal gain and during AGC				5	
External AGC voltage for max gain External AGC voltage for min gain **Internal AGC voltage**		4.05 0.5	4.5 3.8	4.95	V
AGC range VHFL AGC range VHFH AGC range UHF		60 60 50			dB
Tuning sensitivity VHFL Tuning sensitivity VHFH Tuning sensitivity UHF		1 5 3		10 23 35	MHz/V
Power gain measured with 10:2 IF Dummy (Dummy loss = 15dB)			32		dB
Gain taper in each band				5	dB
Noise figure VHFL Noise figure VHFH Noise figure UHF			6.5 5.5 5.5	8 7 7	dB

Parameter	Min	Typ	Max	Unit
RF bandwidth (3 dB) VHFL RF bandwidth (3 dB) VHFH RF bandwidth (3 dB) UHF		10 10 10	20 20 20	MHz
Image rejection VHFL Image rejection VHFH Image rejection UHF	60 60 60	70 70 70		dB
IF rejection channel E2(frequency = 48.25MHz) Other channels	70 80			dB
Input 1 dB compression Point	75			dBuV
Input IP3 (two tone)	85			
Input level producing 50 kHz of oscillator detuning (PLL open loop)	80			
Oscillator shift with supply voltage variation of ± 10 % (open loop)			± 250	kHz
Oscillator temperature drift 25...40 °C(open loop)			1	MHz
Antenna Leakage up to 1GHz			30	dBuV
Phase Noise 1KHz offset 10KH offset ***wide loop bandwidth***[6] 100KHz offset Fig.9, Fig.10	74 74 110			dBc/Hz
Phase Noise, 1KHz offset 10KH offset ***narrow loop bandwidth***[7] 100KHz offset Fig.9, Fig.10	74 80 110			
Cross modulation[8]				dBµV
N±1 Channel / disturbing voltage producing 1 % of Xmod	65			
N±2 Channel / disturbing voltage producing 1 % of Xmod	70			

Some of the measurement graphs are presented in Fig 9, Fig 10 and Fig.11.

[6]. ***Loop filter components for wide loop bandwidth; C68=4.7nF, C65=100pF, R39=68Kohm. This would be suitable for COFDM purpose.***

[7]. ***Loop filter components for narrow loop bandwidth; C68=22nF, C65=1nF, R39=22Kohm. This would be suitable for multi-standard purpose to cover both analog and digital standards.***

[8]. *Wanted signal 60 dBµV, unwanted signal 30% AM modulated with 2.5 kHz, AGC set to full of 4.5 V*

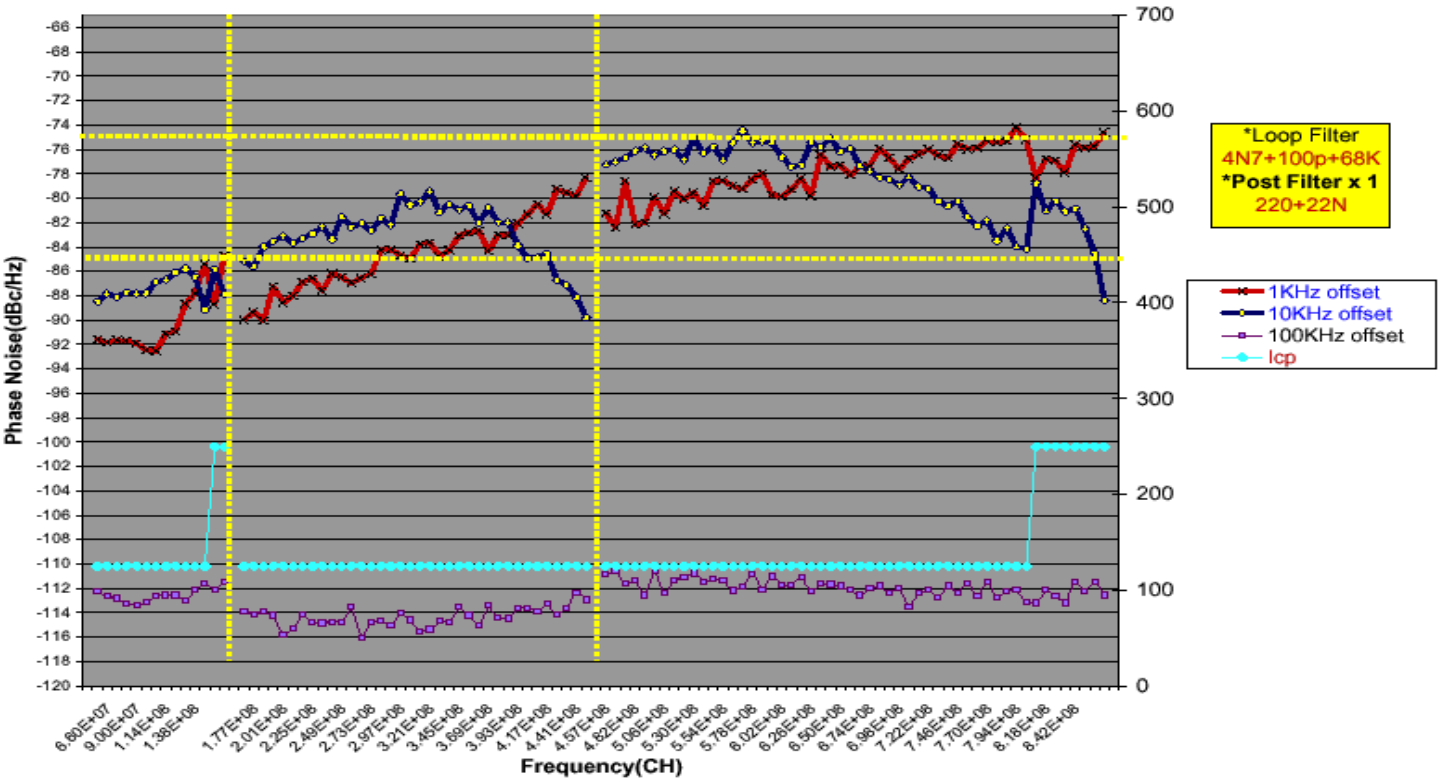


Figure 9A. Phase Noise of DVB-T Tuner by Wide Loop Bandwidth in regard to I_{cp}(fref = 166.667KHz)

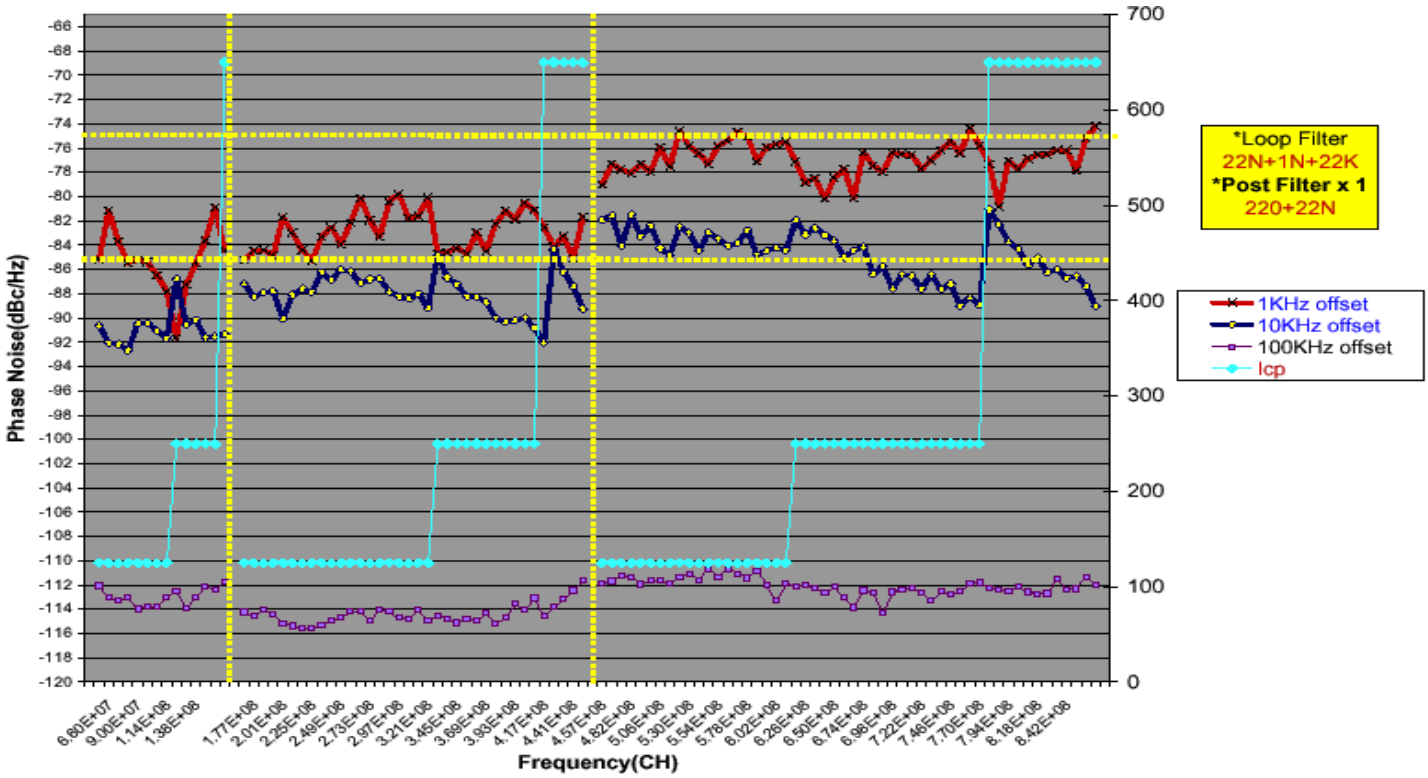


Figure 9B. Phase Noise of DVB-T Tuner by Narrow Loop Bandwidth in regard to I_{cp}(f_{ref} = 166.667KHz)

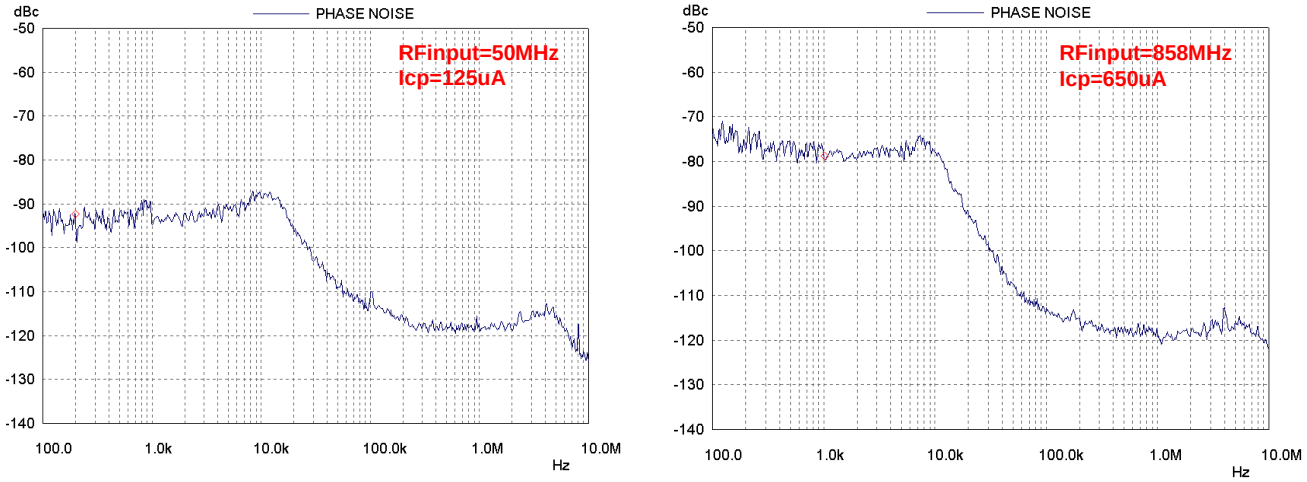


Figure 10A. Phase Noise Log Plots of DVB-T Tuner by Wide Loop Bandwidth (f_{ref}=166.667KHz)

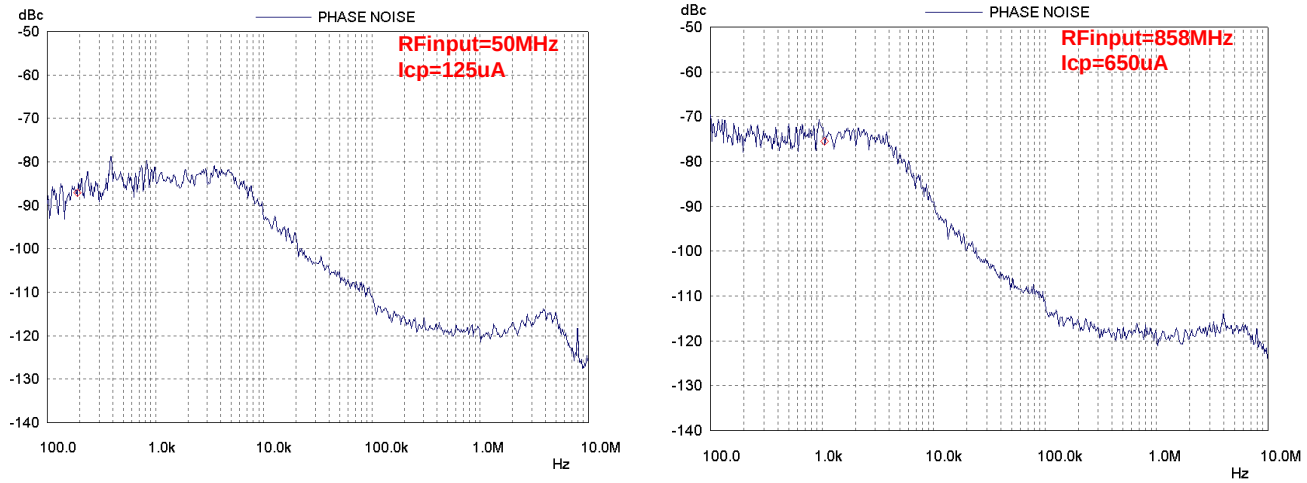


Figure 10B. Phase Noise Log Plots of DVB-T Tuner by Narrow Loop Bandwidth (f_{ref}=166.667KHz)

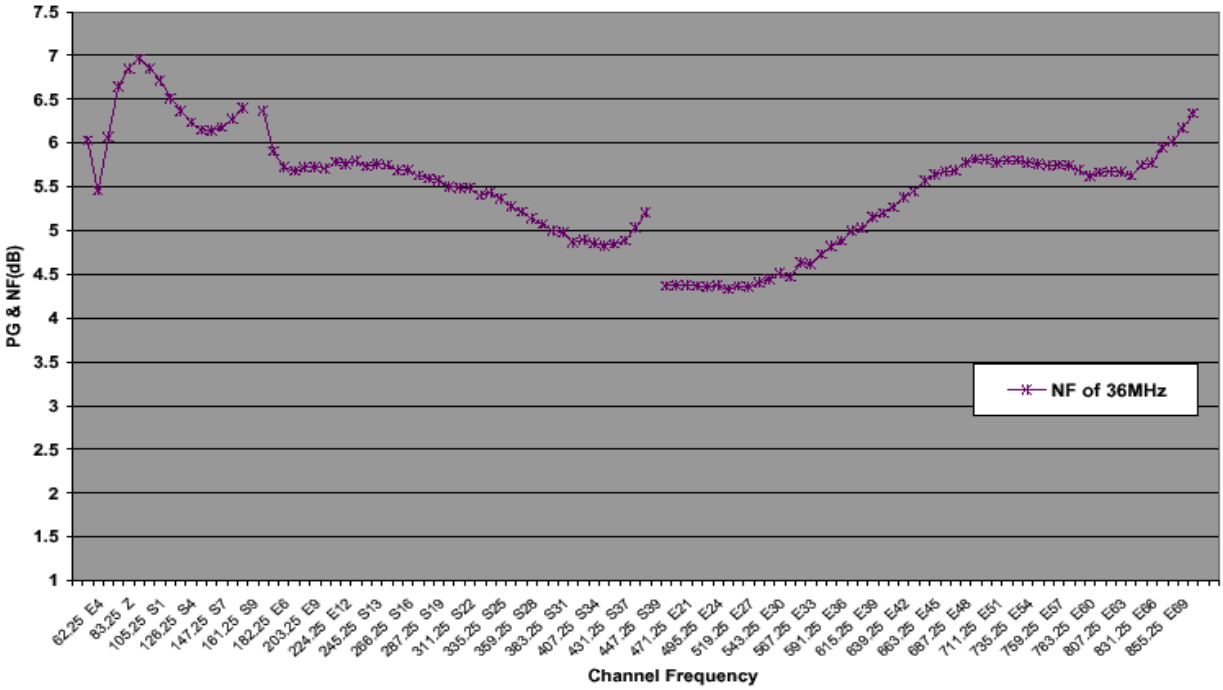


Figure 11A. Noise Figure

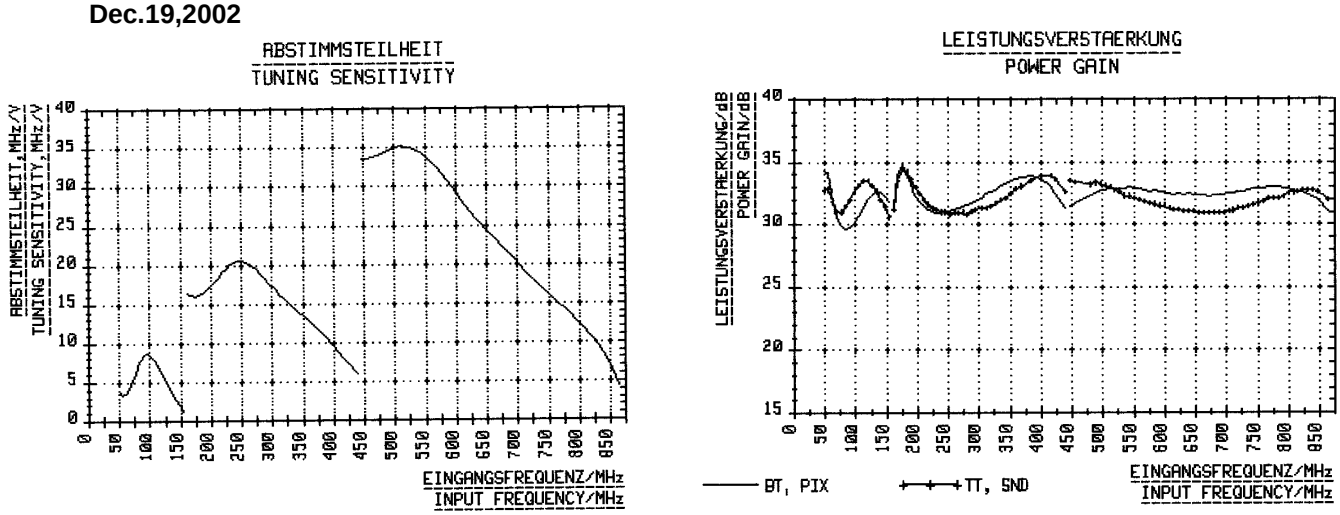


Figure 11B. Tuning Sensitivity(VCO Gain) and Power Gain[9]

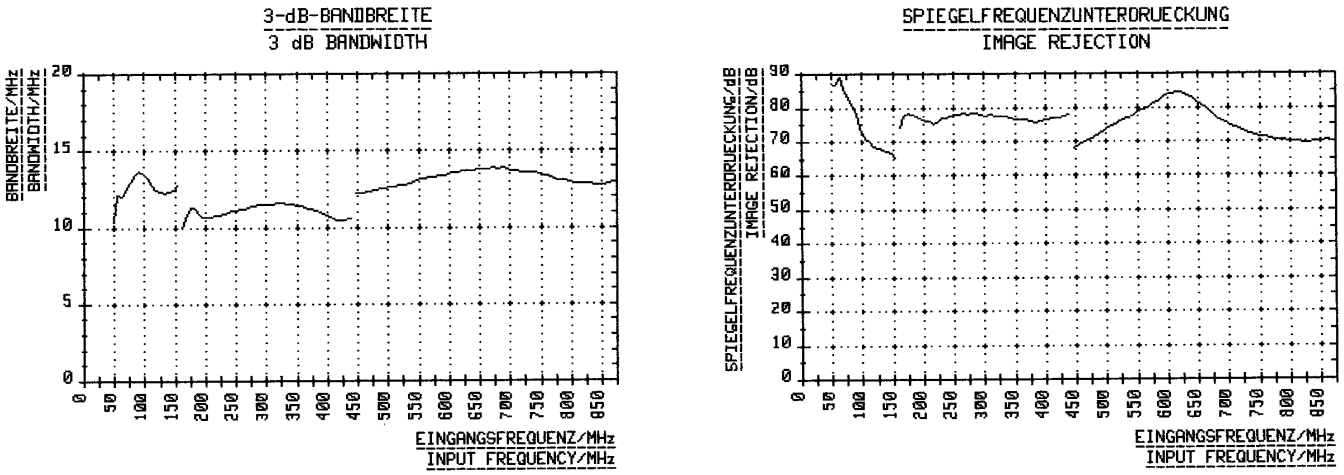


Figure 11C. 3dB Bandwidth at Tuner IF Output and Image Rejection

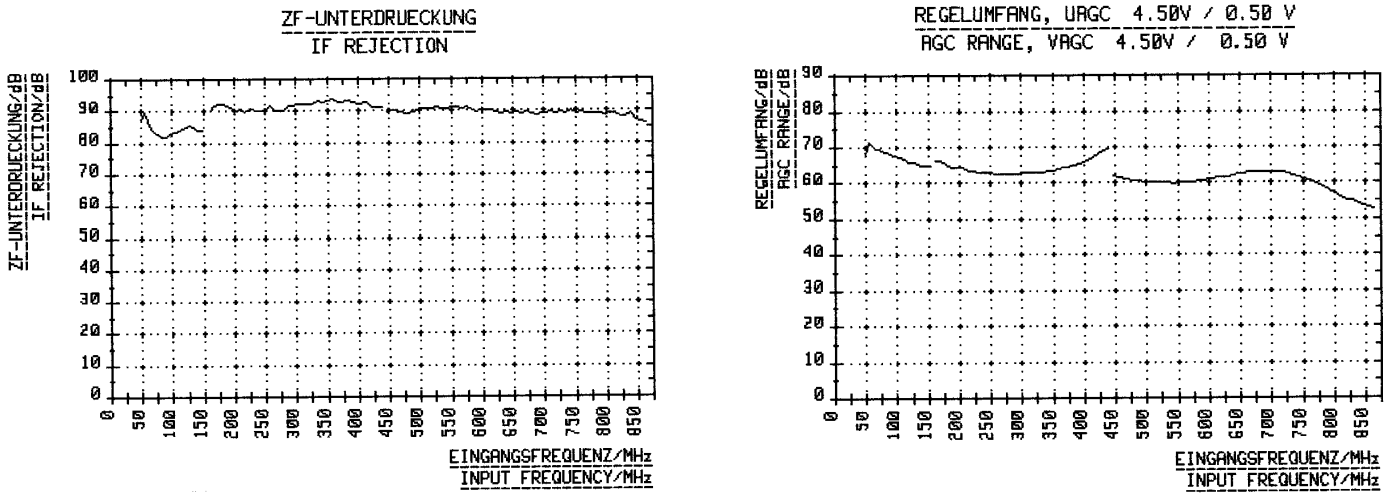


Figure 11D. IF Rejection and AGC Reduction Range

[9] *. The IF dummy loss of 15dB is not compensated in the graph. 38.9MHz & 33.4MHz were measured instead of 36.125MHz.*

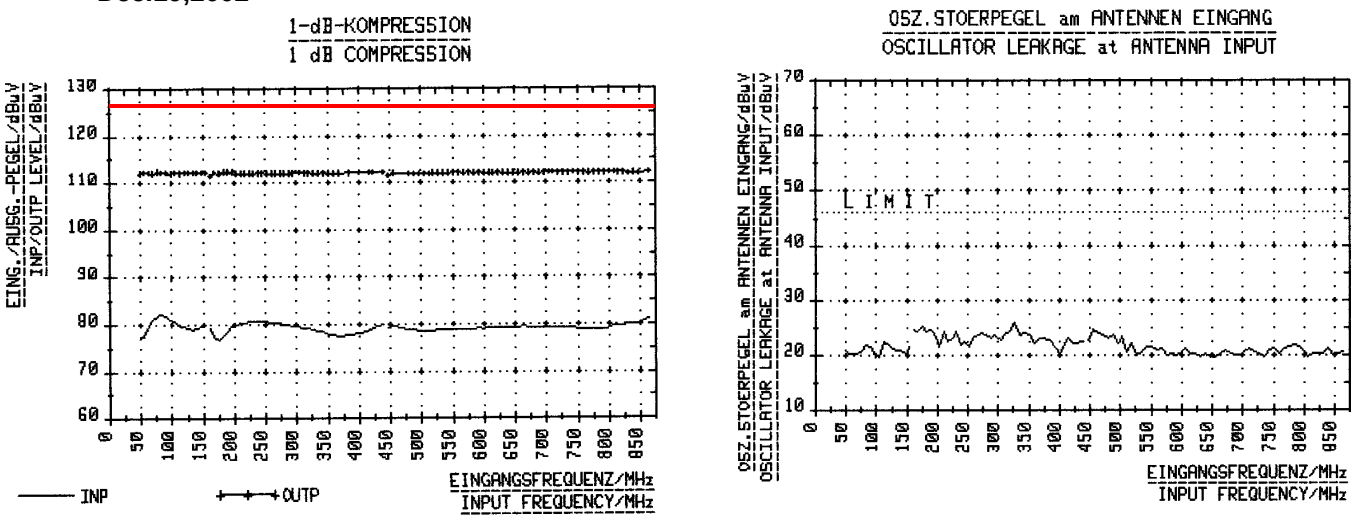


Figure 11E. 1dB Compression Point[10] and Antenna Leakage

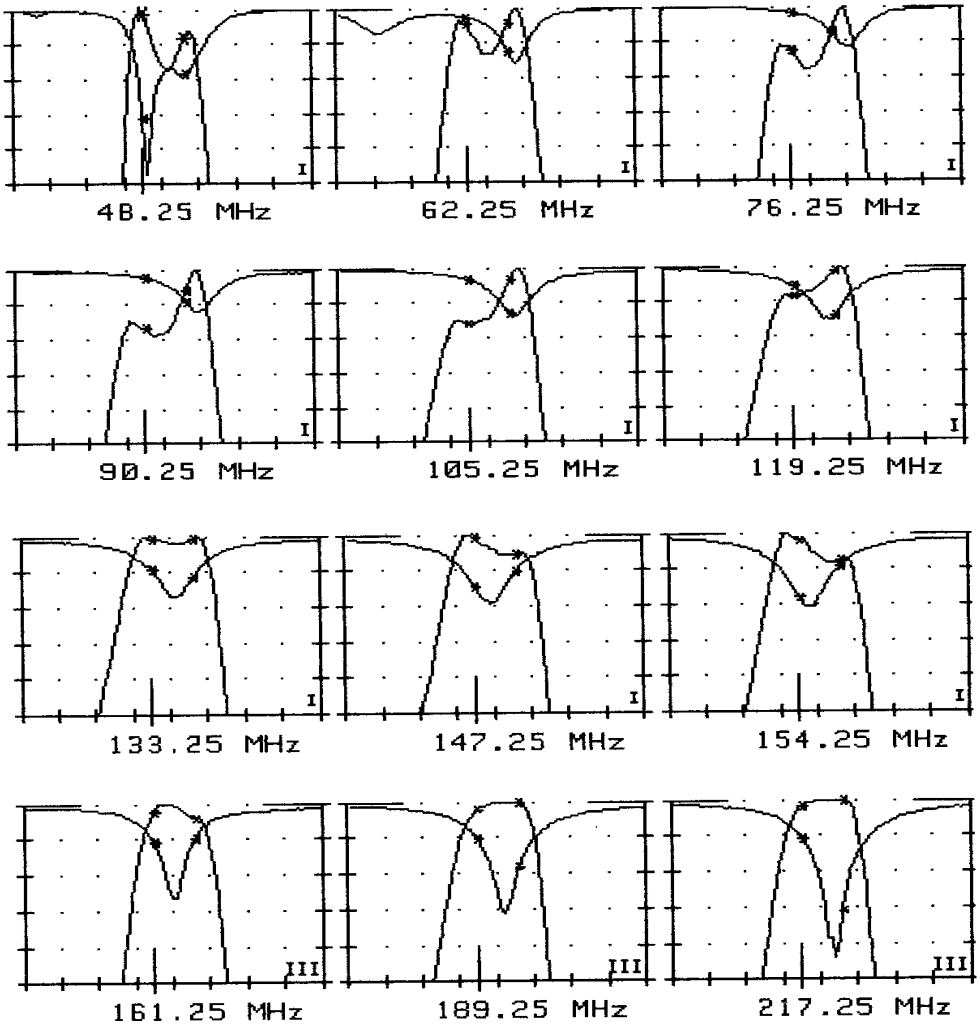


Figure 11F. IF Response[11] and Antenna VSWR

[10]. *The IF dummy loss of 15dB is not is not compensated. The red line shows the real output 1dB compression level of the tuner.*
[11]. *The markers in graphs are the picture carrier, 38.9MHz and the sound carrier, 33.4MHz of analog PAL Standard.*

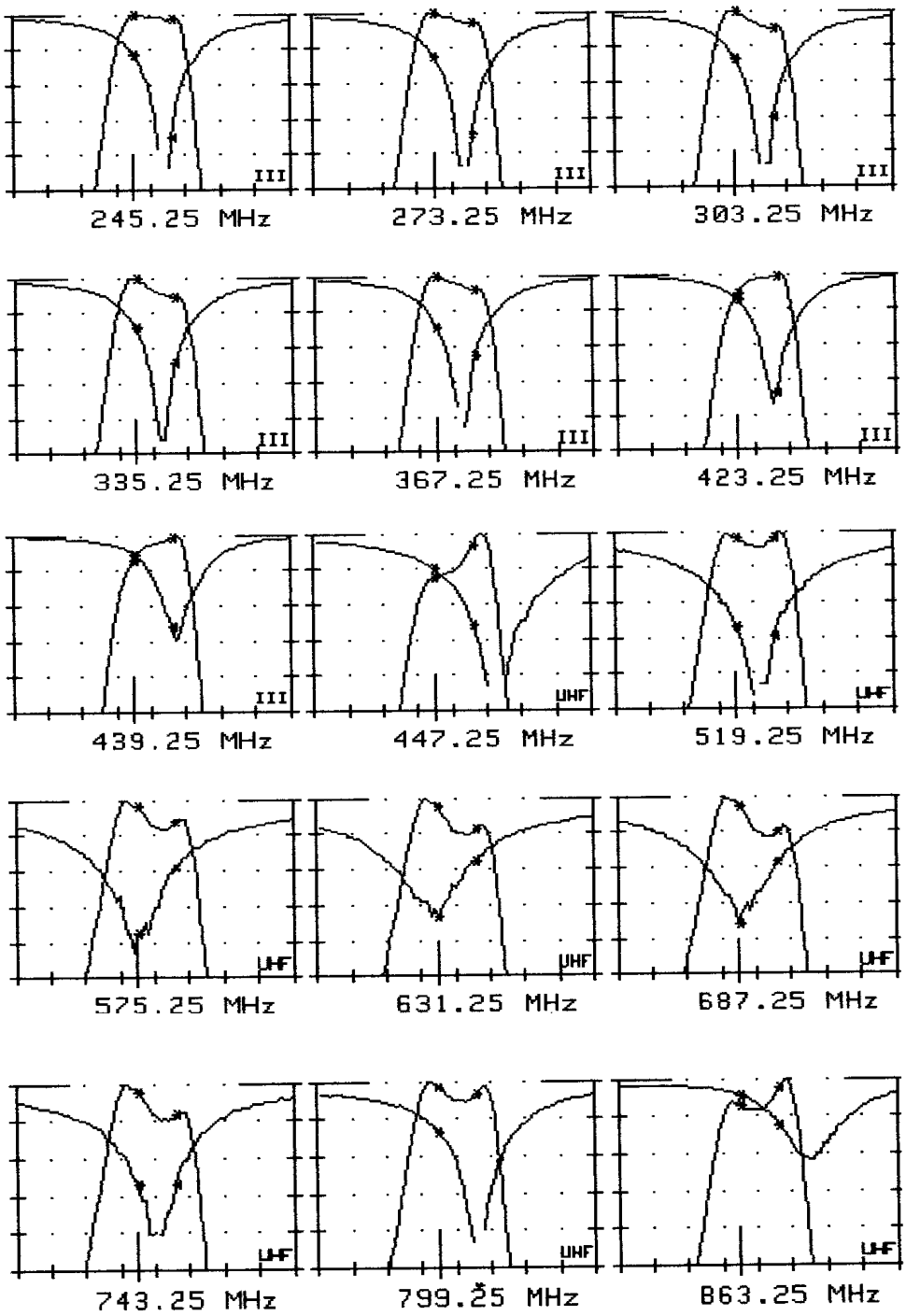


Figure 11F. IF Response[12] and Antenna VSWR

[12]. *The markers in graphs are the picture carrier, 38.9MHz and the sound carrier, 33.4MHz of analog PAL Standard.*

5.2 DVB-T Reception Test

- The DVB-T reference Tuner with TUA6034 was tested together with other Infineon ICs.
- C/N performance & Input sensitivity of some channels were tested in wide PLL loop BW.

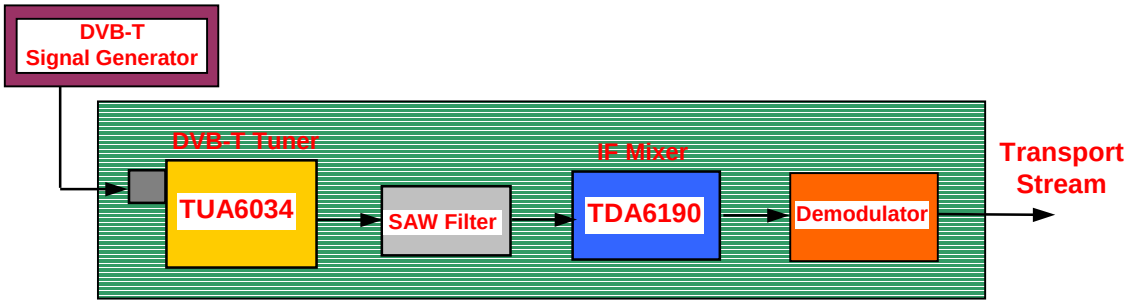


Fig12. The Test Board Configuration

A. C/N Performance (dB)[13]

Constellation = 64QAM, Guard Interval = 1/32, RF Input level = -50dBm

RF Input Frequency		60MHz		300MHz		500MHz	
Mode	Code Rate		Icp		Icp		Icp
2K	1/2	15.4	50uA	15.3	125uA	15.7	50uA
	2/3	18.4		18.3		18.7	
	3/4	19.8		19.7		20.2	
	5/6	21.1		21.2		21.7	
	7/8	22		22		22.7	
8K	1/2	15.4	125uA	15.3	125uA	15.7	50uA
	2/3	18.4		18.3		18.8	
	3/4	19.8		19.7		20.3	
	5/6	21.3		21.2		21.8	
	7/8	22.1		21.7		22.7	

RF Input Frequency		650MHz		858MHz	
Mode	Code Rate		Icp		Icp
2K	1/2	15.4	125uA	15.7	250uA
	2/3	18.4		18.5	
	3/4	19.9		20	
	5/6	21.4		21.4	
	7/8	22.3		22.4	
8K	1/2	15.4	125uA	15.7	250uA
	2/3	18.5		18.6	
	3/4	20		20.1	
	5/6	21.4		21.5	
	7/8	22.4		22.5	

B.Input Sensitivity (unit: dBm)

C/N = 50dB, 64QAM, 2K mode, GI=1/32, CR=2/3, Tuner AGC=Full

Tuner	650MHz	Icp	858MHz	Icp
IFX	-78.3	125uA	-77.1	250uA

[13]. BER vs C/N Test Result of Fig.12 setup, and the C/N performance requirement of EACEM(European Association of Consumer Electronics Manufacturers) is given in Appendix 7.

6. PLL Programming[14]

Logic allocation of Write Data

	MSB	bit6	bit5	bit4	bit3	bit2	bit1	LSB	Ack
Address byte	1	1	0	0	0	MA1	MA0	0	A
Prog. divider byte 1	0	n14	n13	n12	n11	n10	n9	n8	A
Prog. divider byte 2	n7	n6	n5	n4	n3	n2	n1	n0	A
Control info byte 1	1	CP	T2	T1	T0	RSA	RSB	OS	A
Bandswitching byte	P7	P6	P5	P4	P4	P2	P1	P0	A
Auxiliary byte	ATC	AL2	AL1	AL0	0	0	0	0	A

Divider ratio:

N =16384 x n14 + 8192 x n13 + 4096 x n12 + 2046 x n11 + 1024 x n10 + 512 x n9 +
256 x n8 + 128 x n7 + x 64 x n6 + 32 x n5 + 16 x n4 + 8 x n3 + 4 x n2 + 2 x n1 + n0

Address selection: (Vs = 5 V)

MA1	MA0	voltage at CAS pin
0	0	(0 ~ 0.1) x Vs
0	1	Open
1	0	(0.4 ~ 0.6) x Vs
1	1	(0.9 ~ 1) x Vs

Band selection (via Bandswitching byte)

UHF	VHF2	VHF1
000 001 00	000 000 10	000 000 01

Charge Pump Current

Icp(uA)	Mode	CP	T2	T1	T0
50	Nomal	0	0	0	X
250		1			X
50	Extended	0	1	1	0
125		0			1
250		1			0
650		1			1

Reference Divider Rations

Reference Divider Ratio	f_{ref}(KHz)[15]	Mode	T2	T1	RSA	RSB
80	50	Normal	0	0	0	0
128	31.25	Normal	0	0	0	1
24	166.67	X	X	X	1	0
64	62.5	X	X	X	1	1
32	125	Extended	1	1	0	0
28	142.86	Extended	1	1	0	1

Tuner PLL control software, WinPLL is also available along with the evaluation board & the reference tuner.

[14]. *Please refer to chapter 5.2 of TUA6034 data sheets for more details of programming*
[15]. *with 4MHz Quartz*

7. Component List & Ordering Information

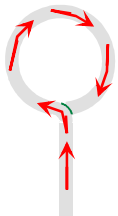
(units : Farad, Ohm)

Part	Value	Size	Tolerance	Material	Part	Value	Size	Tolerance	Material
C1	330p	O6O3	10%	NPO	**C51**	39p	O6O3	5%	N750
C2	180p	O6O3	10%	NPO	**C52**	1.5p	O6O3	5%	N750
C3	9.1p	O6O3	5%	NPO	**C53**	1.2p	O6O3	5%	N750
C4	1n	O6O3	10%	X7R	**C54**	100p	O6O3	5%	N750
C5	2.4p	O6O3	5%	NPO	**C55**	1.2p	O6O3	5%	N750
C6	**OPEN**	O6O3	5%	NPO	**C56**	1.2p	O6O3	5%	N750
C7	4.7n	O6O3	10%	X7R	**C57**	1.2p	O6O3	5%	N750
C8	0.5p	O6O3	5%	NPO	**C58**	1.2p	O6O3	5%	N750
C9	1n	O6O3	10%	X7R	**C59**	18p	O6O3	5%	N750
C10	4.7n	O6O3	10%	X7R	**C60**	4.7n	O6O3	10%	X7R
C11	10n	O8O5	10%	X7R	**C61**	4.7n	O6O3	10%	X7R
C12	10n	O6O3	10%	X7R	**C62**	4.7n	O6O3	10%	X7R
C13	120p	O6O3	5%	NPO	**C63**	4.7n	O6O3	10%	X7R
C14	4.7n	O6O3	10%	X7R	**C64**	4.7n	O6O3	10%	X7R
C15	470p	O6O3	10%	X7R	**C65**	100p	O6O3	5%	NPO
C16	4.7n	O6O3	10%	X7R	**C66**	18p	O6O3	5%	NPO
C17	4.7n	O6O3	10%	X7R	**C67**	**OPEN**			
C18	4.7n	O6O3	10%	X7R	**C68**	4.7n	O8O5	10%	X7R
C19	4.7n	O6O3	10%	X7R	**C69**	100n	O8O5	10%	X7R
C20	4.7n	O6O3	10%	X7R	**C70**	160n	O8O5	10%	X7R
C21	4.7n	O6O3	10%	X7R	**C71**	4.7n	O6O3	10%	X7R
C22	4.7n	O6O3	10%	X7R	**C72**	4.7n	O6O3	10%	X7R
C23	4.7n	O6O3	10%	X7R	**C75**	33p	O6O3	5%	NPO
C24	22n	O6O3	10%	X7R	**C76,77**	27p	O6O3	5%	NPO
C25	4.7n	O6O3	10%	X7R	**R1**	33K	O6O3	5%	
C26	4.7n	O8O5	10%	X7R	**R2**	33K	O6O3	5%	
C27	1.2p	O6O3	5%	NPO	**R3**	33K	O6O3	5%	
C28	100p	O6O3	5%	NPO	**R4**	22	O6O3	5%	
C29	13p	O6O3	5%	NPO	**R5**	33K	O6O3	5%	
C30	15p	O6O3	5%	NPO	**R6**	33K	O6O3	5%	
C31	27p	O6O3	10%	X7R	**R7**	10K	O6O3	5%	
C32	27p	O6O3	10%	X7R	**R8**	10K	O6O3	5%	
C33	1.8p	O6O3	5%	NPO	**R9**	10K	O8O5	5%	
C34	120p	O6O3	5%	NPO	**R10**	33K	O6O3	5%	
C35	120p	O6O3	5%	NPO	**R11**	5,6	O8O5	5%	
C36	470p	O6O3	10%	X7R	**R12**	22	O6O3	5%	
C37	470p	O6O3	10%	X7R	**R13**	22	O6O3	5%	
C38	120p	O6O3	5%	NPO	**R14**	33k	O6O3	5%	
C39	470p	O6O3	10%	X7R	**R16**	100K	O6O3	5%	
C40	39p	O6O3	5%	NPO	**R18**	150K	O6O3	5%	
C41	**OPEN**				**R19**	150K	O6O3	5%	
C42	4.7n	O6O3	10%	X7R	**R20**	33K	O6O3	5%	
C43	4.7n	O6O3	10%	X7R	**R21**	33K	O6O3	5%	
C44	4.7n	O8O5	10%	X7R	**R22**	33K	O6O3	5%	
C45	100p	O8O5	5%	NPO	**R23**	33K	O6O3	5%	
C46	100p	O8O5	5%	NPO	**R24**	**OPEN**	O6O3		
C47	4.7n	O8O5	10%	X7R	**R25**	2.7	O6O3	5%	
C48	560p	O6O3	10%	X7R	**R26**	0	O6O3		
C49	2.7p	O6O3	5%	N750	**R27**	**OPEN**	O6O3	5%	
C50	2.2p	O6O3	5%	N750	**R28**	33K	O6O3	5%	

Part	Value	Size	Tolerance	Part	Turns	D.of Wire	D. of Coil	Direction	Pre-form.
R29	330	O6O3	5%	**L1**	12	0,4	2,2	CW	
R30	330	O6O3	5%	**L2**	9	0,4	2,5	CW	
R31	12	O6O3	5%	**L3**	9	0,3	2	CW	
R32	2.2k	O8O5	5%	**L4**	6	0,3	1,6	CCW	
R33	8,2	O6O3	5%	**L5**	3	0,4	2,2	CW	**0,5mm**
R34	2.7k	O6O3	5%	**L6**	**Printed**				
R35	5,6	O6O3	5%	**L7**	9	0,3	2	CCW	
R36	1.8k	O6O3	5%	**L8**	5	0,4	1,8	CW	
R37	1.8k	O6O3	5%	**L9**	13	0,3	3	CW	
R38	**OPEN**			**L10**	18	0,3	3,2	CW	
R39	68K	O6O3	5%	**L11**	8	0,3	2	CW	
R40	220	O8O5	5%	**L12**	15	0,3	1,9	CW	
R42	1.2K	O6O3	5%	**L13**	**Choke Coil=3.9uH**				
J1	0	O6O3		**L14**	5	0,3	1,7	CCW	
J2	0	O8O5		**L15**	3	0,4	1,9	CCW	**0,5mm**
J3	0	O8O5		**L16**	2	0,5	1,6	CW	**1,2mm**
J4	0	O8O5		**L17**	**Printed**				
J5	0	O6O3		**L18**	2	0,5	1,6	CCW	
J6	0	O6O3		**L19**	4	0,4	1,7	CW	
J7	0	O8O5		**L20**	4	0,4	1,7	CW	
J8	0	O8O5		**L21**	4	0,4	2	CW	**0,6mm**
J9	0	O8O5		**L22**	4	0,4	1,6	CW	**0,6mm**
J10	0	O8O5		**L23**	**Printed**				
R15	10k	O6O3	5%	**L24**	4	0,4	1,6	CCW	**0,6mm**
R17	15	O6O3	5%	**L25**	8	0,3	2	CCW	
R41	15	O6O3	5%	**L26**	8	0,3	2	CW	
J12	0	O6O3		**L27**	15	0,3	2	CW	
				L28	15	0,3	2	CW	
L36	**390nH**	O8O5		**L29**	8	0,3	1,6	CCW	
				L30	18	0,3	3	CCW	
				L31	13	0,3	2,2	CW	
				L32	4	0,4	1,9	CW	
				L33	2	0,4	1,9	CW	**1,2mm**
				L34	12	0,3	2,3	CW	
				L35	12	0,3	2,3	CW	

Note1) All the coils are full-turn types. The Unit of the Diameter of Coil & Wire is 'mm'.

Full-Turn, CCW



Note2) J1 & C70 are only for internal Tuner AGC.

Note3) Pre-form. value is the distance between each turn of the coils. The pre-formation of coils should be done before alignment by a coil manufacturer or by line workers.

Note4) ***The SMD component list above is made with reference to the tuner with 3 x MOSFET.***

Part	Semiconductor	Package		Company	Ordering Code
IC1	TUA6034 / L1	TSSOP-38		Infineon Technologies AG	Q67034-H0006
TR1	BF2030W	SOT343		Infineon Technologies AG	Q62702-F1774
TR2[16]	BF2030W	SOT343		Infineon Technologies AG	Q62702-F1774
TR3[15]	BF2030W	SOT343		Infineon Technologies AG	Q62702-F1774
VD1	BB565	SCD80	SC79	Infineon Technologies AG	Q62702-B873
VD2	BB659C	SCD-80	SC79	Infineon Technologies AG	Q62702-B884
VD3	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873
VD4	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873
VD5	BB689	SOD-80	SC79	Infineon Technologies AG	Q62702-B890
VD6	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873
VD7	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873
VD8	BB659C	SCD-80	SC79	Infineon Technologies AG	Q62702-B884
VD9	BB659C	SCD-80	SC79	Infineon Technologies AG	Q62702-B884
VD10	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873
VD11	BB689	SOD-80	SC79	Infineon Technologies AG	Q62702-B890
VD12	BB689	SCD-80	SC79	Infineon Technologies AG	Q62702-B890
VD13	BB689	SOD-80	SC79	Infineon Technologies AG	Q62702-B890
VD14	BB659C	SOD-80	SC79	Infineon Technologies AG	Q62702-B884
VD15	BB565	SCD-80	SC79	Infineon Technologies AG	Q62702-B873

Q1	4MHz
PCB	FR4 / 1.5mm
Jack	75 Ω IEC Female
Pin-Head	Standard Pin

Products	Ordering Code	Price
Reference Tuner	Q67034-H0006	250Euro
Evaluation Board	Q67034-H0007	75Euro

Ordering & Contact Information

1. **Ordering on the Web ;**

http://www.infineon.com/business/techlit/ordering/index.htm

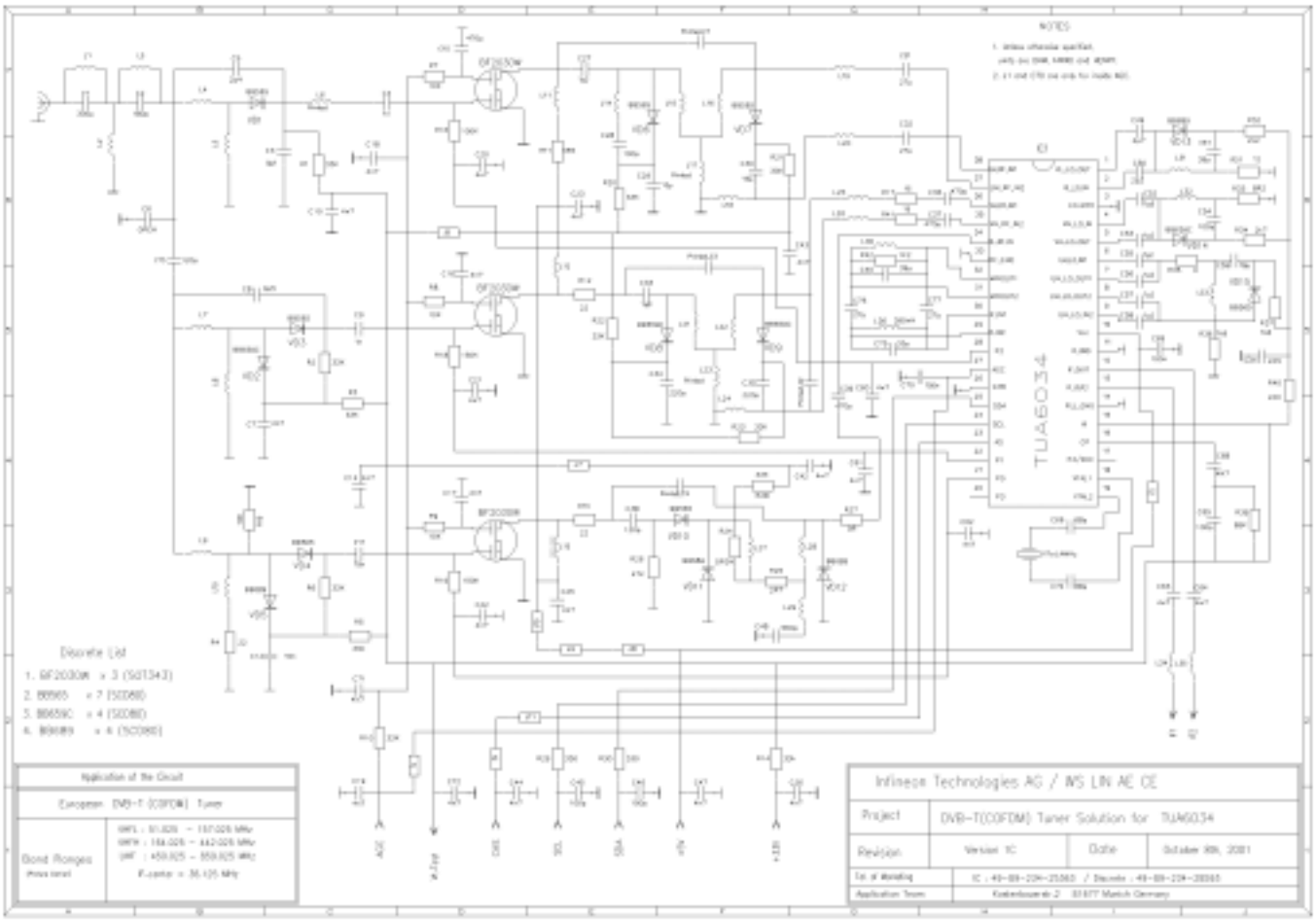
2. **For more information please contact our local sales colleagues in your region.**

http://www.infineon.com/business/offices/index1.htm

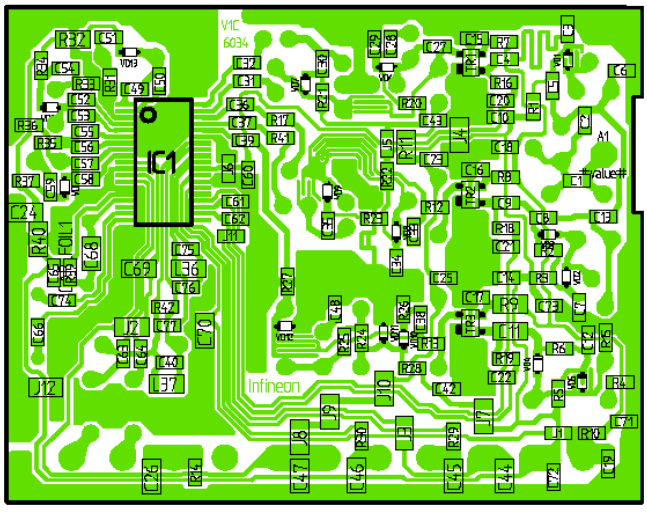
[16]. *Instead of TR1, TR2 one Double-MOSFET, BG3130 can be adopted.*

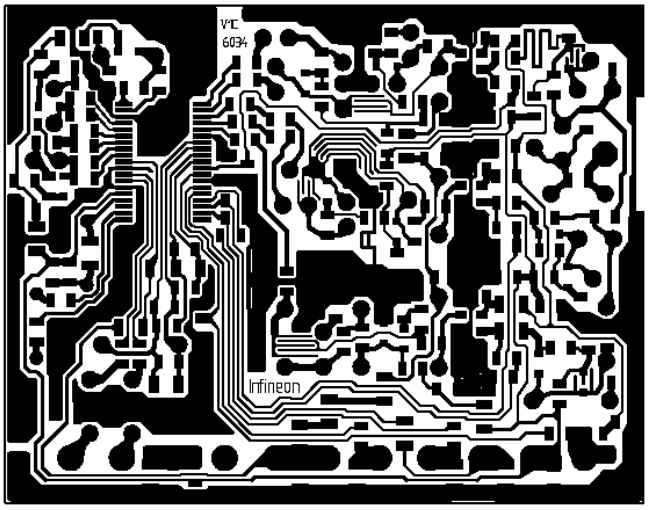
8. Circuit and Layout[17]

8.1 Circuit diagram



8.2 Layouts





[17] *Please refer to Appendix for larger drawings with better resolution, the coil side drawing and the layout with BG3130.*

8.3 Pin Layout & Outline Dimensions

To give an impression of the real sized tuner, a photo of the tuner sample with the pin-out are given in

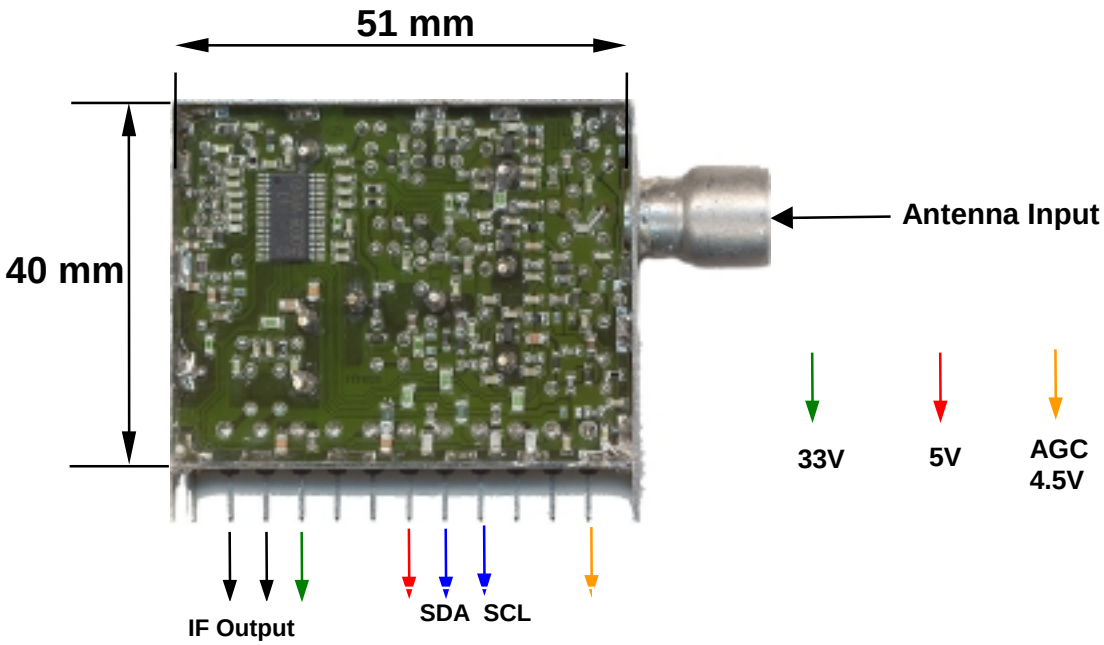


Figure 11. Picture of the Tuner without Covers

9. Automatic Tuner Test Set-up of the Team

This automatic tuner set-up consists of the following RF measurement equipment:

Hewlett-Packard 8970B noise meter

Hewlett-Packard 5305A frequency counter

Hewlett-Packard 8561E spectrum analyzer

Rhode&Schwarz FMA modulation analyzer

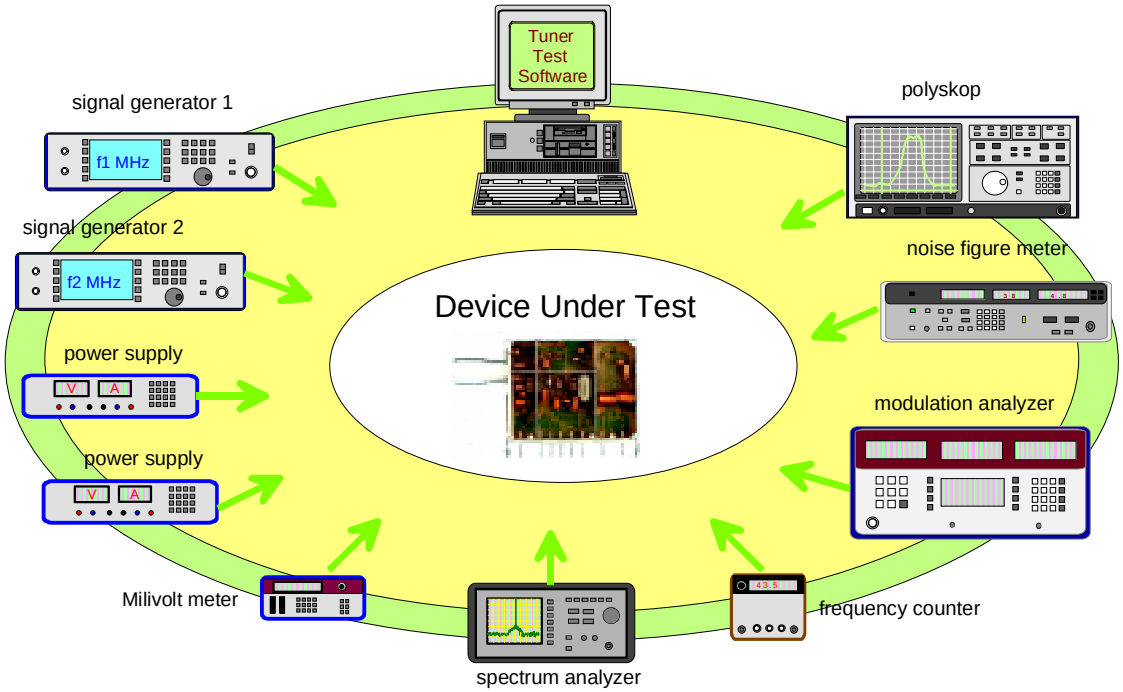
Rhode&Schwarz NGPS voltage supply(2x)

Rhode&Schwarz URV5 milivolt meter

Marconi Instruments 2031 signal generator (2x)

Marconi Instruments 2024 signal generator(2x)

All these instruments are controlled via the IEE bus by a tuner test software from a PC.
Test data will be attached to every sample tuner that is available on request.



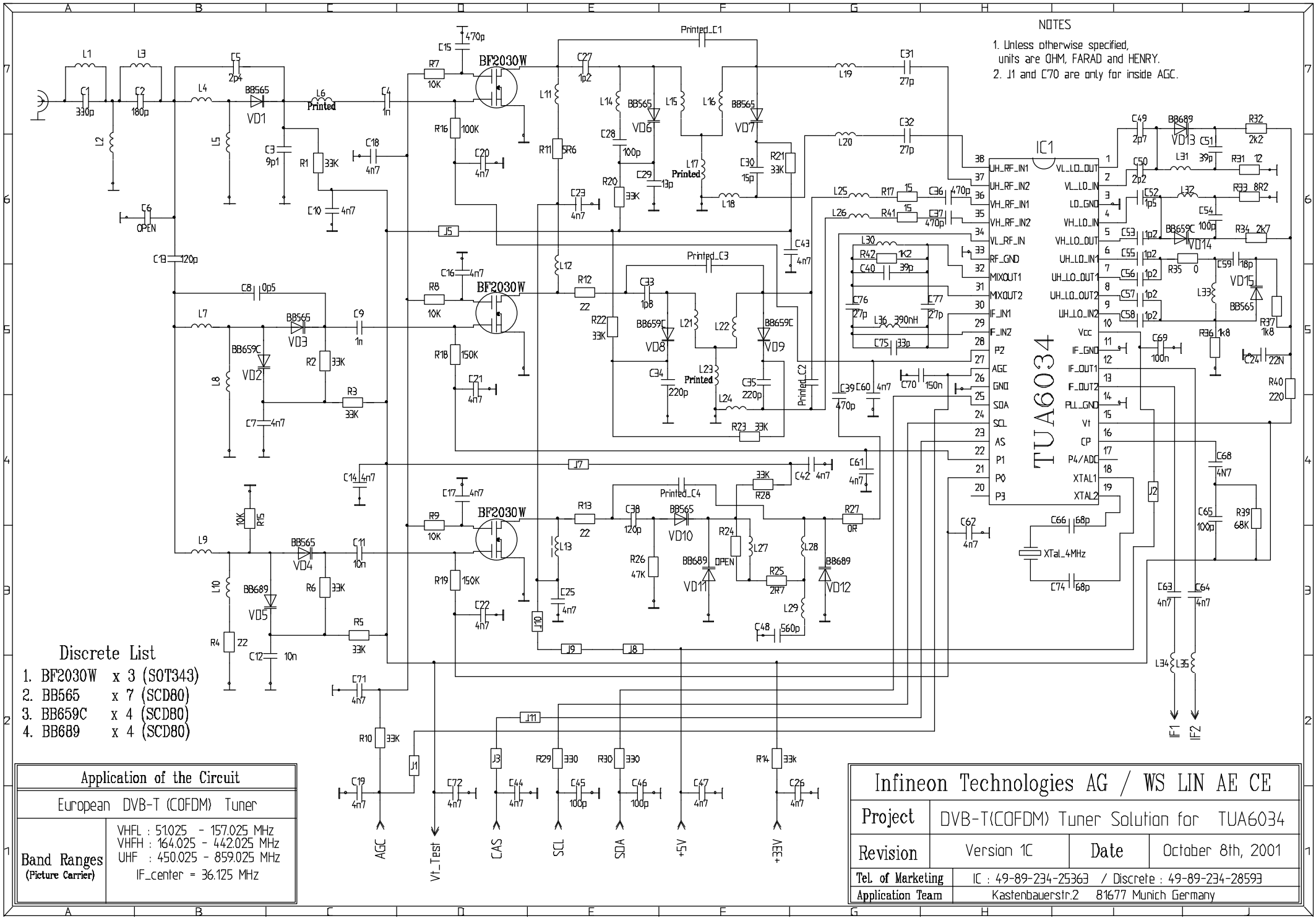
Information on the Web

1. **Infineon Homepage**
   http://www.infineon.com/

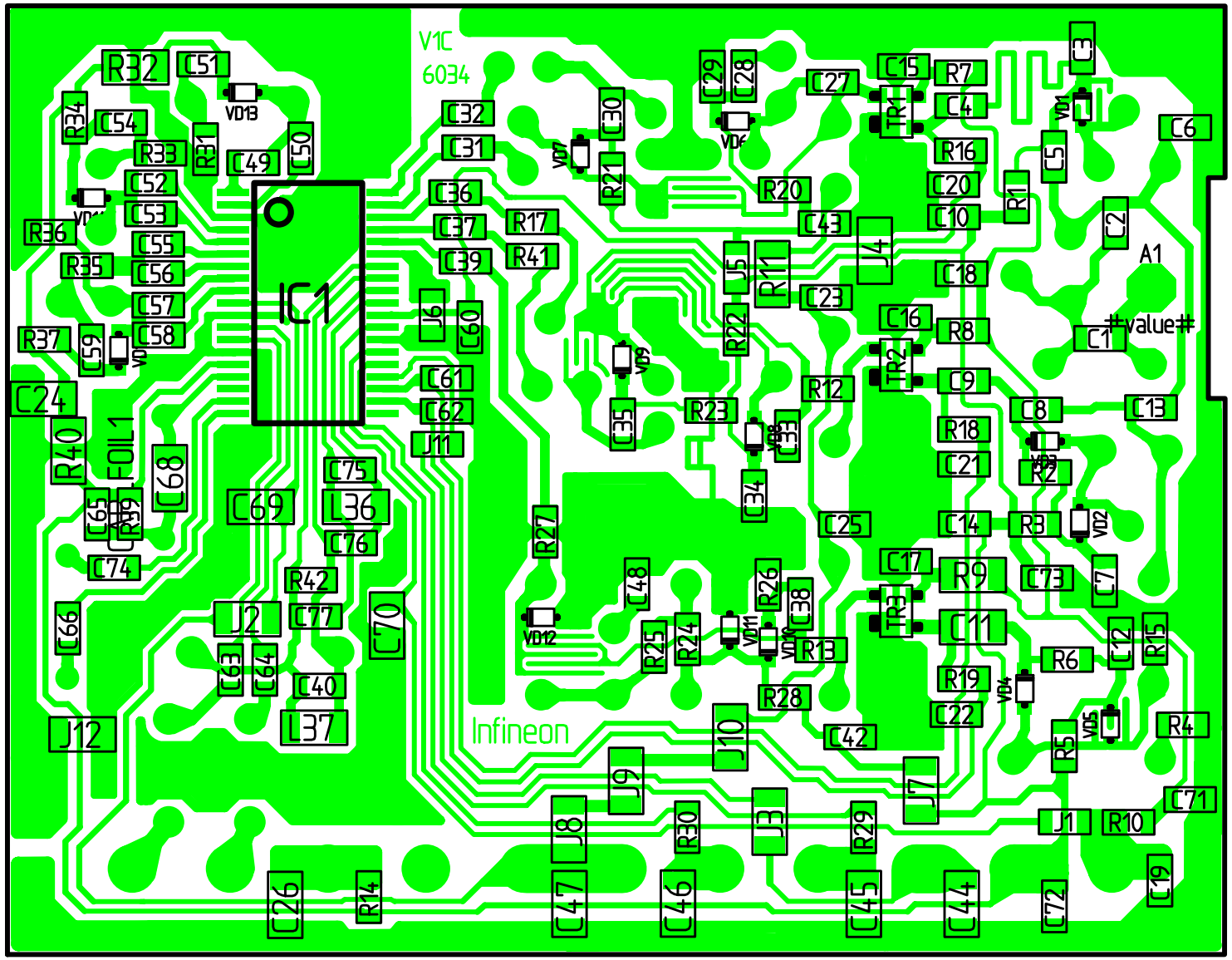
2. **Ordering Info.**
   http://www.infineon.com/business/techlit/ordering/index.htm

3. **Analog & Digital Tuner ICs Info.**
   http://www.infineon.com/cgi/ecrm.dll/ecrm/scripts/prod_cat.jsp?oid=-8036

4. **Tuner MOSFETs & Varicap Diodes Info.**
   http://www.infineon.com/cgi/ecrm.dll/ecrm/scripts/prod_ov.jsp?oid=26213&cat_oid=-8960
   http://www.infineon.com/cgi/ecrm.dll/ecrm/scripts/prod_ov.jsp?oid=26227&cat_oid=-8960
   http://www.infineon.com/cgi/ecrm.dll/ecrm/scripts/prod_ov.jsp?oid=26231&cat_oid=-8960
   http://www.infineon.com/cgi/ecrm.dll/ecrm/scripts/prod_ov.jsp?oid=13798&cat_oid=-8148

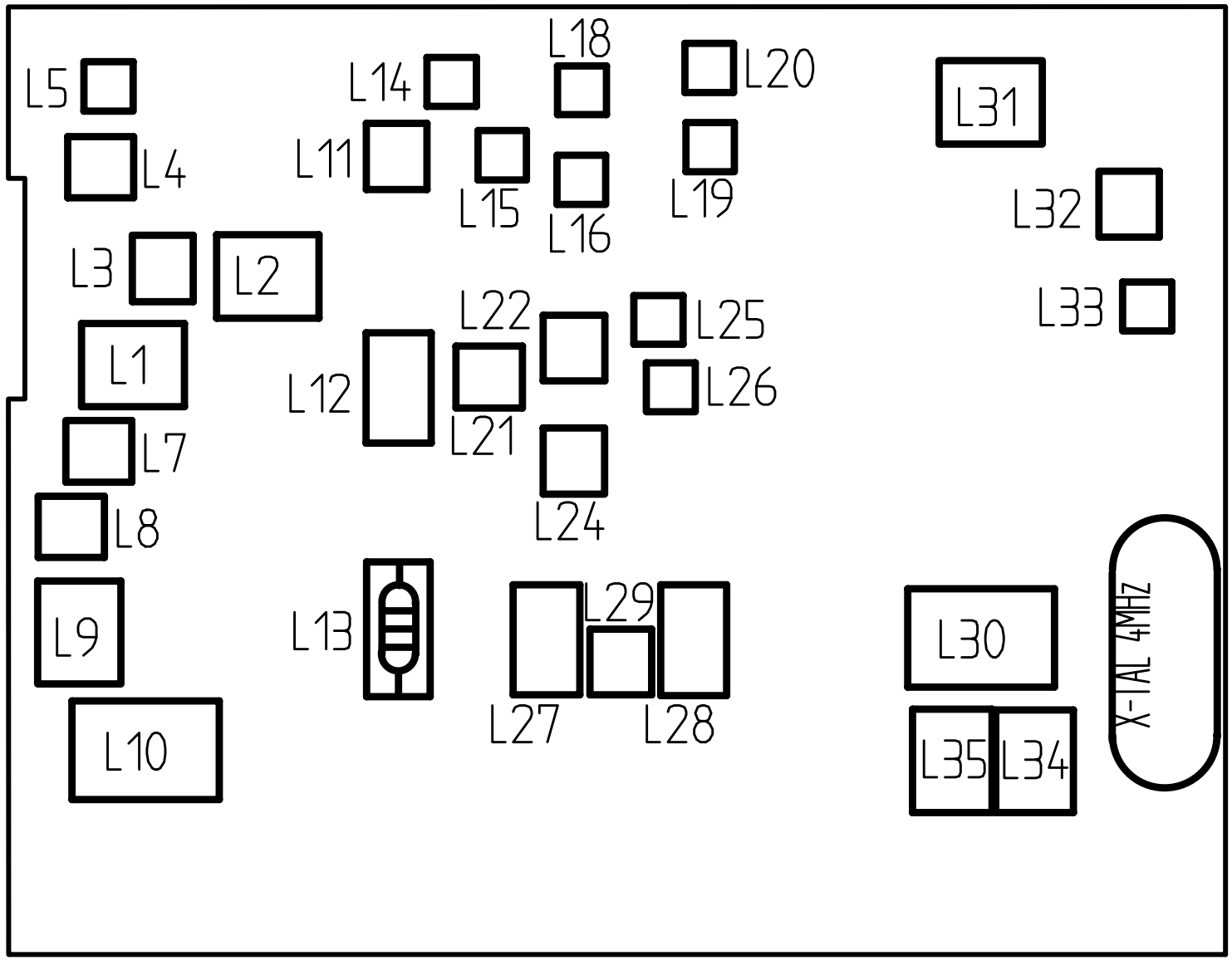

NOTES
1. Unless otherwise specified, units are OHM, FARAD and HENRY.
2. J1 and C70 are only for inside AGC.
IC1
TUA6034
BF2030W
BF2030W
BF2030W
Printed_C1
Printed_C2
Printed_C3
Printed_C4
Discrete List
1. BF2030W x 3 (SOT343)
2. BB565 x 7 (SCD80)
3. BB659C x 4 (SCD80)
4. BB689 x 4 (SCD80)
Application of the Circuit
European DVB-T (COFDM) Tuner
Band Ranges (Picture Carrier)
VHFL : 51.025 - 157.025 MHz
VHFH : 164.025 - 442.025 MHz
UHF : 450.025 - 859.025 MHz
IF_center = 36.125 MHz
Infineon Technologies AG / WS LIN AE CE
Project
DVB-T(COFDM) Tuner Solution for TUA6034
Revision
Version 1C
Date
October 8th, 2001
Tel. of Marketing
IC : 49-89-234-25363 / Discrete : 49-89-234-28593
Application Team
Kastenbauerstr.2 81677 Munich Germany
AGC
Vt_Test
CAS
SCL
SDA
+5V
+33V
IF1
IF2

Infineon DVB-T Tuner Ver.1C with TUA6034T ES

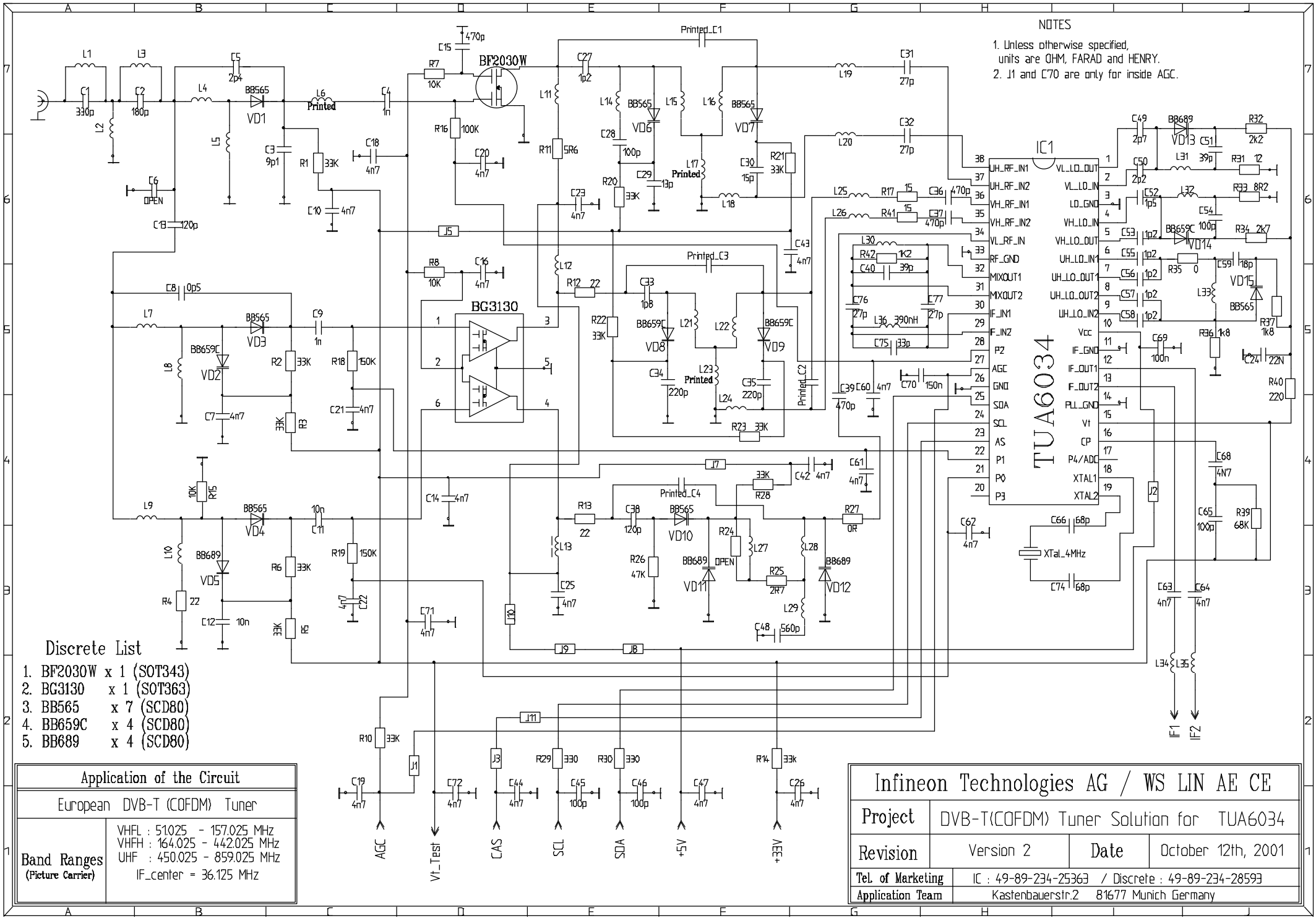


Components (3.90 10/31/101 3band_34v1c.tc)

Infineon DVB-T Tuner Ver.1C with TUA6034T ES



Coil Side (3.90 10/31/101 3band_34v1c.tc)



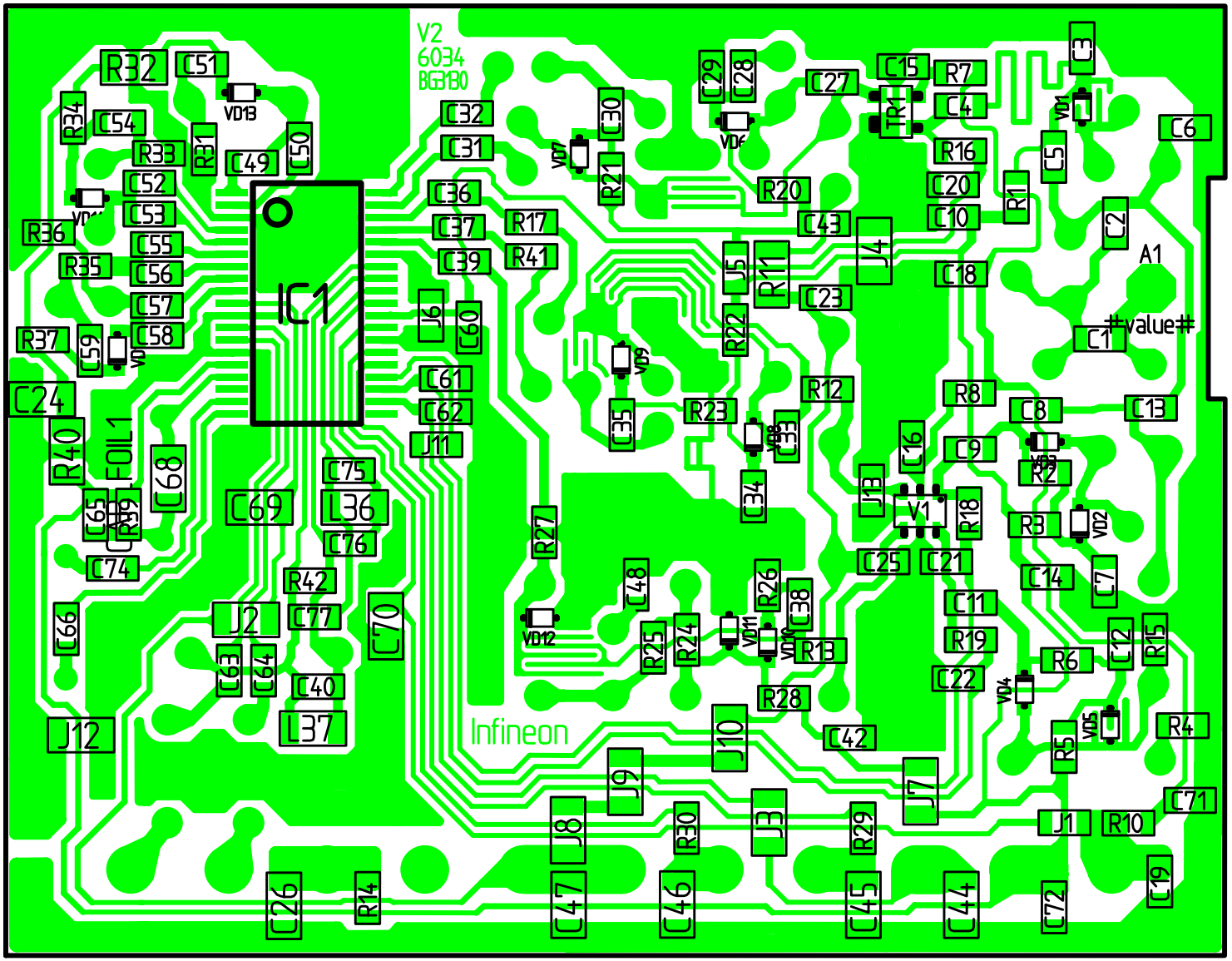
Discrete List

1. BF2030W x 1 (SOT343)
2. BG3130 x 1 (SOT363)
3. BB565 x 7 (SCD80)
4. BB659C x 4 (SCD80)
5. BB689 x 4 (SCD80)

Application of the Circuit	
European DVB-T (COFDM) Tuner	
Band Ranges (Picture Carrier)	VHFL : 51.025 - 157.025 MHz VHFH : 164.025 - 442.025 MHz UHF : 450.025 - 859.025 MHz IF_center = 36.125 MHz

Infineon Technologies AG / WS LIN AE CE			
Project	DVB-T(COFDM) Tuner Solution for TUA6034		
Revision	Version 2	Date	October 12th, 2001
Tel. of Marketing	IC : 49-89-234-25363 / Discrete : 49-89-234-28593		
Application Team	Kastenbauerstr.2 81677 Munich Germany		

Infineon DVB-T Tuner Ver.2 with TUA6034T, BG3130



Components (3.90 10/31/101 3band_34v2.tc)

Appendix 6. Investigation on a 5-to-33V Converter for the Tuner

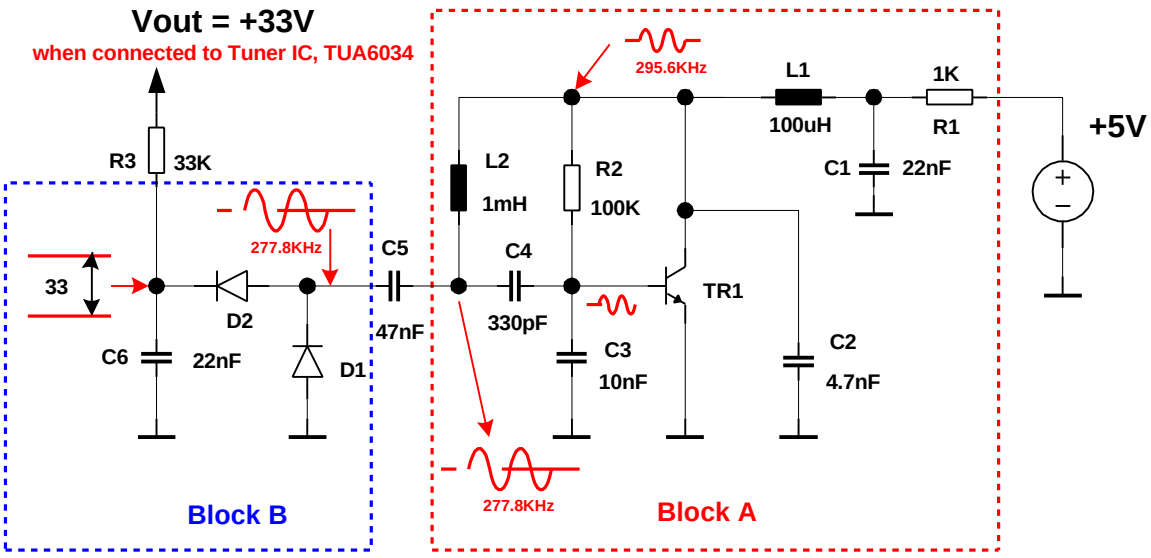
1. This is a brief report concerning a 5-to-33V Converter for tuner applications.

2. This circuit is widely used as a 5 to 33V converter by a lot tuner manufacturers with some modifications on bias circuit and component values.

3. The circuit in Fig.1 is optimized for the purpose of DVB-T tuner with TUA6034.

4. The converter was tested combined with the DVB-T reference tuner with TUA6034.

5. Tested DC-DC Converter Circuit ;



TR1: BC847, BC850 / D1,D2: BAS16-02W x2, BAS28W x1, BAS70-04 x1

Fig.1 5 to 33 Volts DC-DC Converter Circuit

6. The operation of the circuit

The circuit is composed of two important blocks; one is Block A which is a modified Clapp oscillator with a simple bias circuit, and Block B which is a rectifier to generate 33V DC.

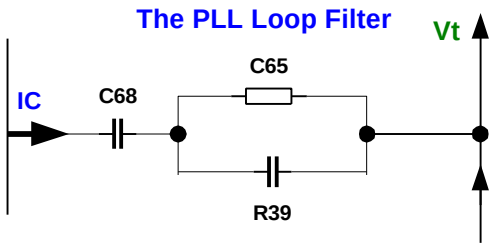
C2, C3 should be chosen large enough to swamp out the transistor's junction capacitances for greater stability. The oscillation frequency is decided by L2 , C2, C3 and C4. However, L2 and C4 is the main frequency decision components. f_{osc} is around 277 KHz by simple calculation.

The oscillation frequency should be carefully selected not to influence any of tuner characteristics. If it is as low as 20KHz, it will make audible noise. We need to consider that phase noise up to 10KHz is especially important to COFDM system. Also harmonics must be checked whether the oscillator generates any frequencies close to the quartz frequency.

A wrong resonator design could make the oscillator consumes too much currents and unstable. Even L2 is a very big coil comparing to other coils inside tuners, it is necessary to keep a proper oscillation in terms of current consumption and oscillation frequency. Therefore it is desirable to tune C4 to change the oscillation frequency. L1, RF choke coil need to be carefully selected not to influence the oscillator and to stop RF signal coming to the oscillator together with C1.

A very simple bias circuit is used for the circuit in Fig.1.

7. Phase Noise Measurement with the DC-DC Conveter in Fig.1
   - The DVB-T tuner with TUA6034T ES was used for all the phase noise measurements.
   - To minimize the additional time constant effects by the converter block, the loop filter of the tuner is fine-tuned.
   - In the below log plots, before means the tuner test with the converter, and after means the tuner test with the converter and with the readjustment of the loop filter.



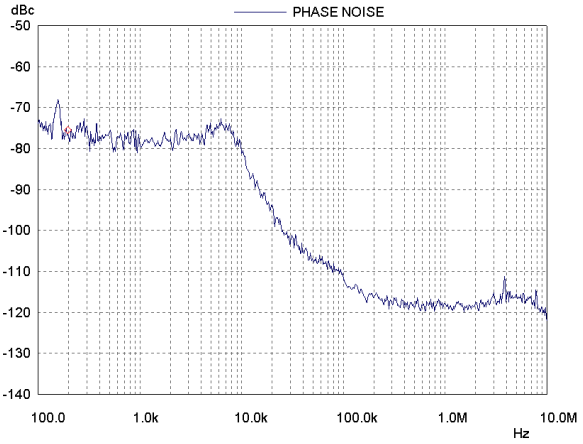
The orginal Loop filter values:
C68=4.7nF, C65=100pF,R39=68Kohm

Readjusted Loop filter values:
C68=4.7nF, C65=91pF,R39=47Kohm

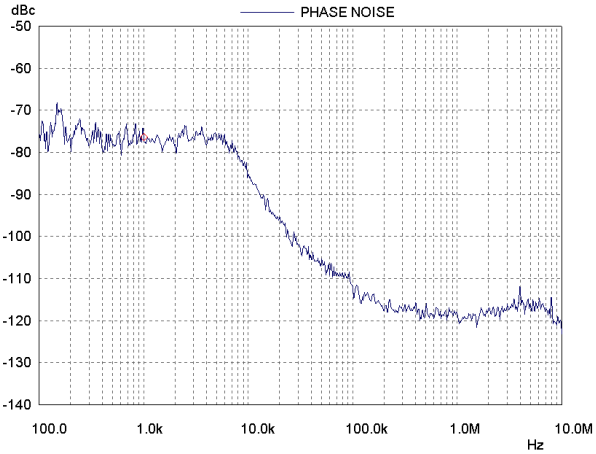
The DC-DC Conveter

Fig.2 The PLL Loop Filter of DVB-T Tuner with TUA6034

- RF Input freq. = 858MHz, Icp=650uA

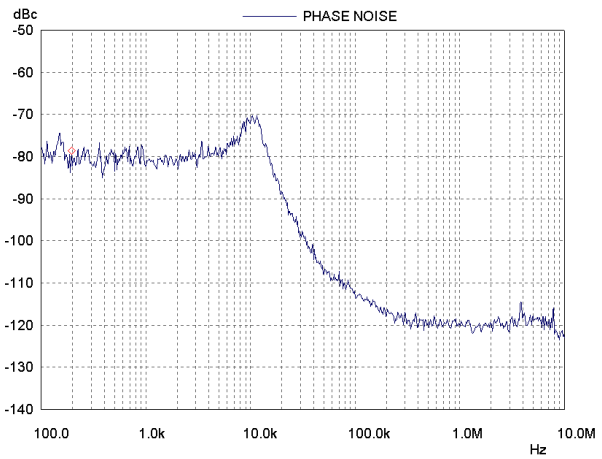


Before

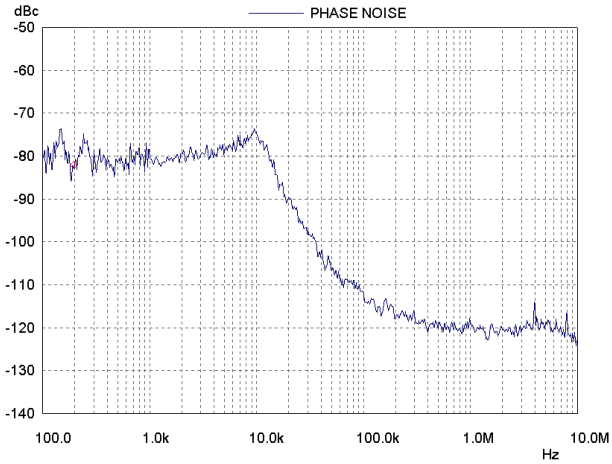


After

- RF Input freq. = 449MHz, Icp=125uA



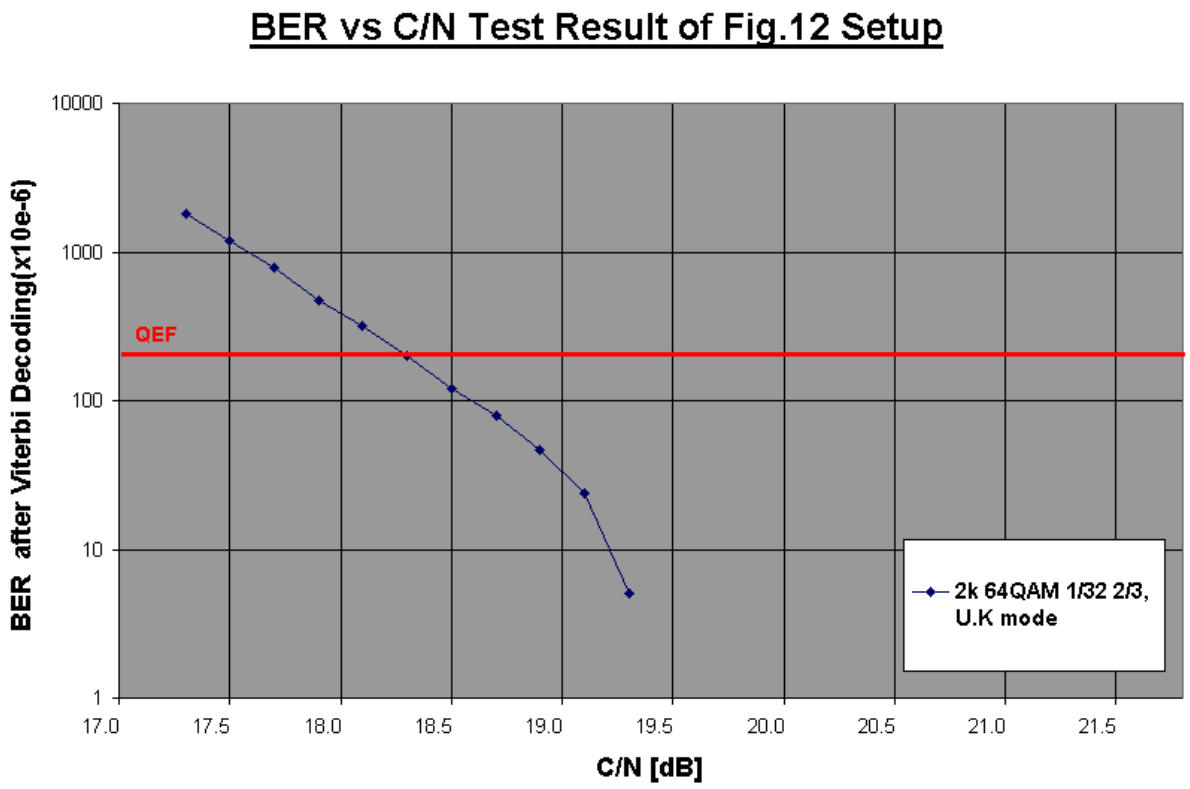
Before



After

Appendix 7. BER vs C/N Test Result of Fig.12 Setup

1. This test was done with the same test setup as in Fig.12.



2. The table[18] below show C/N (dB) for QEF(Quasi Error Free) reception of DVB-T receiver

Modulation	Code rate	Gaussian	Ricean	Rayleigh
QPSK	1/2	5.6	6.1	7.9
	2/3	7.4	8.2	10.9
	3/4	8.4	9.3	13.2
	5/6	9.4	10.5	15.6
	7/8	10.2	11.2	18.8
16-QAM	1/2	11.3	12.1	13.7
	2/3	13.6	14.1	16.7
	3/4	15	15.5	19.2
	5/6	16	16.9	21.8
	7/8	16.4	17.5	25.3
64-QAM	1/2	16.9	17.2	18.5
	2/3	19	19.6	21.8
	3/4	20.5	21.1	24.2
	5/6	21.8	22.5	27.8
	7/8	22.6	23.5	30.4

The Test in Fig.12 satisfies the requirement in the above table.

[18] EACAM(European Association of Consumer Electronics Manufacturers) Technical Report Number TR-030, Ver1.0, page 83.

Appendix 8. Loop Filter Optimization for PAL & DVB-T

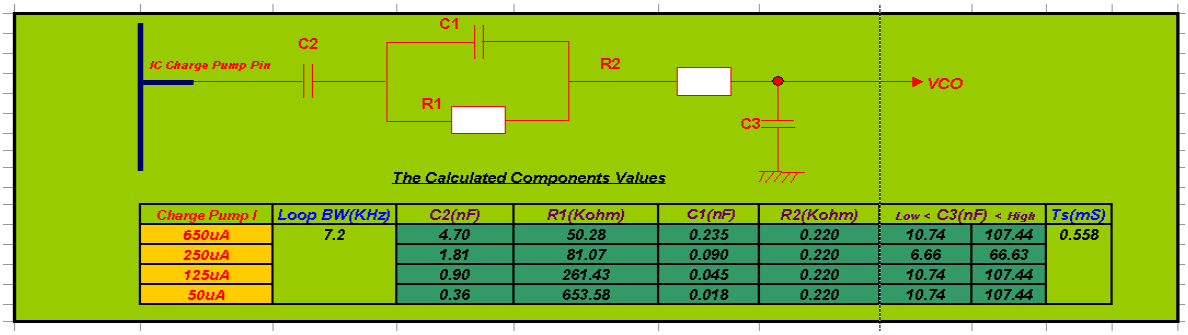
1. This investigation is about how to design a proper loop filter to satisfy both DVB-T and PAL standard at the same time for a tuner with Infineon **TUA6034** MOPLL IC.

2. Comparing the requirements of both DVB-T(digital) & PAL(analog) concerning PLL Loop Filter.

Requirement	DVB-T (COFDM System)	PAL (Analog)
PLL Reference Frequency, fref	166.667KHz	62.5KHz
Loop Bandwidth of PLL	Normally wide	Normally narrow
Phase Noise	Very important, especially offset of 1KHz ~ 10KHz	Not important
Settling Time	Wide Loop Bandwidth makes faster settling time than narrow loop bandwidth	Narrow Loop Bandwidth makes slower settling time than wide loop bandwidth.
Reference Spur Rejection	Important. Loop Bandwidth must be much lower than fref/10(=16.667KHz) to suppress reference spurs efficiently.	Important Loop Bandwidth must be a lot lower than fref/10(=6.25KHz) to suppress reference spurs enough.

3. If a tuner is developed only for DVB-T usage with **TUA6034**, the given wide loop filter, of which the main loop filter block is composed of 4.7nF+68 kohm+100pF, in the DVB-T application note is good enough to meet DVB-T phase noise requirement. However, if the tuner will be used for both analog and digital standard, there should be some compromises in the loop filter optimization because of the different desires given in the above table.

4. This is how the original wide loop bandwidth can be easily calculated for the reference tuner by a simple spread-sheet program. All the formaulae are available in the **TUA6034** DVB-T Tuner Application note.

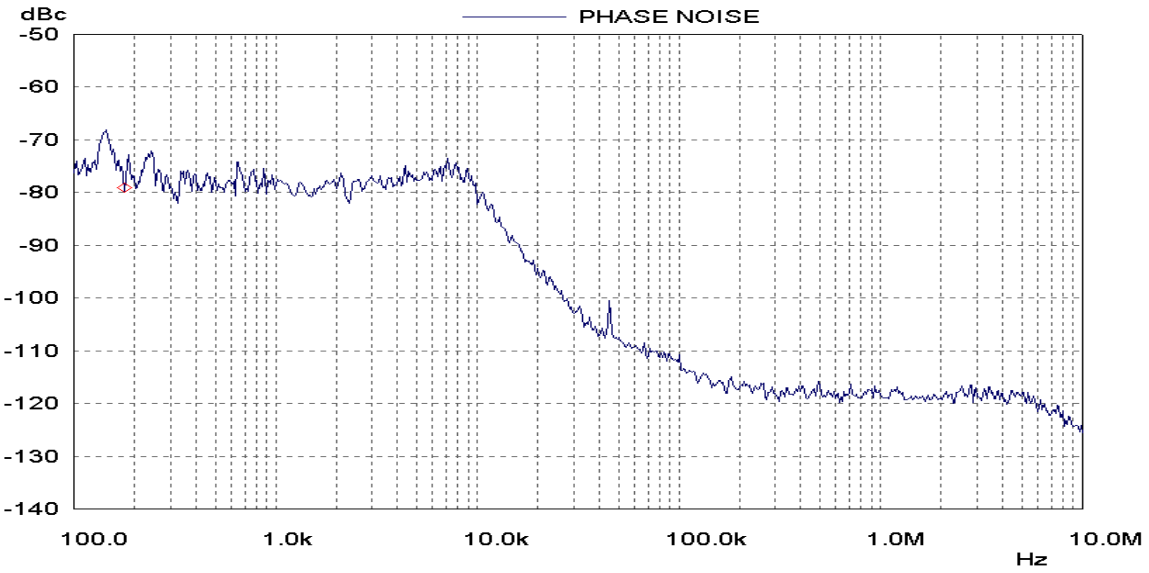


The Calculated Components Values

Charge Pump I	Loop BW(KHz)	C2(nF)	R1(Kohm)	C1(nF)	R2(Kohm)	Low < C3(nF) < High		Ts(mS)
650uA	7.2	4.70	50.28	0.235	0.220	10.74	107.44	0.558
250uA		1.81	81.07	0.090	0.220	6.66	66.63	
125uA		0.90	261.43	0.045	0.220	10.74	107.44	
50uA		0.36	653.58	0.018	0.220	10.74	107.44	

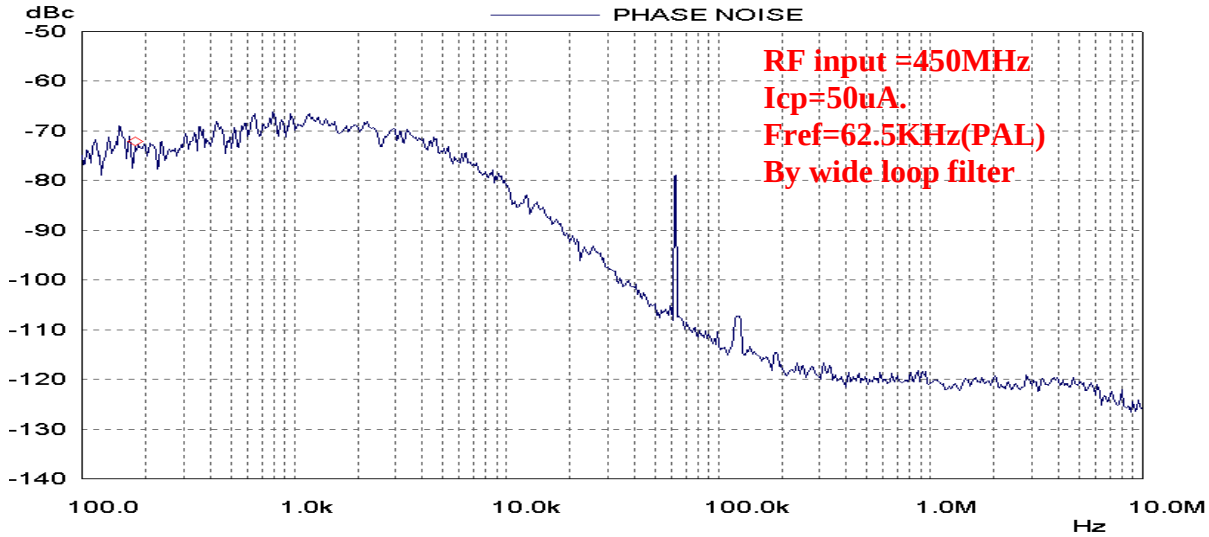
The loop filter above was optimized for the highest oscillator frequency, and the loop bandwidth was set to 7.2KHz. fref = 166.667KHz. Among the calculated initial values, R1 & C1 would need to be optimized meticulouly on the board. The final loop filter for this loop bandwidth consists of C2=4.7nF, R1=68kohm, C1=100pF, R2=220ohm, C3=22nF. The next log plot shows how the loop filter works ; RF input = 858MHz, Icp=650uA,

5. However, if the same loop filter optimized as above is used for analog PAL applications which employ

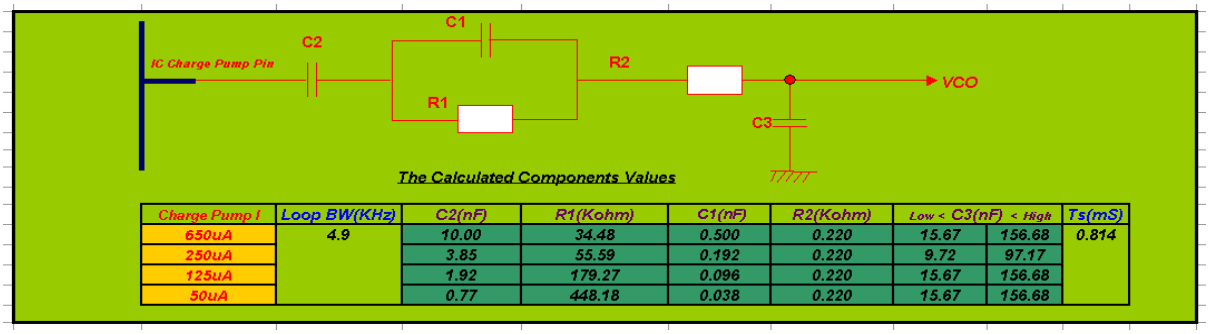


5. However, if the same loop filter optimized as above is used for analog PAL applications which employ normally 62.5KHz reference frequency, there will be a reference spur problem by wide PLL loop bandwidth optimized for DVB-T. In addition to wide loop bandwidth, charge pump at fref=62.5KHz will pump alternating pulses of currents with longer periods than at fref=166.667KHz. This could lead to more leakage current on accound of capacitor dielectric charactersitics which have some resistance.

   The log plot below shows how fref=62.5KHz makes a spur by wide loop bandwidth.
   Fref=62.5KHz, Icp=50uA, RF input=450MHz(UHF lowend). The same loop filter as in No.4 was used.



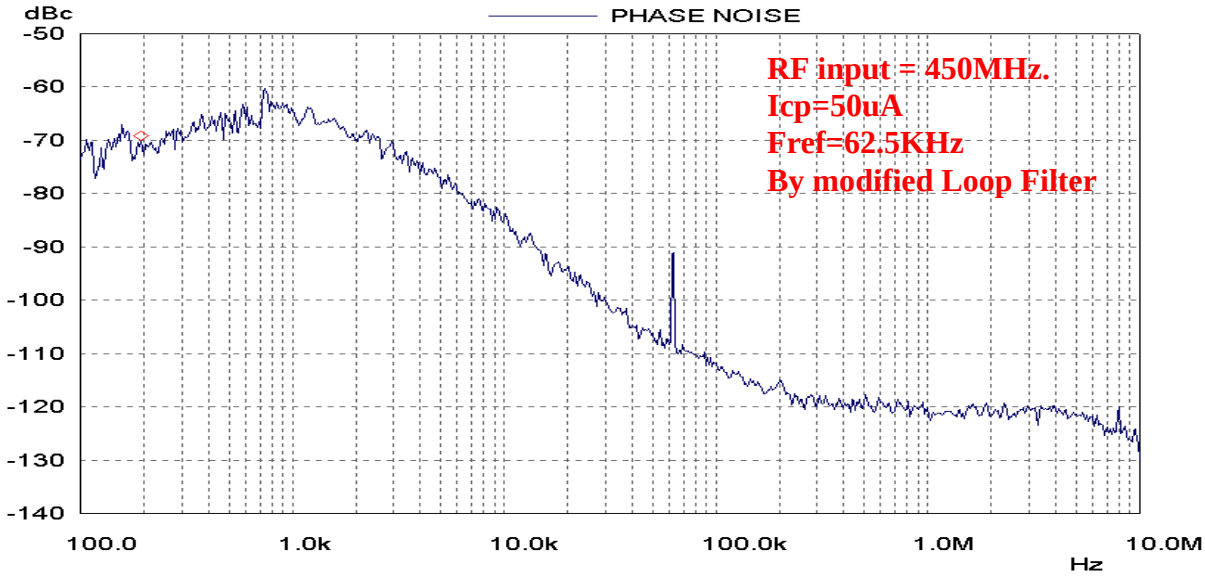
6. Considering the fact that loop bandwidth for analog applications is normally narrower than 3KHz and for digital DVB-T , wider than 7KHz, a compromised loop bandwidth for both applicactions would be about 5KHz, more or less. Below routine shows how the loop filter components were calculated for the compromised loop bandwidth.



The Calculated Components Values

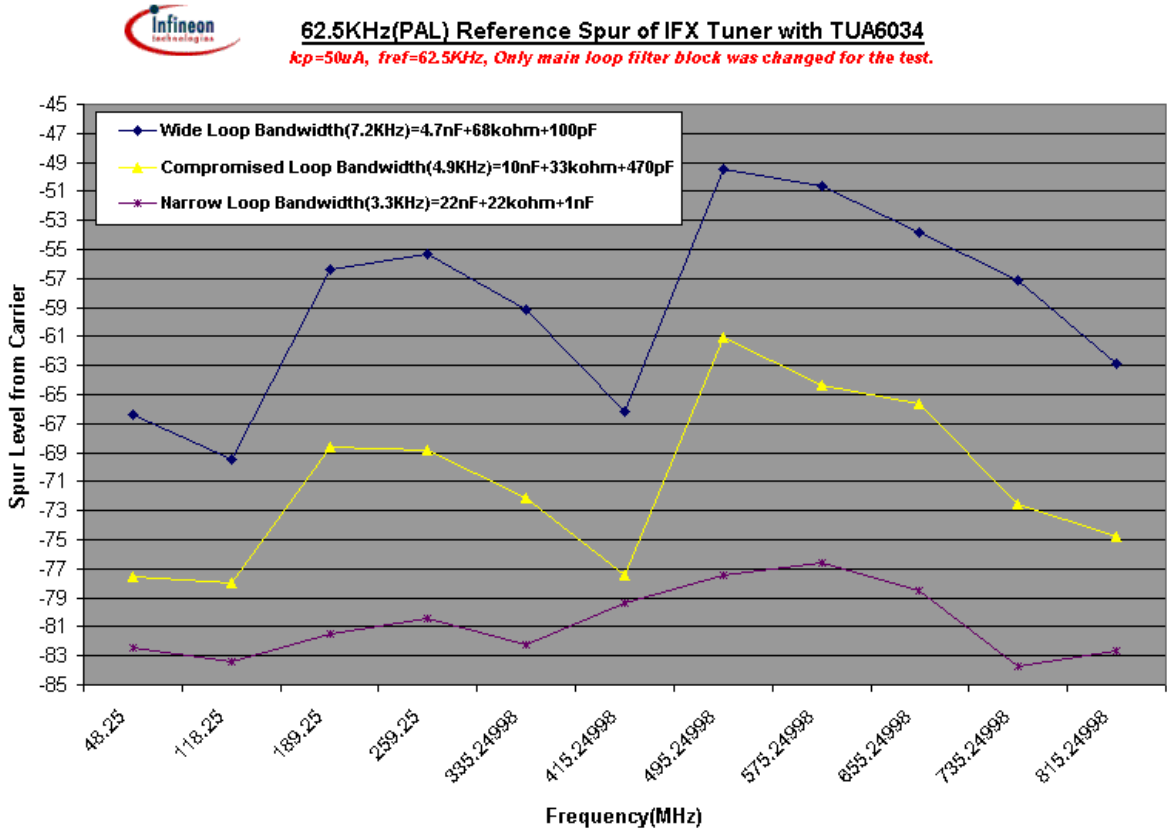
Charge Pump I	Loop BW(KHz)	C2(nF)	R1(Kohm)	C1(nF)	R2(Kohm)	Low < C3(nF) < High		Ts(mS)
650uA	4.9	10.00	34.48	0.500	0.220	15.67	156.68	0.814
250uA		3.85	55.59	0.192	0.220	9.72	97.17	
125uA		1.92	179.27	0.096	0.220	15.67	156.68	
50uA		0.77	448.18	0.038	0.220	15.67	156.68	

   The phase noise log plot below shows how 62.5KHz reference spur is improved by the loop filter calculated in the above drawing. The used values are C2=10nF, R1=33kohm, C1=470pF, R2=220ohm, C3=22nF.

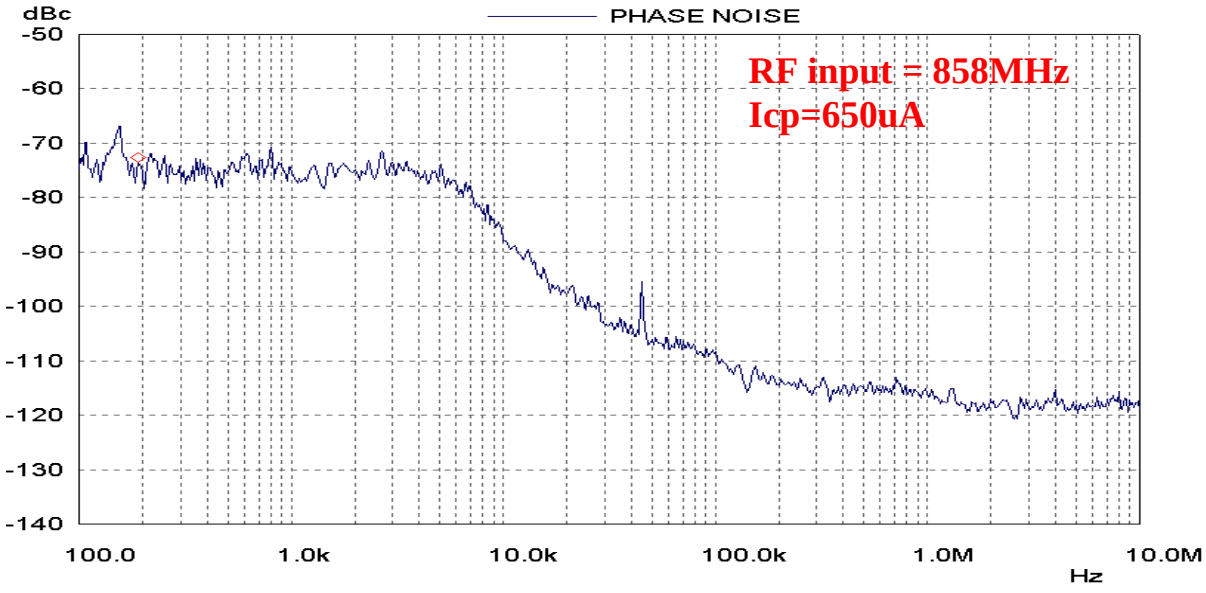


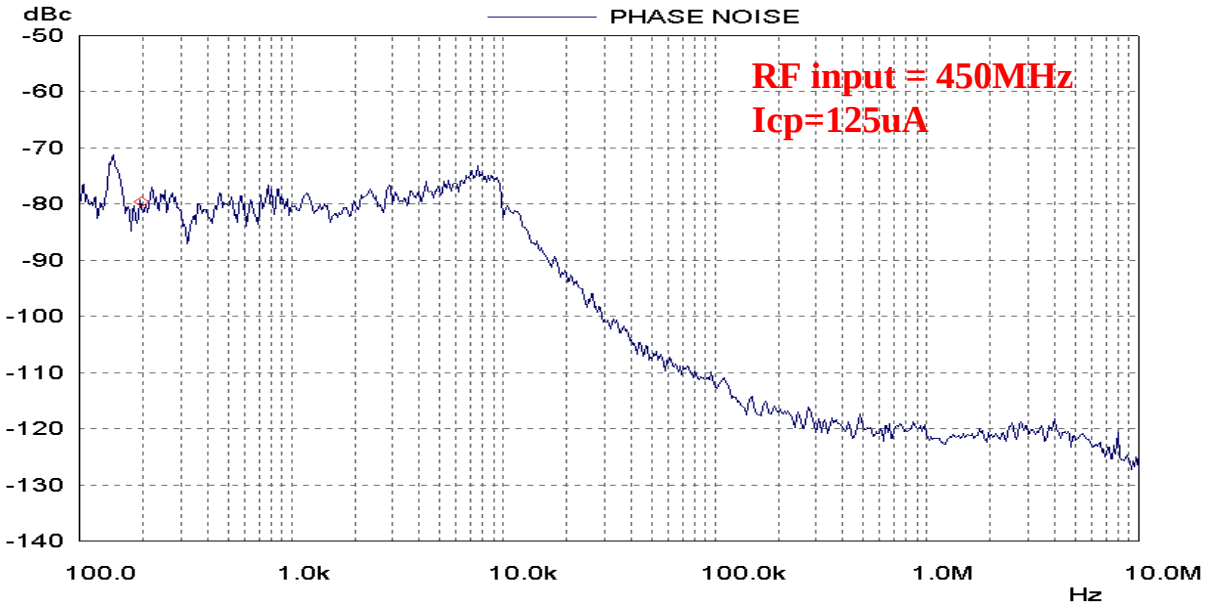
An additional graph below shows overall imprvement by narrowing loop bandwidth. The blue line is the result by wide loop bandwidth, the yellow line by the compromised loop bandwidth and the purple by narrow loop bandwidth. All were measured in the same condition as fref=62.5KHz, Icp=50uA.

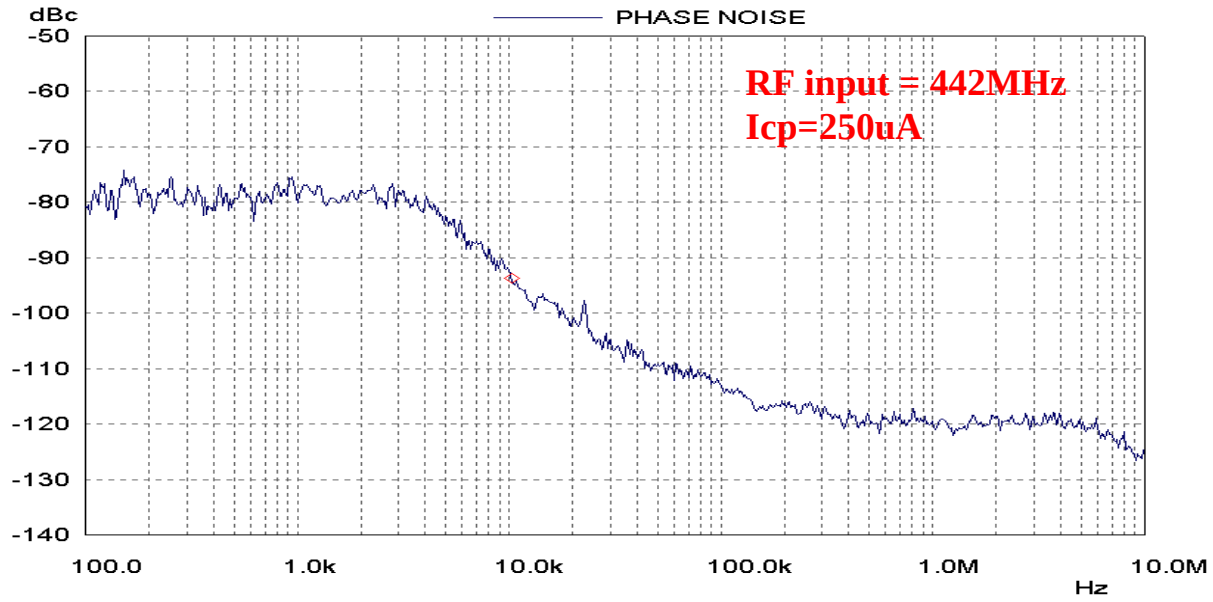
The compromised loop bandwidth results in resonable reference spur rejection lower than -60dBc in the whole bands and compromised phase noise characteristics between narrow and wide PLL loop bandwidth.

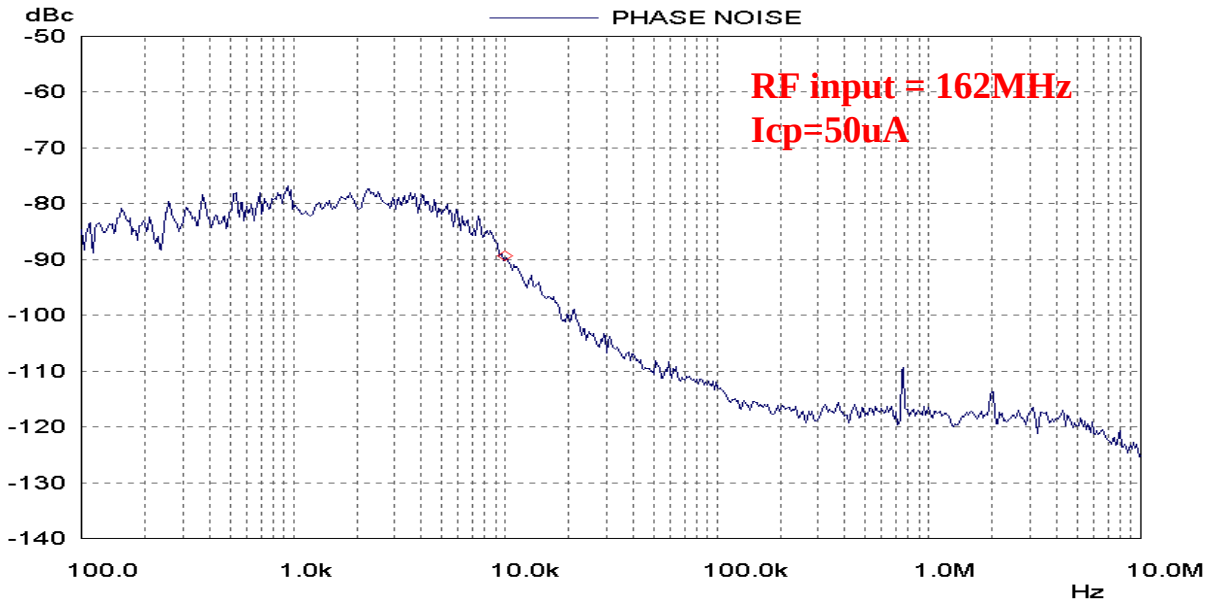


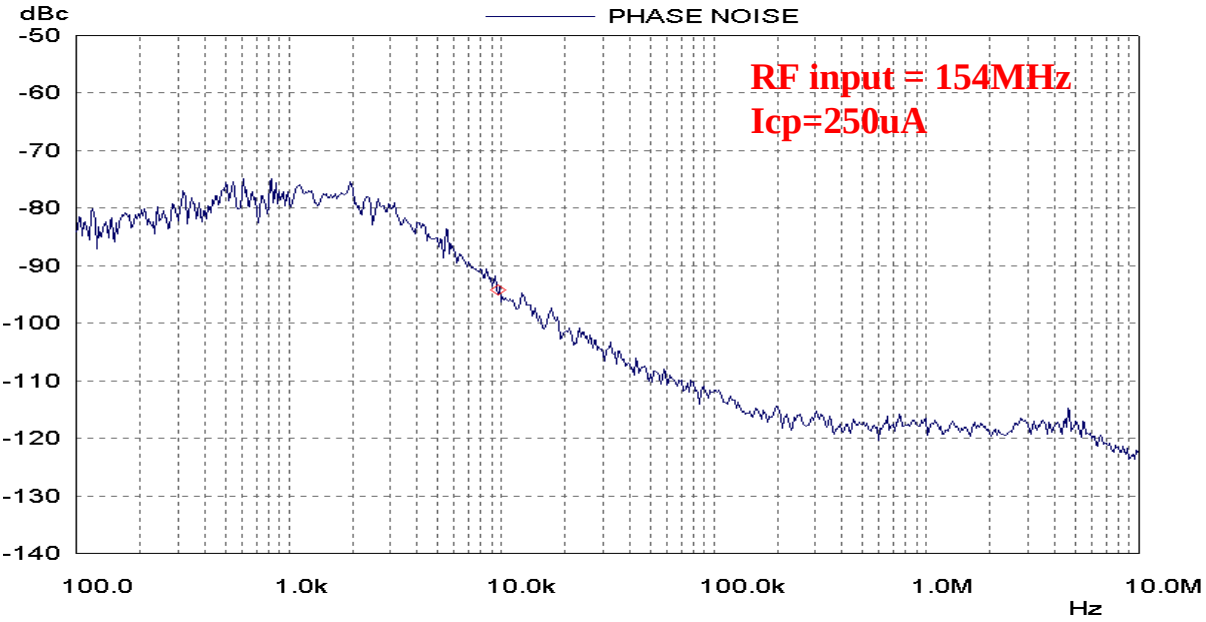
7. Following graphs are the phase noise log plots by the compromised PLL loop filter in the DVB-T measurement condition as fref=166.667KHz.

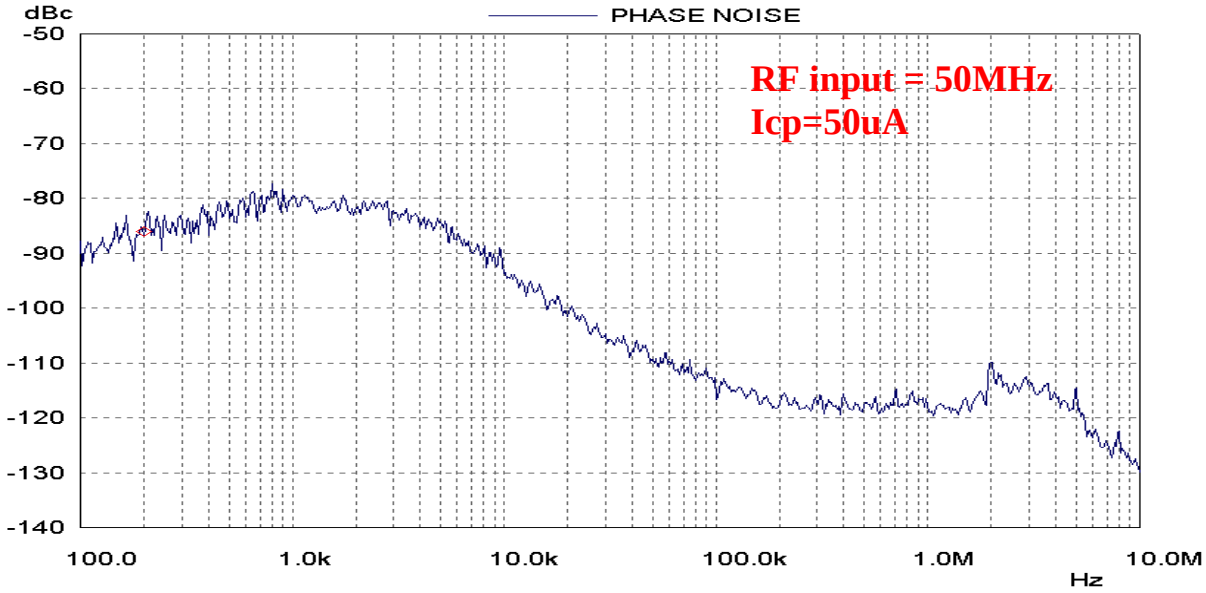



dBc
PHASE NOISE
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
RF input = 450MHz
Icp=125uA
100.0
1.0k
10.0k
100.0k
1.0M
10.0M
Hz


dBc
PHASE NOISE
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
RF input = 442MHz
Icp=250uA
100.0
1.0k
10.0k
100.0k
1.0M
10.0M
Hz


dBc
PHASE NOISE
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
RF input = 162MHz
Icp=50uA
100.0
1.0k
10.0k
100.0k
1.0M
10.0M
Hz


dBc
PHASE NOISE
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
RF input = 154MHz
Icp=250uA
100.0
1.0k
10.0k
100.0k
1.0M
10.0M
Hz


dBc
PHASE NOISE
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
RF input = 50MHz
Icp=50uA
100.0
1.0k
10.0k
100.0k
1.0M
10.0M
Hz

Appendix9. DVB-T Field Test in Munich

1. The DVB-T Test set-up in Fig.12 is used for the field test.

2. DVB-T signal in Munich:
   - Currently (Dec. 2002) there is only one DVB-T channel in Munich area and the transmitted level is very low. Fig. 1 shows the live signal received via a root-top antenna. The signal was fed to the tuner input for the receiver test. Marker 1,2 is the DVB-T signal of 8MHz Bandwidth and Marker3,4 is +1 channel PAL signal.

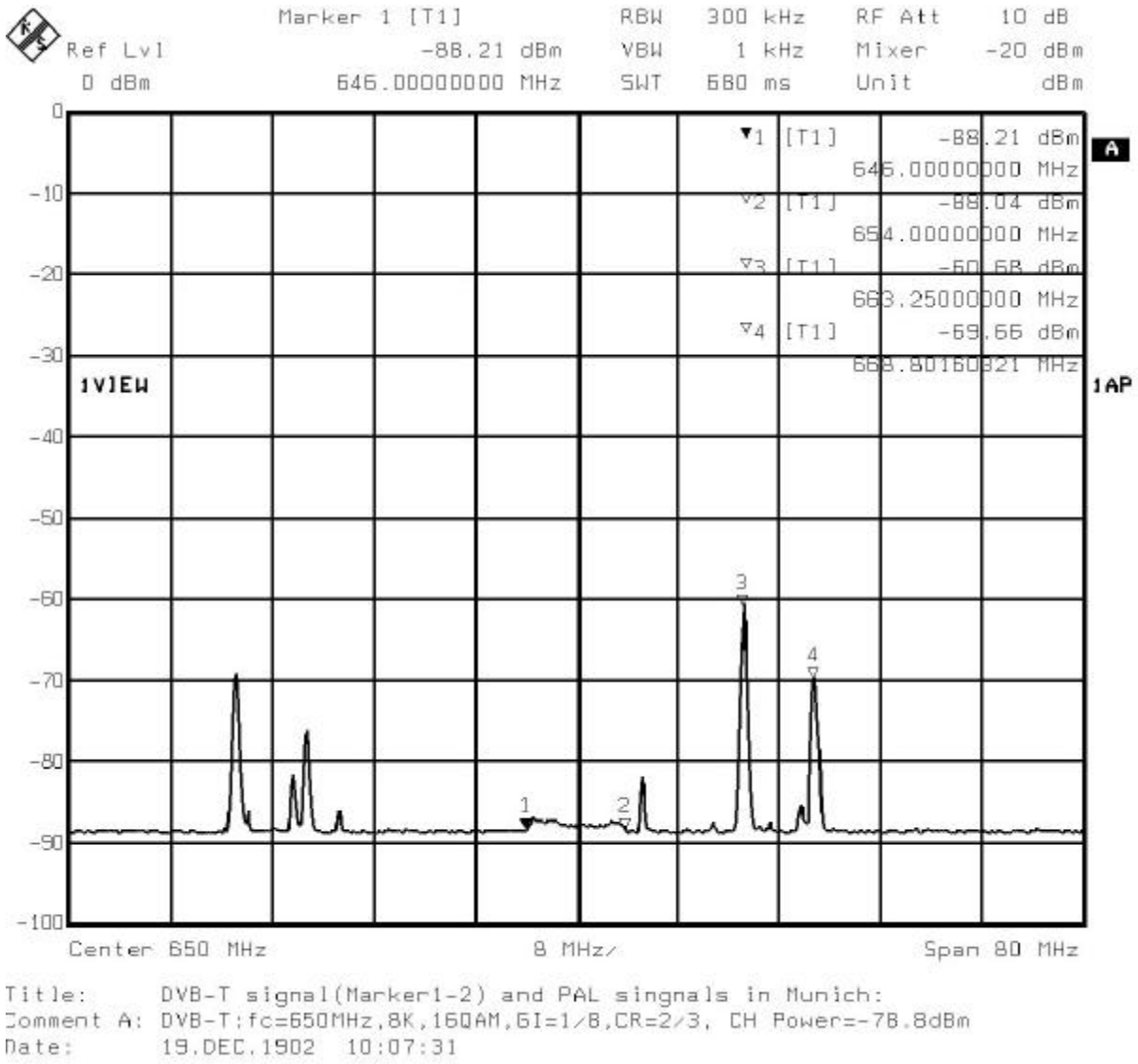


Fig.1 DVB-T signal in Munich: CH43, fc=650MHz, Bandwidth=8MHz
8K mode, 16QAM, 2/3 Code Rate, 1/8 Guard Interval

3. Measurement result including BER with the Infineon DVB-T receiver set-up:

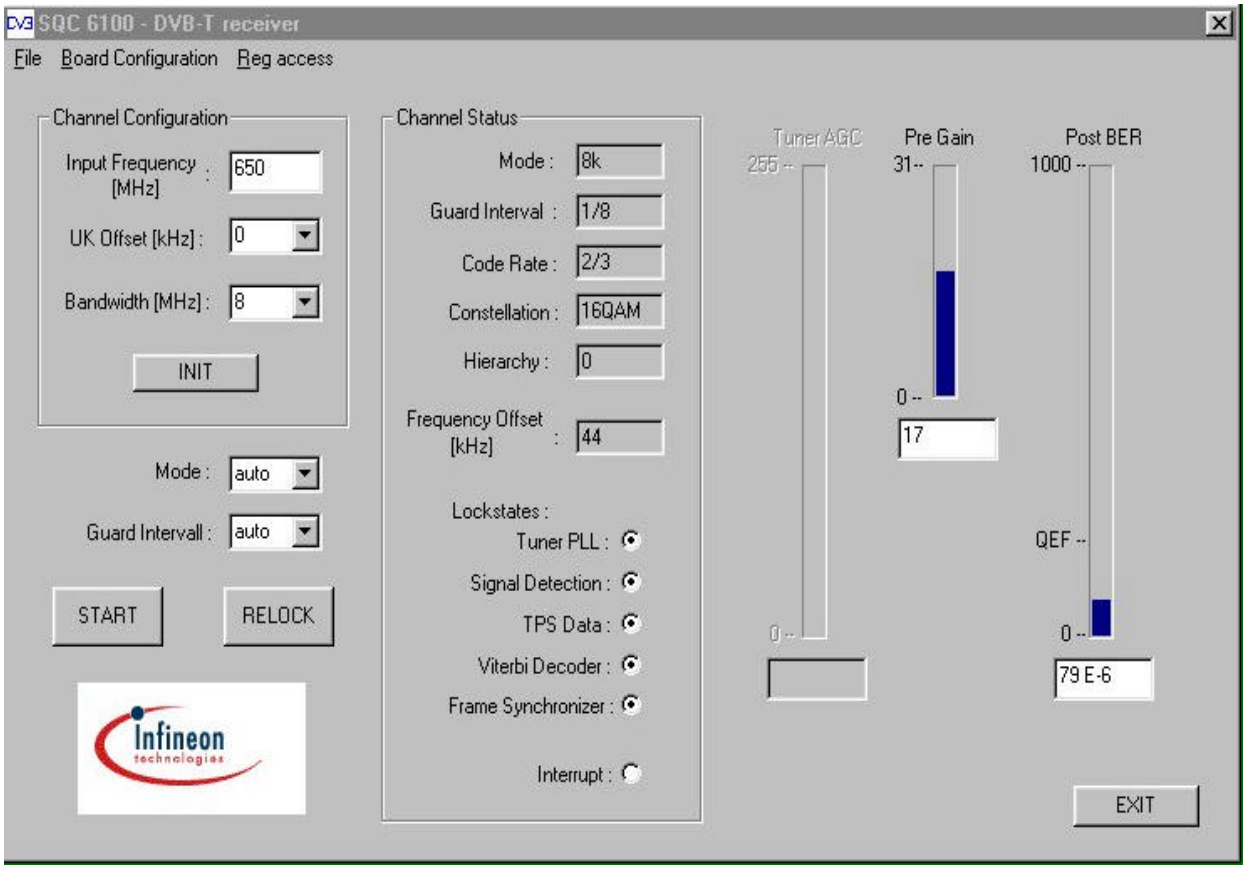


Fig.2 DVB-T Reception Result with the signal in Fig.1

Fig.3 DVB-T Test Set-up and the Received Program

Appendix10. DVB-T Half with TUA6034T, TDA6192T

1. The module is Version 1 of Infineon reference half NIM(Network Interface Module) for DVB-T receiver.

2. Infineon components inside the Half NIM ;

	Model	pcs	Package
Tuner IC	TUA6034T	1	TSSOP38
MOSFET	BF2030W	1	SOT343
	BG3130	1	SOT363
VCD	BB565	7	SCD80
	BB659C	4	SCD80
	BB689	4	SCD80
BJT	BC847W	1	SOT323
2xDiode	BAS70-04W	1	SOT323

3. Electrical characteristics of the tuner block is comparable to the result given in 5.1. The loop filter is slightly optimized to compensate the time constant influence from the 5-33V DC-DC converter and the double side PCB is adopted.

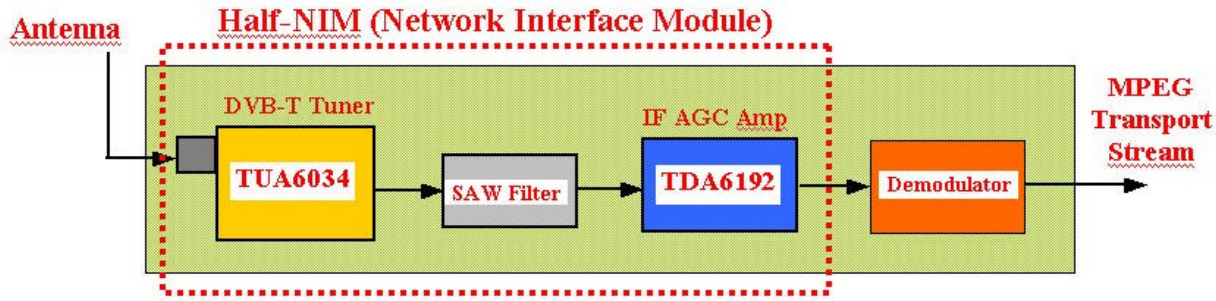


Fig1. Function Blocks inside the Half NIM

4. Top & Bottom Pictures of Infineon DVB-T Half NIM

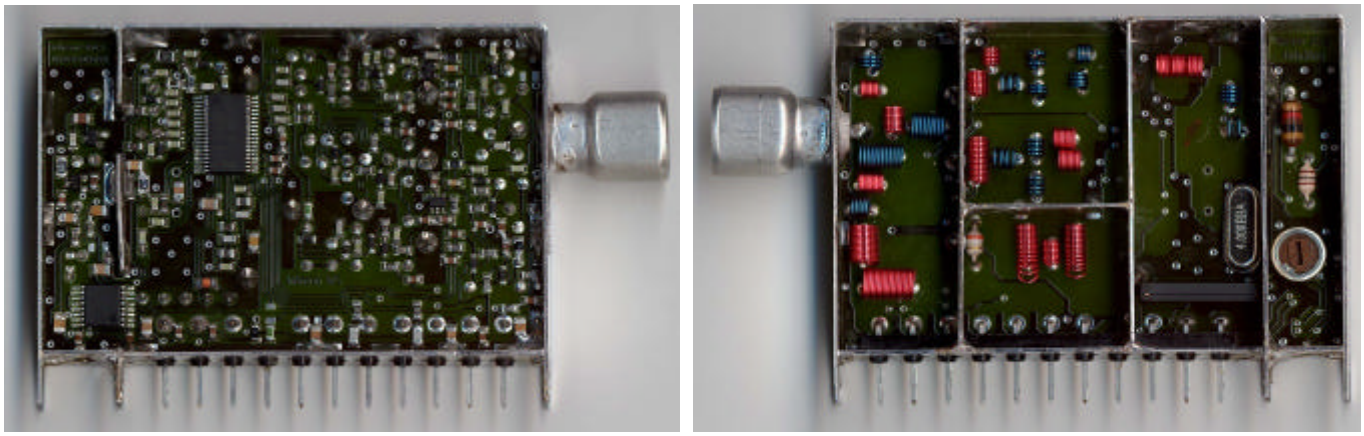


Fig2. Infineon Reference Half-NIM Ver.1

5. Some Measurement Results of the Half NIM

A. Conversion Characteristics from Antenna input to IF output: Measured with an RF active probe unsymmetrically. Power Gain will be 3dB higher when symmetrically measured.

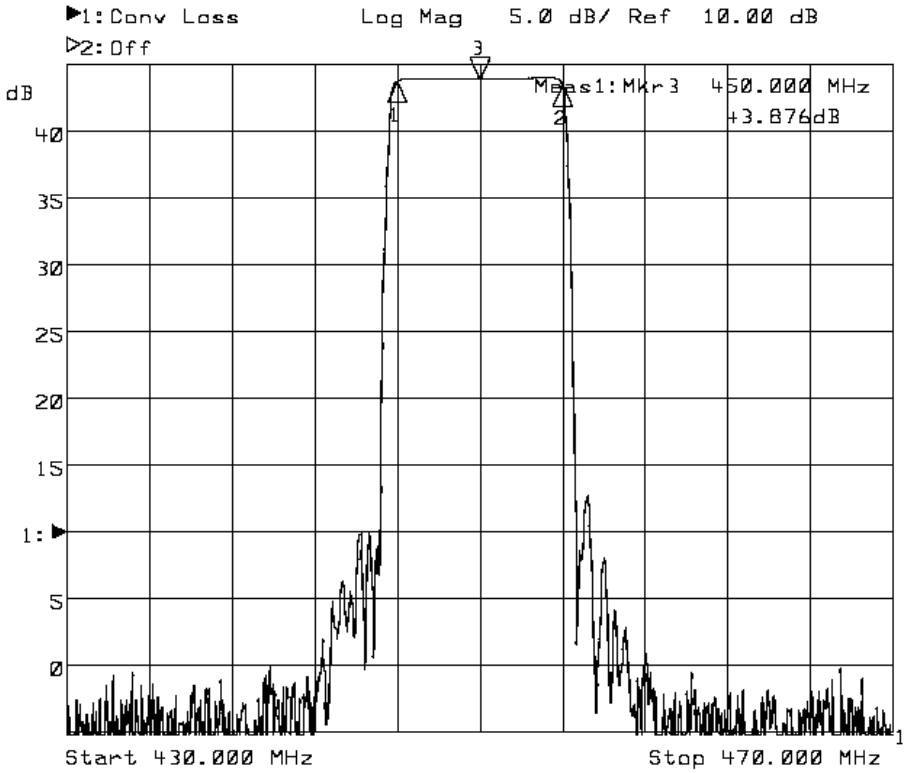


Fig3. CH Center Frequency = 450MHz

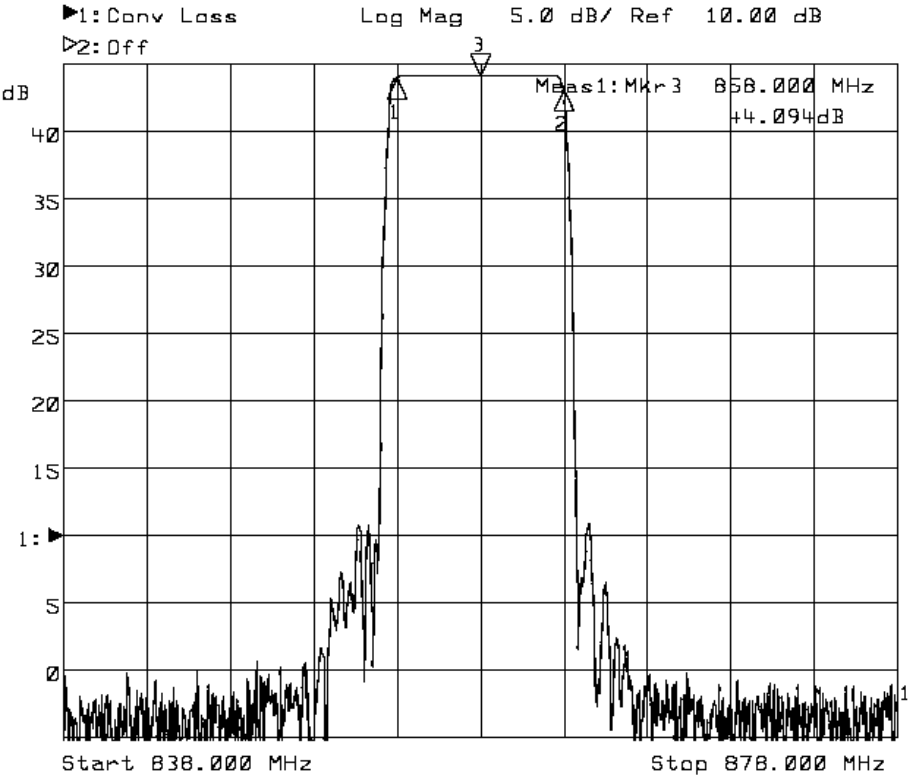
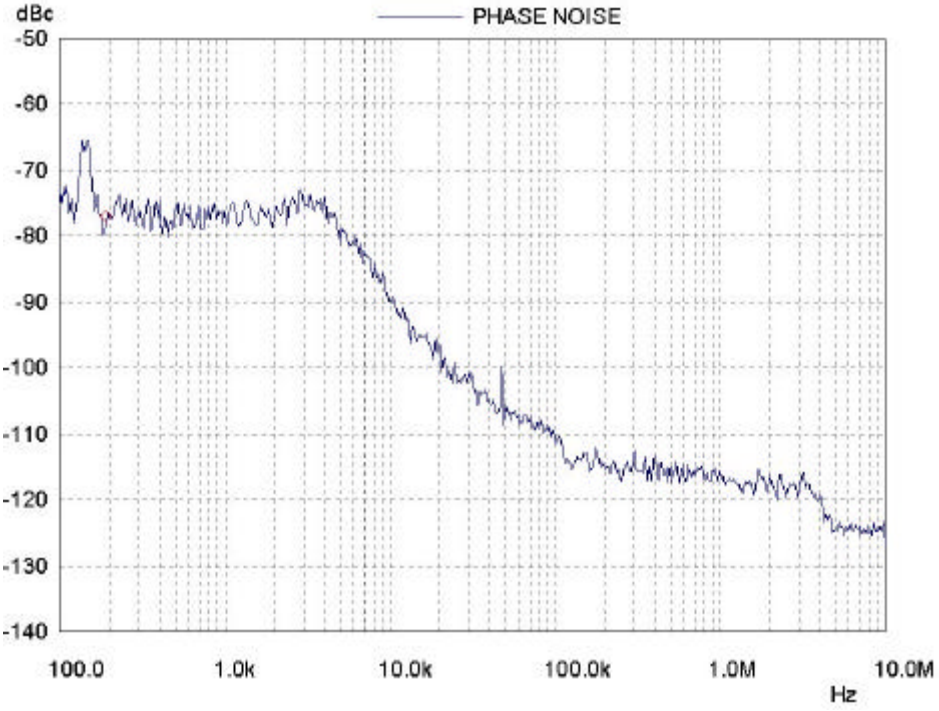


Fig4. CH Center Frequency = 858MHz

B. Phase Noise: RF Input=858MHz, Icp=650uA



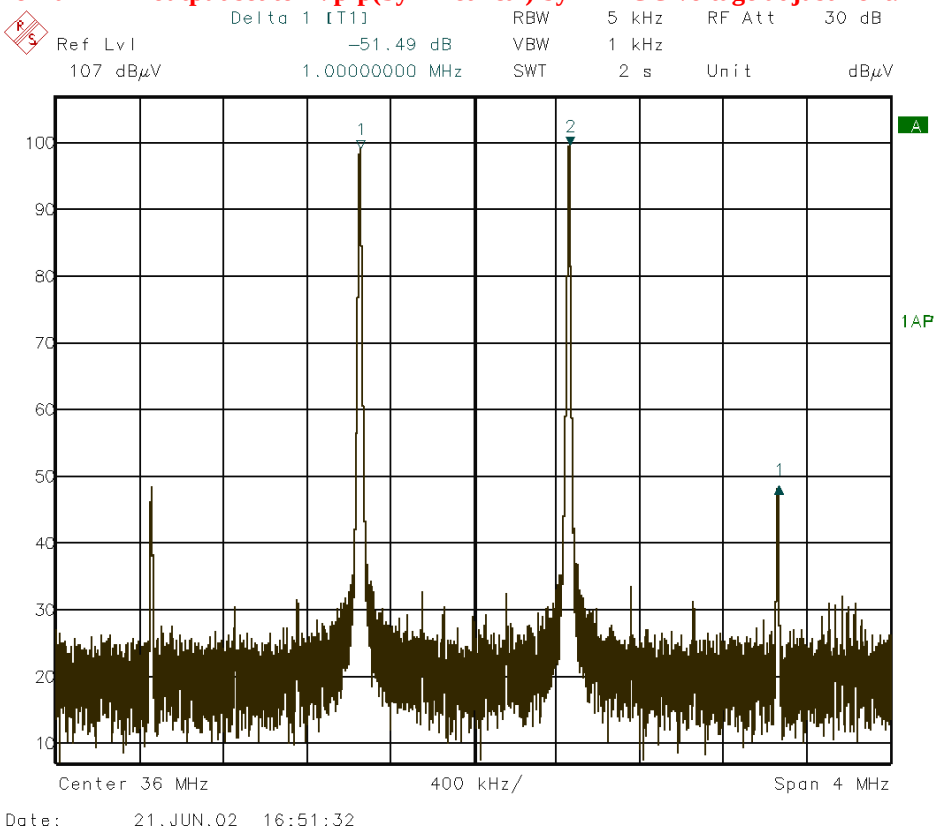
C. 2-Tone Intermodulation of the Half NIM

- Internal AGC of TUA6034 used for making one closed AGC-loop.

- RF Input = 857.5MHz + 858.5MHz, 60dBuV, Tuned to 858MHz.

- Tuner AGC Take-over point programmed to 115dBuV(Symmetrical, This is the maximum programmable AGC Top level).

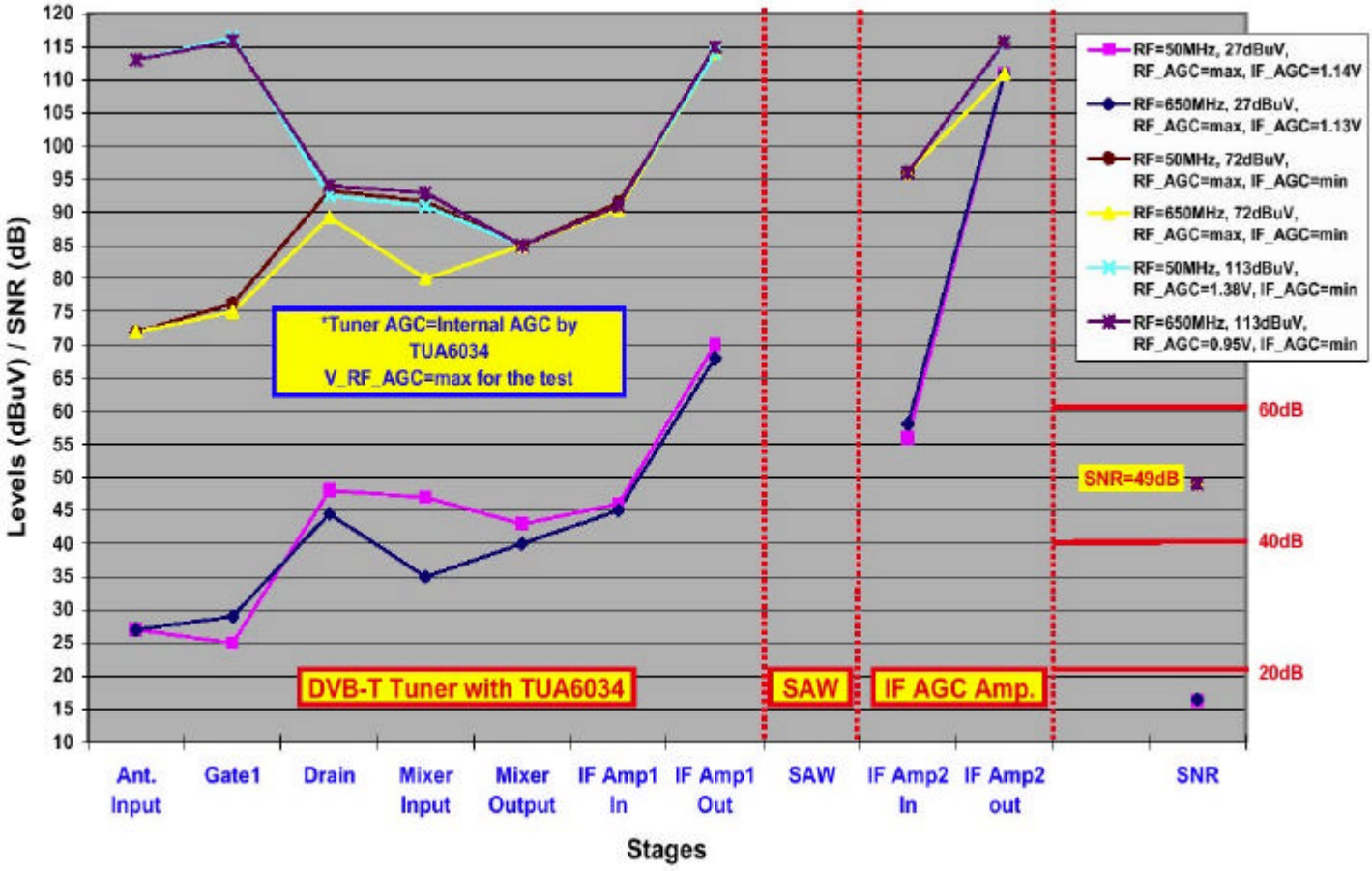
- The Half NIM output set to 1Vp-p(Symmetrical) by IF AGC voltage adjustment.



D. Signal Level Flow and SNR of the Half NIM:

- Input RF Levels= 27dBuV, 72dBuV, 113dBuV respectively.

- Measured with an RF active probe, Symmetrical Level values



6. Layout of the Half NIM

For more information and the design supports for the half NIM, please contact your local Infineon representatives.