

## G.728 on $\mu$ PD7701x

The ITU-T Recommendation G.728 describes a Low Delay Code Excited Linear Predictive (LD-CELP) algorithm that provides high-quality coded speech at 16 kbits/s instead of the 64 kbits/s currently used. The algorithmic delay is only 0.625 ms.

NEC's  $\mu$ PD7701x 16-bit fixed-point DSP family is particularly suitable for the implementation of the G.728 fixed-point version that is fully compatible to existing floating point implementations. Additional functions and compression algorithms like G.711 and G.722 can be implemented in parallel due to the flexibility of a general purpose DSP and the processing power of the  $\mu$ PD7701x family.

This G.728 fixed-point realisation on NEC's  $\mu$ PD7701x family combines a low cost, low power single chip solution with high end speech quality.

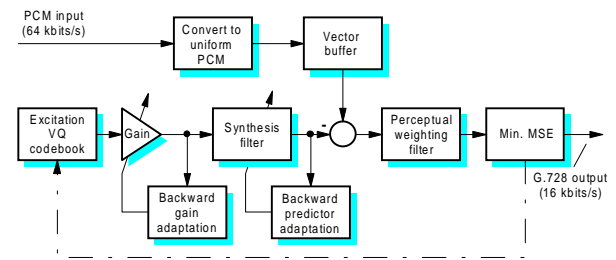
## Introduction to ITU-T Rec. G728

This LD-CELP algorithm combines a high compression rate from 64 kbits/s to 16 kbits/s with a speech quality that is comparable to that obtained with G.711 at 64 kbits/s or G.726 at 32 kbits/s. The G.728 LD-CELP backward adaptation technique reduces the algorithmic delay to 0.625 ms.

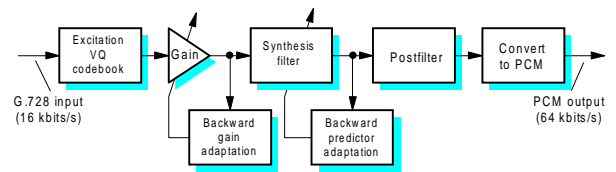
In the encoder the input speech is grouped into blocks of 5 samples. For each block the encoder passes each of 1024 candidate codebook vectors through a gain scaling unit and a synthesis filter. From all these vectors the encoder identifies the one that minimises the error to the input signal vector. The 10-bit index of this best codevector is transmitted to the decoder. The computation of some predictor coefficients is spread over four output vectors.

Consequently the coefficients calculated in the decoder are only identical if encoder and decoder are synchronised. After receiving a 10-bit index, the decoder extracts the codevector from the excitation codebook. The synthesis filter coefficients

and the gain are updated in the same way as in the encoder and the five output samples are calculated.



G.728 encoder

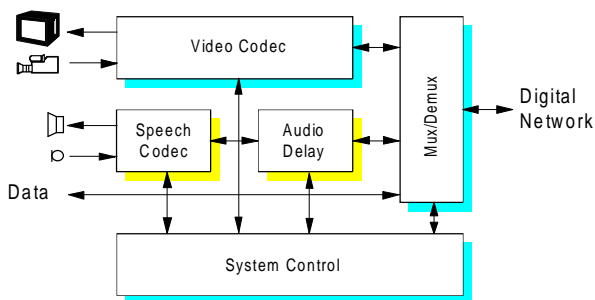


G.728 decoder

## Application areas

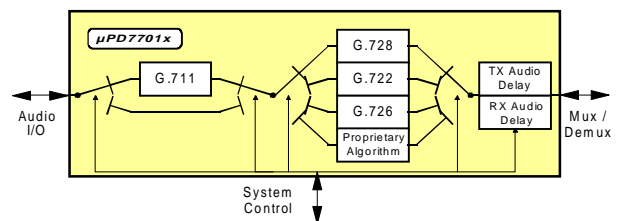
The following list shows some typical application areas for G.728:

**Videophone:** The strictly simplified block diagram of a videophone is shown below. The audio and video codec are important and complex



blocks of such a videophone.

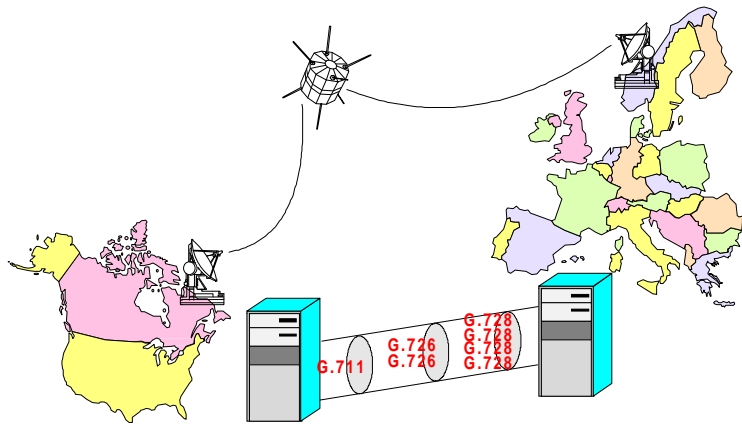
Depending on the transmission rate that is available on the digital network different compression algorithms can be selected in the audio codec. While in the past a simple compression according to G.711 or high-quality wide-band coding methods like G.722 have been used, the usage of G.728 offers similar speech quality according to G.711 with drastically reduced bitrate.



**Mobile and Cordless Phones:** It has already been proposed to use the G.728 codec especially within the GSM system in order to substantially improve the speech quality. For future mobile radio systems the G.728 standard is also under discussion, since the implementations of the proposals for a 8 kbits/s speech codec submitted to ITU-T so far may be even more expensive and more power consuming than G.728.

**Speech Recording/Playback:** G.728 is an excellent candidate for speech recording/playback systems where speech quality is ranked higher than the bitrate. This may be the case in mailboxes and message systems, but especially in emergency call recording systems and alarm message systems.

**DCME-Systems:** G.728 is of high interest for DCME (Digital Circuit Multiplication Equipment) which is used to increase the transmission capacity of transatlantic cable connections or satellite links. Using G.728 instead of the conventional G.726 technology doubles the capacity. If large trunks with a multitude of channels are available, one can exploit the speech pauses, which allows to double the capacity once more.



## Features and Options

The G.728 implementation on NEC's  $\mu$ PD7701x family combines the processing power of this family with the flexibility of a general purpose DSP. Additional functions as well as the optimisation of I/O configuration can be implemented according to the user's requirements. The following list shows the features of NEC's G.728 module:

- Bit-exact implementation as approved by ITU-T Recommendation G.728 fixed point specification
- Testprogram for testing against ITU-T testpattern available
- G.728 object code fully relocatable in the DSP-memory
- No external memory required if using any of the  $\mu$ PD7701x ROM based devices (also the low-cost  $\mu$ PD77015)
- Slow memory version available for  $\mu$ PD77016 RAM based implementation
- Worst case signal delays only 1.135 msec:
 

Tx: buffering of 5 input samples:	0.625 msec
Tx: encoding process	0.307 msec
Rx: decoding process	0.203 msec
- Bit robbing selectable: The bit robbing option according to Rec. G.728, 3.11 in the encoder

replaces certain bits of the compressed data stream with synchronisation bits, but minimises the effect of this bit error on the decoder side.

- Weighting-filter on/off: For transmission of non speech signals (modem ...) the weighting-filter in the encoder can be switched off (see Rec. G.728, 4.6.1)
- Postfilter on/off: For transmission of non speech signals (modem ...) the postfilter in the decoder can be switched off (see Rec. G.728, 4.6.1)
- Delay line implementation for synchronisation of audio- and video signals in video systems possible
- Easy combination of G.728 module with G.722 and G.711 ITU-T Recommendation compliant modules. These modules are also available from NEC.
- I/O interface optimising: The I/O timing as well as the data protocol can be changed according to the user's requirements.

## Processor and System Requirements

The computational load for encoder and decoder is listed in the following table. The worst case processor time load for full duplex G.728 processing is 82,4% for using a 5 sample (= 0.625 ms) sub-frame or 80% if using a 20 sample (= 2.5 ms) sub-frame. The free timeload can be used for power reduction (software controlled power save mode) or for implementation of additional fea-

tures as for example up- and down sampling filters or delay lines.

	Time load (Mips)	Program memory (32 bit)	Data RAM (16 bit)	Data ROM (16 bit)
G.728 Encoder	15.1-16.4	2591	813	1236
G.728 Decoder	10.0-10.8		1160	
G.728 Full Duplex	25.8-27.2		1973	

## μPD7701x Family Overview

		μPD77016	μPD77015	μPD77017	μPD77018	7701x core*
Internal memory	Instruction ROM	-	4k x 32 bit	12k x 32 bit	24k x 32 bit	user defined
	Instruction RAM	1.5k x 32 bit	256 x 32 bit			user defined
	Data ROM	-	2 x 2k x 16 bit	2 x 4k x 16 bit	2 x 12k x 16 bit	user defined
	Data RAM	2 x 2k x 16 bit	2 x 1k x 16 bit	2 x 2k x 16 bit	2 x 3k x 16 bit	user defined
External memory	Instr. memory	48k x 32 bit	-			-
	Data memory	2 x 48k x 16 bit	2 x 16k x 16 bit			user defined
ALU bus		40 bit				
Multiplier		16 x 16 --> 31 bit				
Barrelshifter		40 bit				
Working registers		8 x 40 bit				
Loop/repeat counter		1 repeat counter / 4 nested loop counters				
Host I/F, max. throughput		8 bit, 8.25 Mbytes/s				user defined
Serial I/F, max. throughput		2 SIOs, 8/16 bit, 16.6 Mbits/s				user defined
Interrupts		4 external, 6 internal				10
Min. instruction cycle time		30 ns				< 20 ns
Master clock for 33 Mips		66 MHz	33, 16.5, 8.25, 4.125 MHz (int. PLL)			t.b.f.
Power supply		+5 V	+3 V			
Typical power dissipation		0.7 W	90 mW	120 mW	150 mW	t.b.f.
Power down modes		0.4 W (halt)	3 mW (halt), 3 μW (stop)			t.b.f.
Packages		160 QFP	100 TQFP			user defined

\*under development

NECs new μPD7701x 16-bit fixed-point DSP family offers one of the most advanced architectures on the market. Their members are characterised by a clearly structured Harvard architecture with:

- Two identical memory banks (X, Y) with separate address computation units
- Powerful 16/40-bit arithmetic operation unit
- Program control unit with high performance loop counter
- Memory-mapped peripherals
- JTAG-based on-chip debug hardware and boundary scan facilities

All μPD7701x devices share the same core architecture but have a couple of device specific characteristics which are summarised in the table.

Devices under development will extend this family with a DSP core and more variants in performance/speed.

## How to get G.728 on μPD7701x

Philips was instrumental in the drawing up of the fixed point version of the G.728 Recommendation and has registered related patents. NEC Corporation and Philips have signed a contract which enables NEC to sell the G.728 implementation from Philips to its customers.

NEC has the right to grant its customers a non-exclusive and non-transferable licence to use the G.728 object code on the μPD77016 as well as to develop user specific application programs including the G.728 object code for μPD7701x ROM based devices. The object code can be obtained

for a small licence fee, for μPD7701x ROM based devices a small royalty will be added. The object code comes together with a detailed documentation as well as with some test S/W which allows to verify G.728 compliance.

The easiest way to use G.728 with the μPD7701x family however is to select the brand-new μPD77523 firmware chip, that combines G.728, G.722, G.711 and supplementary functions on a single device. It is perfectly prepared for use in videophones and videoconferencing systems.

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