

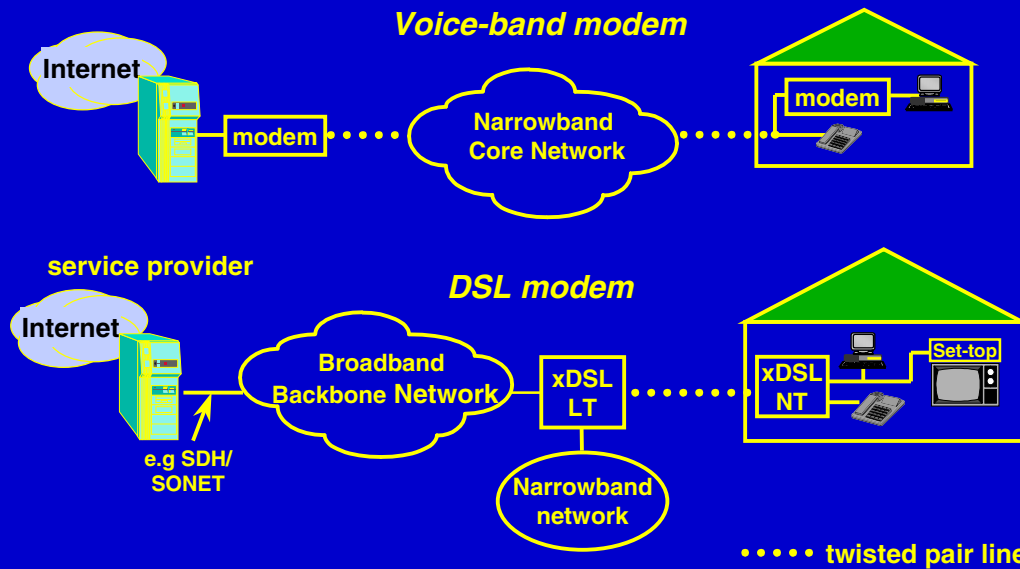
Requirements for Embedded Data Converters in an ADSL Communication System

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**▼ Introduction**

- ADSL communication system
- Shannon-Hartley theorem
- DMT cat. I signal transmission

▼ The Analog Front End (AFE) Challenge**▼ Converter specification****▼ Conclusion**

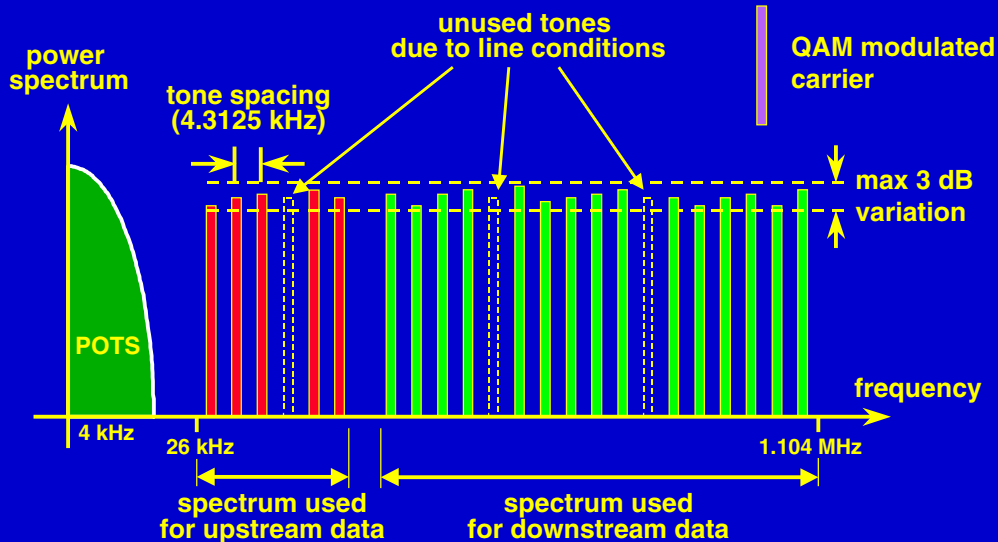


- ▼ How to transmit the maximum data over the limited bandwidth of the single twisted pair telephone line, without disturbing POTS and ISDN communications ?

- ▼ Theoretical transmission limit: Shannon - Hartley

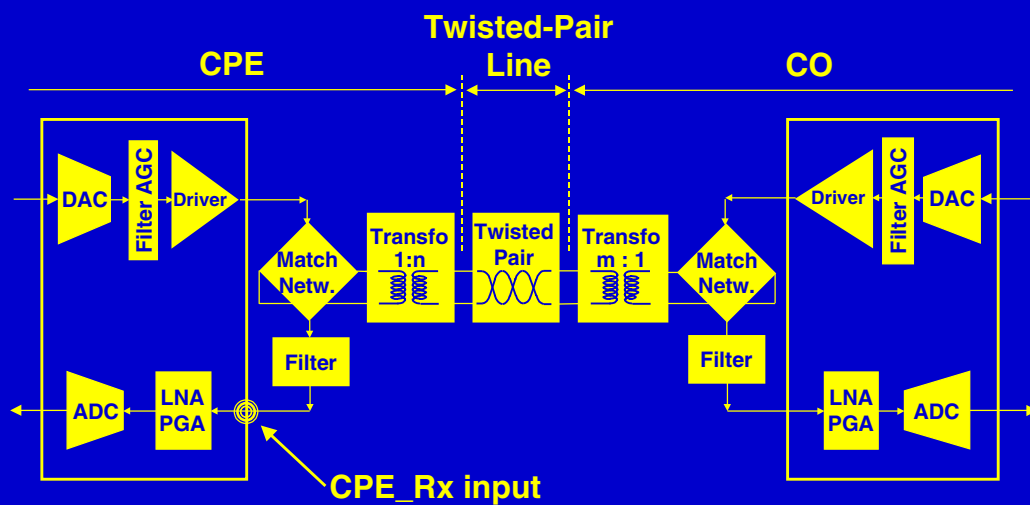
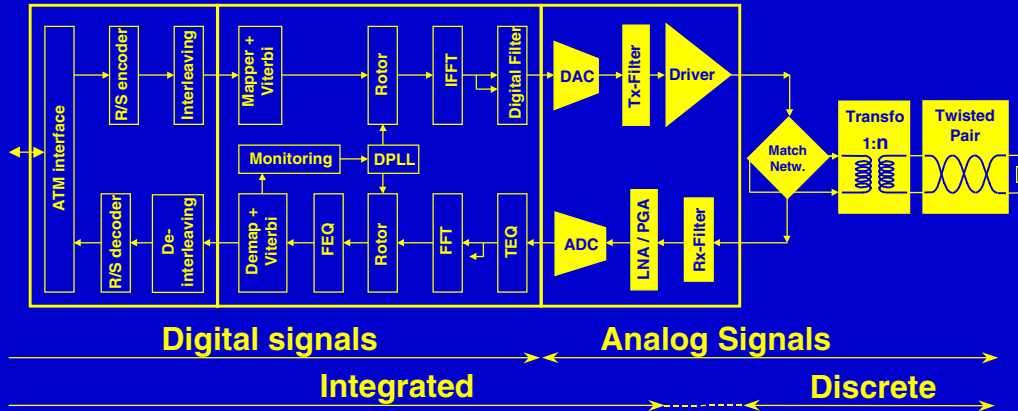
$$Capacity(bps) = \int_{f_{min}}^{f_{max}} \log_2(1 + SNR(f)) \cdot df \approx \frac{1}{3} \cdot \int_{f_{min}}^{f_{max}} SNR_{dB}(f) \cdot df$$

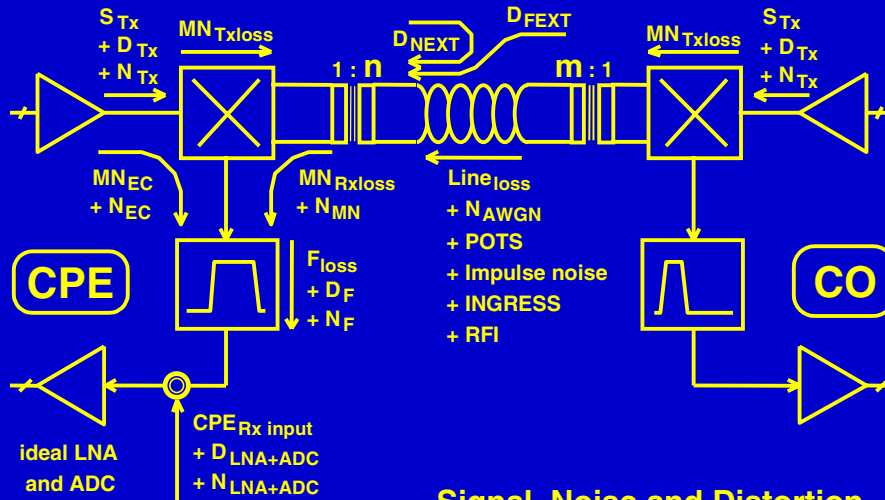
- ▼ Discrete Multi Tone (DMT) approaches the Shannon limit by splitting the 1.104 MHz transmission band in 256 QAM modulated carriers: (1 ... 256) x 4.3125 kHz.
- ▼ The lowest DMT carriers are not modulated to avoid interference with POTS or ISDN.



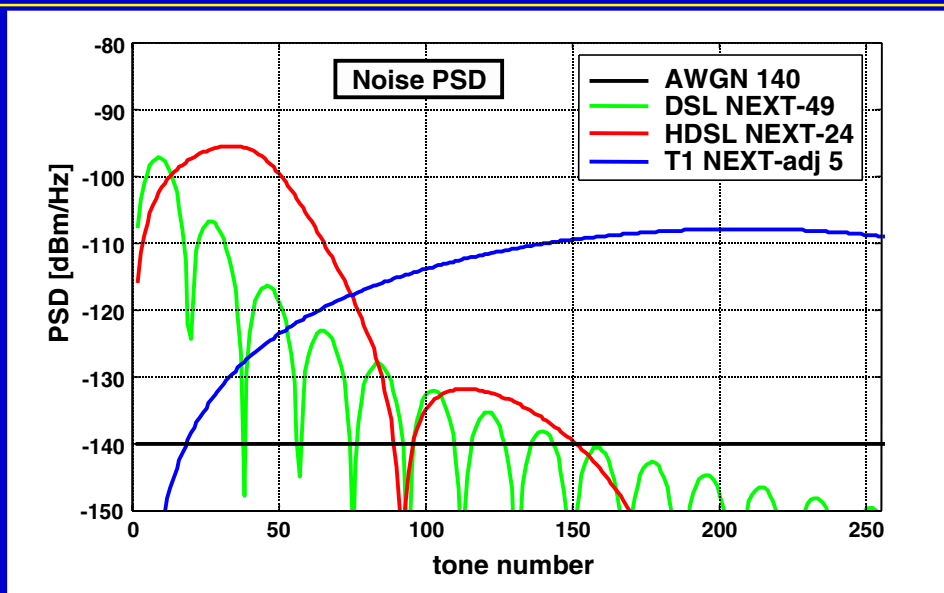
- ▼ Introduction
- ➡ ▼ The Analog Front End (AFE) Challenge
 - ADSL reference model
 - AFE reference model
 - AFE signal flow
 - Interference by other transmissions
 - Driver supply - transformer ratio
- ▼ Converter specification
- ▼ Conclusion

ADSL-System : Reference Model

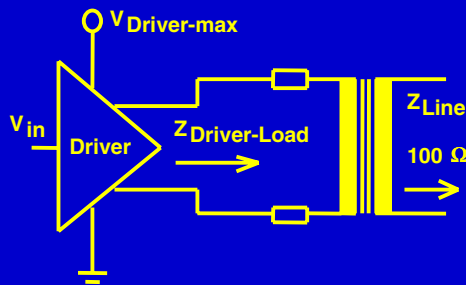




Signal, Noise and Distortion for the CPE_{Rx} input



- ▼ Low Driver supply → High transformer ratio
- High transformer ratio → Low Rx-input signal
- Low Rx signal → Low noise LNA/PGA and ADC



$$P_{Driver-rms} = P_{Line-rms} \cdot MN_{loss} \cdot Transfo_{loss}$$

$$V_{Driver-max} = CF \cdot \sqrt{P_{Driver-rms} \cdot Z_{Driver-Load}}$$

$$m = \sqrt{\frac{100\Omega}{Z_{Driver-Load}} \cdot MN_{loss}}$$

- ▼ e.g. 37 Vpk @ 1:1 transfo at CO-side

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- ▼ The Analog Front End (AFE) Challenge
- ▼ Converter specification
 - SNR spec of the ADC
 - Bandwidth spec of the ADC
- ▼ Conclusion



- ▼ QAM modulation: 3 dB/bit + 3dB margin + 8 dB to meet BER of 10^{-7} 56 dB
- ▼ Crest Factor > 5.6: > 15 dB for clipping < 10^{-8} 15 dB
- ▼ Line attenuation: ~ 0 ... 60 dB taken up in the LNA / PGA 0 dB
- ▼ Echo signal from the Driver (out-of-band) increases the dynamic range of Rx input 5 ... 15 dB
- ▼ Signal path Filter / LNA / PGA / ADC 10 dB

TOTAL: 86 ... 96 dB



14 ... 16 bit ADC required



- ▼ DMT uses the full 1.104 MHz bandwidth
- ▼ The Amplitude and Phase roll-off near the Nyquist frequency can be equalised in the digital circuit if this roll-off is stable.
- ▼ To allow the maximum number of bits in the highest tones, a higher ADC frequency is used

Signal bandwidth ~ 2 MHz



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- ▼ Conclusion



- ▼ ADSL system shows a high inter-dependency between the requirements of the various blocks in the AFE
 - ❑ driver supply → transformer ratio
 - ❑ transformer ratio → Rx-signal attenuation
 - ❑ Rx-filter & Matching Network → EC signal at Rx-input
 - ❑ Driver supply & Driver Distortion & Matching Network & Rx-filter → Input swing at LNA input
 - ❑
- ▼ Higher AFE performance
 - Higher ADSL performance (reach and bitrate)
 - Less discrete components (cost and area)
- ▼ ADSL modem requires high resolution ADC
 - ~ 15 bit, 2 MHz signal bandwidth