TA0327
Technical Article

ADSL2+ Line Driving Solutions

This paper presents a short overview of the ADSL application environment, and then focuses on the implementation of line drivers in ADSL applications. An example of how to set up an ADSL2+ analog line interface using STMicroelectronics' TS615 or TS616 is presented. Magnetic circuits such as hybrid or line transformer circuits will not be described in detail.

The DSL concept

Digital Subscriber Line (DSL), is a technology which converts current twisted-pair telephone lines into access paths for multimedia and high-speed data communications.

A modem is connected to a twisted-pair telephone line, creating three information channels: a high-speed downstream channel, a medium-speed upstream channel and a POTS (Plain Old Telephone Service), split off from the modem by filters. These channels depend on the implementation of the architecture as described in Table 1.

Table 1: ADSL spectrum allocations

	POTS (4kHz)	ISDN	Upstream (Hz)	Downstream (Hz)	Comments
ADSL2+					
Annex A	yes		30k>130k	2.2M	
Annex B	yes	yes	64k>256k	2.2M	Over ISDN
Annex C					All digital loop. Over POTS.
Annex I	no	no	4k>130k	2.2M	Large Upstream without ISDN.
Annex J	no	no	4k>256k	2.2M	Long reach. Modulation chosen to increase the data rate on long lines.
Annex M	yes	no	30k>256k	2.2M	

Table 1: ADSL spectrum allocations

	POTS (4kHz)	ISDN	Upstream (Hz)	Downstream (Hz)	Comments
ADSL2					
Annex A	yes		30k>130k	1.1M	
Annex B	yes	yes	64k>256k	1.1M	Transmission via ISDN line.
Annex I	no	no	4k>130k	1.1M	All digital loop technology, transmitted via POTS.
Annex J	no	no	4k>256k	1.1M	Large Upstream without ISDN.
Annex L	yes	no	30k>130k	1.1M	Long reach. Chose on modulation to increase the data rate on long lines.
Annex M	yes	yes	30k>256k	1.1M	

The line interface - ADSL remote terminal (RT)

Figure 1 shows a typical analog line interface used for ADSL. The upstream and downstream signals are separated from the telephone line by using a hybrid circuit and a line transformer. On this note, emphasis will be placed on the emission path. Several criteria must be recalled:

- **Power supply.** The choice of the power supply of the driver is directly linked to several factors:
  - the turn ratio of the line transformer;
  - the output capabilities of the driver (maximum output swing, output current, linearity versus load);
  - the line matching technique (refer to the article entitled “STMicroelectronics ADSL line interfaces” by the same author);
  - and the insertion loss of the hybrid circuit.

  To fit with +5 V and +12 V power supplies available in multimedia equipment, we show here the implementation of drivers in +5 V and +12 V single supplies.
- **Temperature considerations.** ADSL drivers must adequately dissipate power in order to maintain an operating temperature range where their linearity and stability are not affected. This aspect is very important to improve the SNR of the downstream signal, and to improve the data reception rate. In this article, we will focus on techniques that improve heat dissipation, and on the linearity of the drivers by showing the measurements of intermodulation products.

Figure 1: Typical ADSL line interface

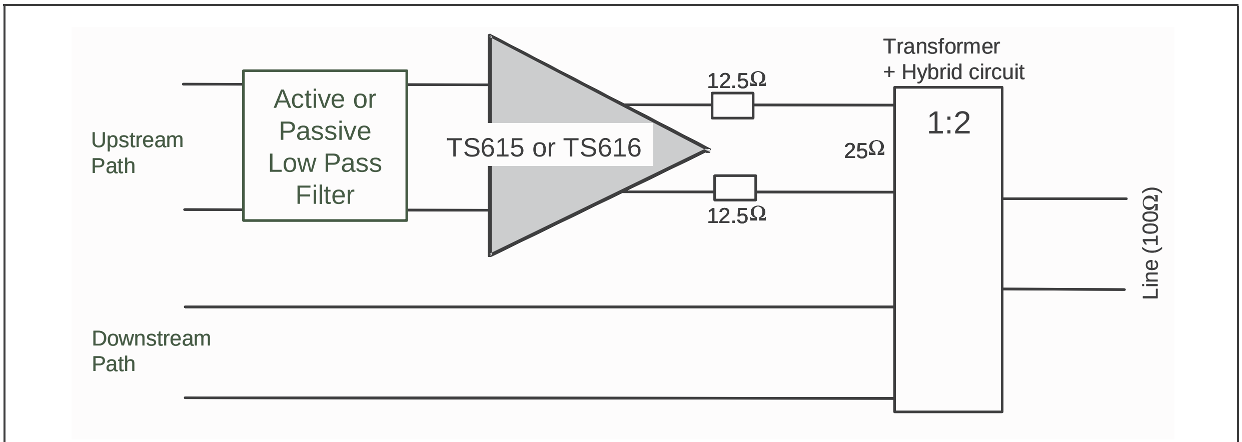


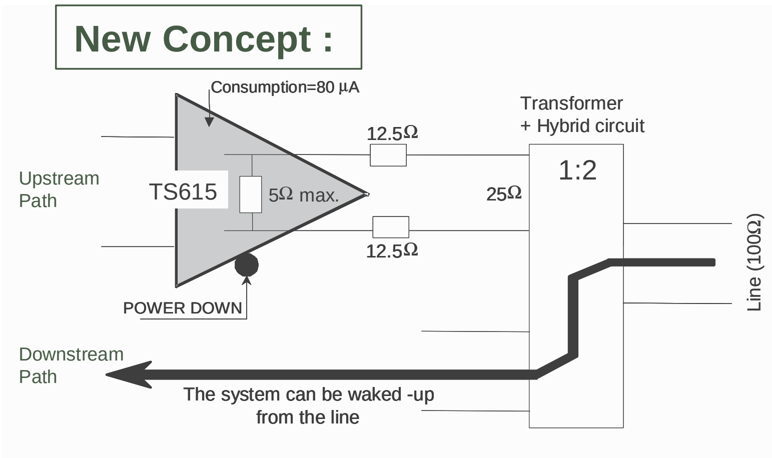
Table 2: Main characteristics of the drivers

		power down	Bw Gain=4 (MHz)	SR (V/µs)	Iout Typ. (mA)	Noise (nV/VHz)	Icc per op. (mA)	HD2/HD3 (dBc)	Vout differential (Vpp min)	Packages
TS616	CFA	no	40	420	420	2.5	13.5 (@12V) 11.5 (@5V)	87/83*	20.7 (12V) 7.2 (5V)	SO8 Exposed Pad
TS615	CFA	yes	40	420	420	2.5	14 (@12V) 11.9 (@5V)	87/83*	20.7 (12V) 7.2 (5V)	TSSOP14 Exposed Pad

*) Differential 16Vpp/110kHz on 50Ω.

The TS616 is housed in SO8 exposed pad plastic package with the same standard pin-out as the TS613. This feature allows the TS616 to be evaluated more easily on existing boards. The TS615 uses the same design as the TS616, and in addition, offers the advantage of a power-down mode in order to minimize power consumption when the modem is not in communication. In power-down mode the TS615 short-circuits the output short. As described below, this feature allows one to maintain a good impedance matching with the line while the modem is in sleep mode, as well as allowing one to wake-up the modem via the telephone line (an important advantage that ADSL modems have over POTS solutions).

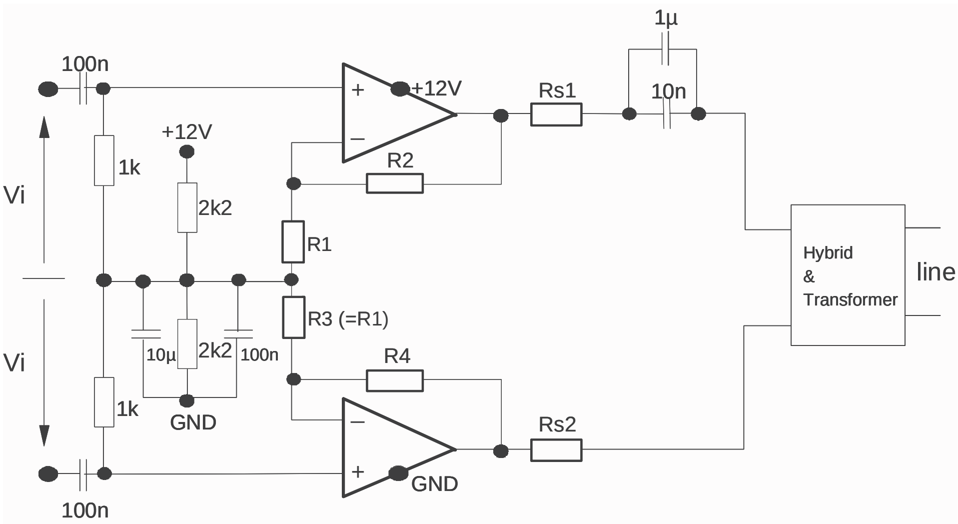
Figure 2: TS615 power-down mode



12V power supply: Remote ADSL modem terminals must be designed to be easily connected to a PC. For such applications, the driver should use a +12V single power supply, which is available via standard PCI connectors. Note that the TS616 and TS615 can also be powered by a dual +/-6V power supply .

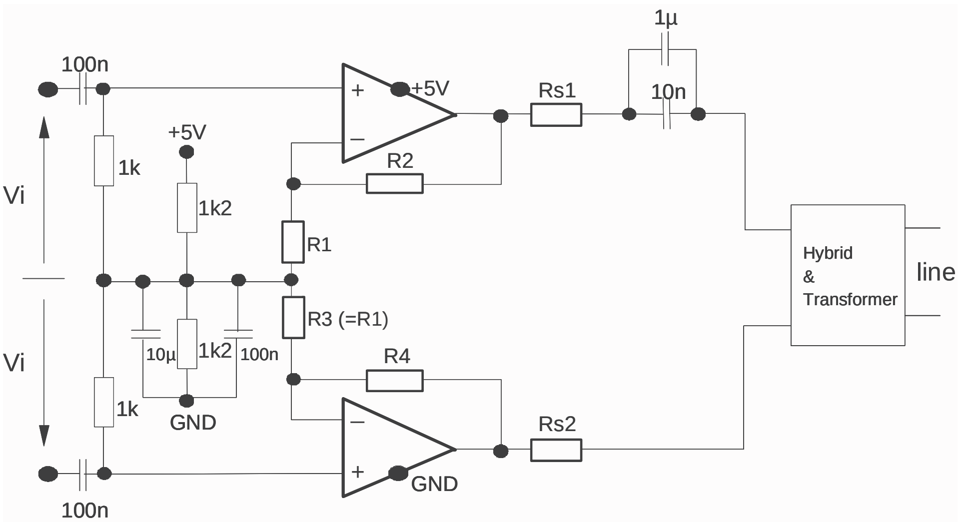
Figure 3 shows a single +12V supply circuit with the TS613 as a remote terminal transmitter in differential mode. Note that one could also use the TS612 in exactly the same schema.

Figure 3: TS616 (or TS615) as a differential line driver with a +12V single supply



The aim is to decrease the power consumption of the line interface by reducing the power supply. As the output swing of the driver will be reduced, the magnetic transformer turn ratio must be increased to maintain the correct power level of the line. A turn ratio of 4.5 fits well with these requirements.

Figure 4: TS616 (or TS615) as a differential line driver with a +5V single supply

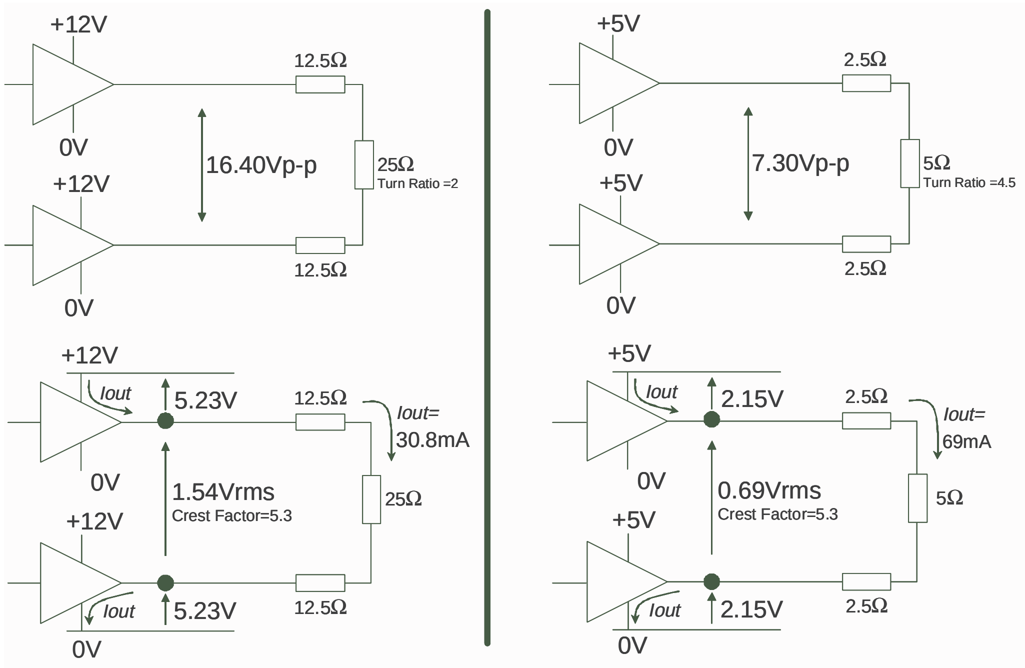


Note: Please see datasheets of TS616 and TS615 or the technical article "STMicroelectronics Solutions for ADSL Line Interfaces" for more detail on single supply implementation.

The power supply can only be reduced to the limit of the capability of the driver to drive a differential load below 10ohms while maintaining good linearity (the linearity of an operational amplifier is directly linked to the load).

Thermal considerations: The choice of the package is directly linked to the evaluation of the junction temperature (Tj) of the driver while in communication. *Figure 5* shows the calculation of the power which the driver must dissipate.

Figure 5: Power dissipation (+12V and +5V power supply)

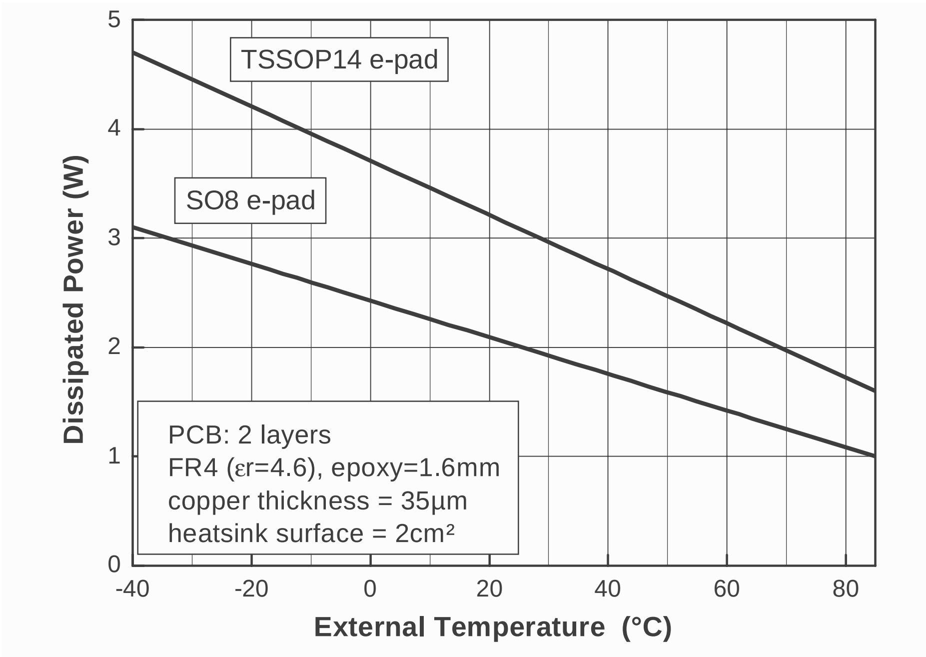


The following table shows the accordance, by package and by power supply, of the maximum external temperature (Ta) which should be reached when the modem is in communication. We consider that Tj=150°C and that Power=(Tj-Ta)/Rthja. Rthja is the junction/area thermal resistance of the product.

	Package	Rthja (°C/W)	Iccmax (mA)	Static Dissipated Power (mW)	Dynamic Dissipated Power (mW)	Total Dissipated Power (mW)	Ta max (°C)
TS616 (5V)	SO8 e-pad	60	15	150	297	447	123
TS616 (12V)			17	408	322	730	106
TS615 (5V)	TSSOP14 e-pad	40	15	150	297	447	132
TS615 (12V)			17	408	322	730	120

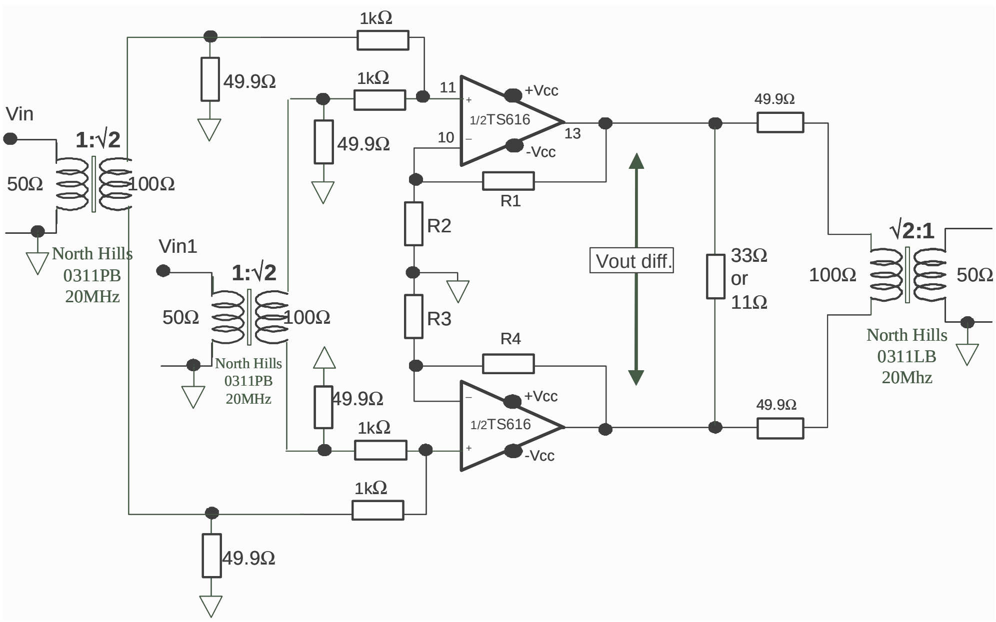
These calculations show that even while in communication, both drivers maintain safe behaviour over the entire temperature range given by datasheets (-40°C to +85°C). The maximum operating temperature of +85°C can be considered as a guarantee. In terms of qualification of TS616 and TS615, a Ta higher than 85°C is not guaranteed by ST.

Figure 6: Thermal considerations: power dissipation of the packages vs. temperature



Note: The pad must be in thermal contact with the heatsink. If the pad and the heatsink are floating, their surface can create parasitic capacitors located on the substrate of the dice. To remove these parasitic capacitors, the copper layer must be connected to -Vcc (GND in case of single supply).

Figure 7: Implementation of the line driver for 2-tone intermodulation measurements*



*) The driver is used in non-inverting summation configuration.

Figure 8: Intermodulation of TS616 and TS615 on 25Ω load (Vcc=12V)

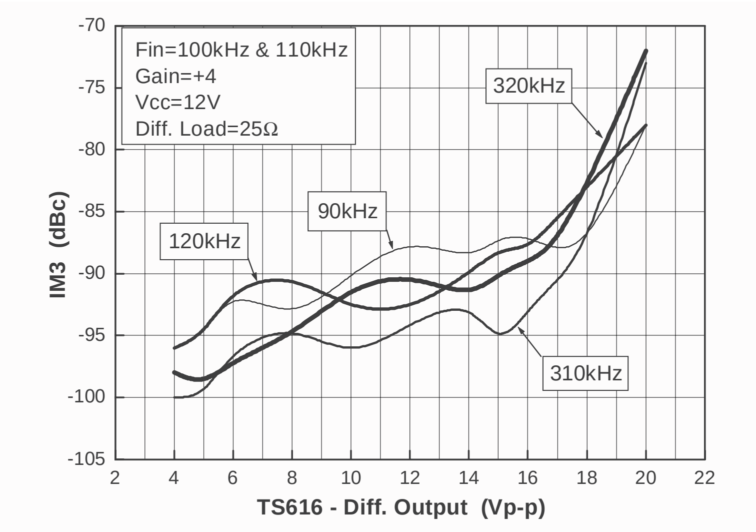
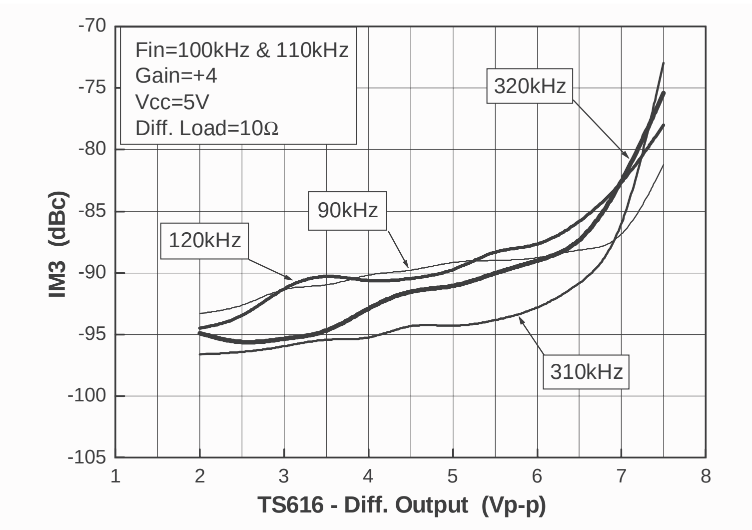


Figure 9: Intermodulation of TS616 and TS615 on 10Ω load (Vcc=5V)*



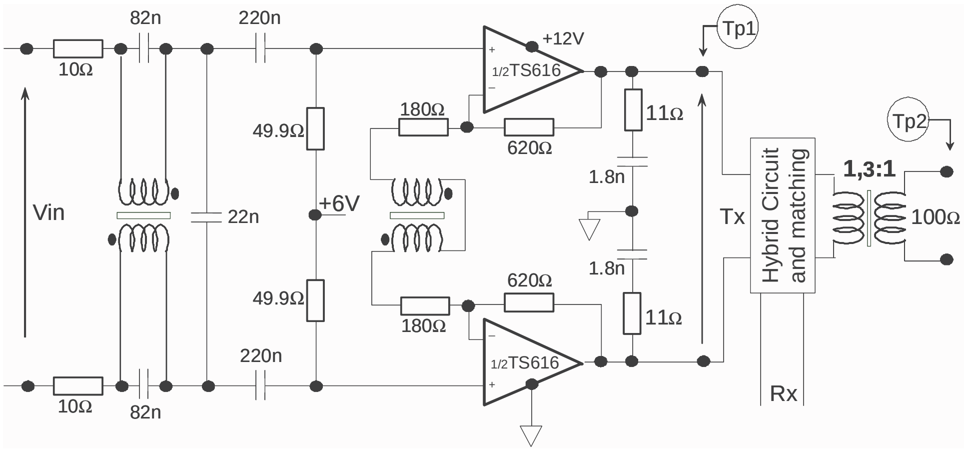
*) Fin=100kHz and 110kHz, differential signal, producing intermodulation products on drivers located at 90kHz, 120kHz, 310kHz and 320kHz.

These measurements have been done on a board with the following physical characteristics: 2-layer PCB, FR4 (εr=4.6), epoxy=1.6mm, copper thickness = 35µm, heatsink surface = 2cm². Please see the evaluation board kit “KITHSEVAL/STDL”, or its accompanying user manual for more information on boards.

Results over the ADSL spectrum

Finally, to achieve a very good SNR, Bilge BAYRAKCI, STMicroelectronics, Zaventem (Belgium), sets up the line interface as shown in *Figure 10*. He uses the TS616 in a 12V single supply, with a mid-supply described in *Figure 3* and a passive third-order, low-pass filter. L1, L2 and T2 are used to decrease the gain at higher frequencies with good common mode rejection. Decreasing the gain and applying a low-pass filter allow one to decrease the noise in the ADSL spectrum.

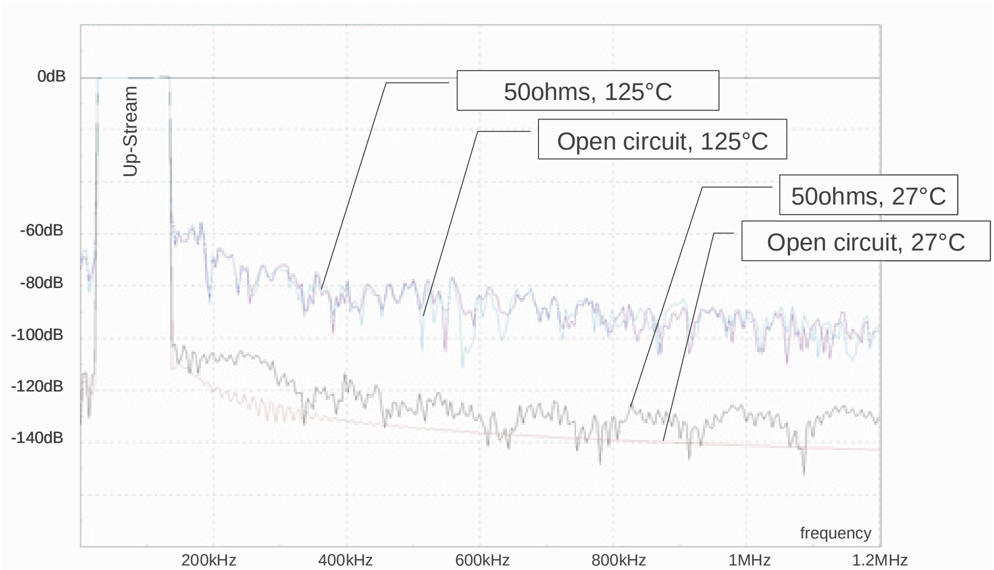
Figure 10: Line interface implemented on the ST's ADSL2+ solution*



*) Hybrid circuit and matching are not described in this paper.

Figure 11 shows simultations performed on TP1 considering a differential load of 50Ω and an open circuit. The focus is on the level of the noise in the down stream signal.

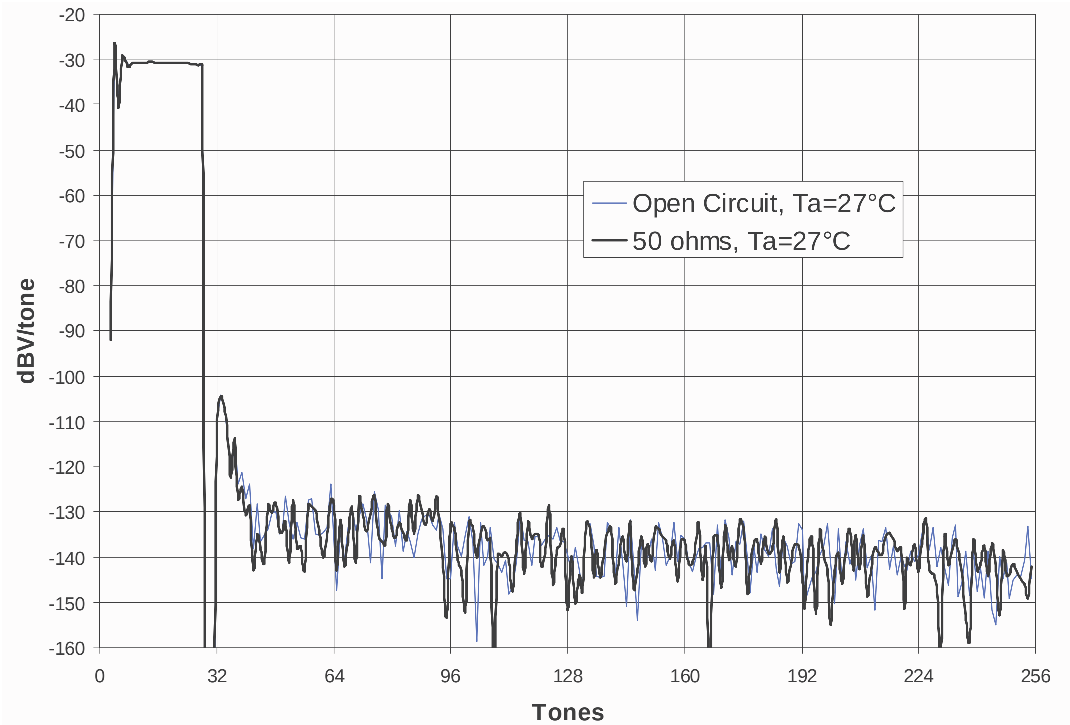
Figure 11: Simulation results in TP*



*) Simulation performed with the TS616 eldo model and the ADSL input signal eldo model (crest factor = 6.2). The temperature is the junction temperature.

Figure 12 shows measurements of ADSL spectrum on the STMicroelectronics solution using the analog Front End ST20184.

Figure 12: Measurements in TP2



1 Revision History

Table 1. Document revision history

Date	Revision	Changes
April 2006	1	– Initial release.