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GATE TO EUROPE

The people of former Yugoslavia, having relatively good connection with the West and relatively open economy, prepared themselves for so called Europe 92. A lot of discussion and action was undertaken about "entering Europe".

Countries behind the "iron curtain" came to the front of it after the fall of the Berlin wall, in the countries of former Yugoslavia a terrible leaden hail massacred people, massacred friendships, massacred the ideals.

What can we do as members of MIDEM society?

First of all, let us try to keep the positive liaisons which have been connecting us for nearly thirty years. Also those, "who work for the profit of their own loss" will find out very soon the effects of the isolation which they provoke.

Let us form new international liaisons. Liaisons with those experts from the countries on similar development stage who would like to join Europe.

Let us continue with the excellent relationships with specialists of technologically most developed countries.

Let us become a real gate to Europe. A gate opened in both directions.

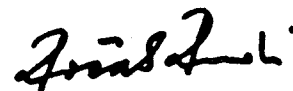
MIDEM must help enter Europe and our countries to become Europe.

The full opening of MIDEM society for admittance to all who except the Rules of the society will help to realise these ideas.

More frequent use of English language in our Journal is the external manifestation and natural need for our new international family. In spite of that, we will still cultivate the creativity and the terminology in Slavic languages.

But, we must not forget, that the gate has to be opened in both directions.

PREDSEDNIK MIDEM
Dr. Rudolf Ročak



ANALYSIS AND DESIGN OF LOW VOLTAGE OVERSAMPLING $\Delta\Sigma$ DATA CONVERTERS

Drago Strle, Janez Trontelj

KEY WORDS: oversampling technique, A/D converter, D/A converter, modulation, demodulation, PCM, CODEC, S-C filters, circuits design, circuits analysis

ABSTRACT: An attractive implementation of high resolution A/D and D/A converters in VLSI technology is oversampling technique. In these paper brief overview of oversampling technique is given with the analysis, design and measured results for 13 bits low voltage oversampled A/D and D/A converters. A detailed design procedure is presented for the analog portions of each converter. Standard second order modulator topology was chosen because of its simplicity, robustness and insensitivity to the accuracy of the elements. It is shown that theoretical limit of 15 bits for oversampling ratio of 128 of such modulators can not be reached even with ideal modules which is proved by the simulation for the second order case.

Low voltage and low consumption operation is possible by appropriate design of basic building blocks and by taking into account important design parameters. Since the supply voltage can be as low as 2.4V the modulator uses fully differential structure to achieve required resolution. Low noise fully differential opamp with resistive common mode feedback circuit is used as a basic building block. Similar opamp is used in 1bit D/A converter circuit as well as in a corresponding S-C filter.

ANALIZA IN NAČRTOVANJE NIZKO NAPETOSTNIH KONVERTERJEV $\Delta\Sigma$ S PREVZORČENJEM

KLJUČNE BESEDE: tehnika prevzorčenja, konverterji A/D, konverterji D/A, modulatorji, demodulatorji, PMC, CODEC, filtri S-C, načrtovanje vezij, analiza vezij

POVZETEK: Ena od možnosti za realizacijo konverterjev A/D in D/A z visoko ločljivostjo je uporaba tehnike prevzorčenja. V članku je podan pregled tehnike prevzorčenja ter analiza, načrtovanje in merilni rezultati 13 bitnega nizkonapetostnega konverterja A/D in D/A. Podan je postopek načrtovanja za občutljivejše analogne dele konverterjev. Zaradi enostavnosti, robustnosti in neobčutljivosti na spremembe elementov in parametrov je za modulator uporabljena topologija drugega reda. Ločljivosti 15 bitov za razmerje med vzorčevalno in Nyquistovo frekvenco 128, ki jih podaja poenostavljena teoretična analiza ni mogoče doseči, kar dokazujejo rezultati simulacij idealiziranega modulatorja drugega reda. Izbira primernih diferencialnih nizkonapetostnih osnovnih gradnikov omogoča gradnjo konverterjev, ki delujejo z nizko napajalno napetostjo in imajo nizko porabo. Primerna je diferencialna struktura z uporovnim sofaznim povratnim vezjem. Podobni operacijski ojačevalniki so primerni osnovni gradniki tako za modulator, kot tudi za eno bitni D/A konverter in pripadajoči filter S-C.

1. Introduction

The introduction of fine line MOS processes provides a cost effective solution to built a flexible VLSI systems. As channel length of MOS processes continue to decrease, digital signal processing is becoming more attractive compared to analog signal processing because of high speed, better programmability, higher reliability, etc., but some analog signal processing is still needed. Among the analog blocks which must be integrated are antialiasing and/or smoothing filters, noise shaping filters, amplifiers and low cost, high resolution A/D and D/A converters. The applications of such analog modules are in the areas of instrumentation, telecommunications, audio, and video. Important requirements in portable systems are low consumption and low voltage operation ($V_{sup} < 3V$) for battery operated systems.

Continuous time or sampled data filtering in analog domain followed by A/D conversion with the Nyquist rate converter was traditional way of signal processing in the

integrated systems. Flash converters are appropriate for video applications, successive approximation converters for audio and telecom voice processing and integrating converters for low speed data acquisition. Analog filtering either continuous time or sampled data needs precise analog components to realize accurate poles and zeros and thus precise transfer function, while A/D and D/A converters needs precise analog components because each level must be accurate to reach required differential and integral linearity which is in the 13-16 bits range. Usually trimming is necessary. This is expensive and time consuming procedure. The problems which remains in these solution are poor repeatability, reliability, programmability as well as high production cost. New solution provides reduction of the number of precise analog components and their precision requirements to the necessary minimum and handle most of the signal processing with the digital DSP.

The main task of an A/D converter is to convert continuous time signal $x(t)$ into a sequence of digital codes $y(kT)$

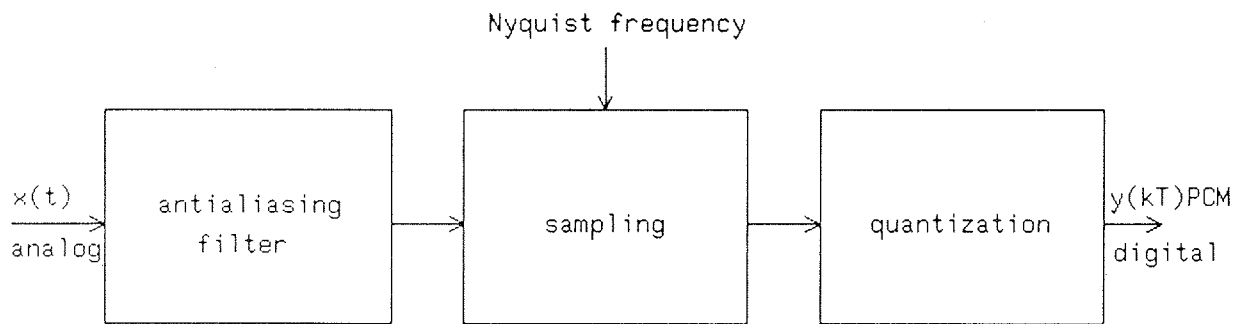


Figure 1: A/D converter block diagram

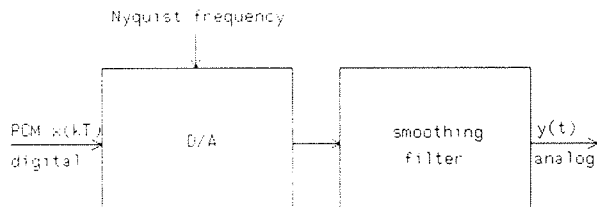


Figure 2: D/A converter block diagram

at the Nyquist rate f_n . In front antialiasing filter is necessary to limit the bandwidth of the analog signal to half of the sampling rate. Similar but reversed situation happens on the other side where high frequency part of the spectrum above $f_n/2$ needs to be filtered out to get pure analog signal. The principle block diagrams of both conversions are shown on figure 1 and 2.

Nyquist rate converters perform A/D conversion of analog signal at its Nyquist rate which means that the spectrum of incoming analog signal must be negligible above $f_n/2$. Oversampled converters on the other hand sample the incoming analog signal at a rate which is much higher than the Nyquist frequency ($f_s \gg f_n$) and in this way they make use of high frequency offered by MOS processes. This is possible if the bandwidth of the signal is small compared to the speed of available VLSI circuits. Because the sampling frequency is much higher than Nyquist rate the requirements for antialiasing filter are very much simplified and in this way it is possible to integrate it on a VLSI chip. Another difference between Nyquist rate converters and oversampling converters is the quantization. For Nyquist rate A/D converters quantization is performed for every sampling period with full precision of the converter. For example for the 16 bit resolution the spacing of the levels is in the microvolt range which requires much higher matching accuracy of integrated elements than it is really available (7). The solutions of these problems are either trimming or self calibration. Both solutions are expensive in terms of silicon area and time needed for test. For oversampled converters many rough amplitude quantizations are performed during one sampling period which are then averaged with decimation digital filters which purpose is to remove the out of band quantization noise and spurious out of band signals and to resample the signal at a Nyquist rate.

During last 5 years many publications appeared in the technical literature about different solutions for oversampling A/D and D/A converters, a few of them are listed at the end of this article (2) (5) (6) (10) (4) (3). Of the available solutions a second order $\Delta\Sigma$ modulator and 1 bit D/A converter was chosen because of its robustness and reliability.

Oversampling second order A/D and D/A converters were designed as well as corresponding analog filters. Both modules are running with the oversampling ratio of 128 and will be used in telecommunications CODEC. The main issues in designing these two blocks were low operating supply voltage which is available from the battery ($V_{sup} < 3V$), low consumption and resolution in the range of 13-14 bits. Since $\Delta\Sigma$ modulators are nonlinear modules accurate analytical technique does not exist to predict the behavior, so our results are based on approximate analytical methods and extensive simulations and measurements.

In these paper short overview of oversampling methods used in A/D and D/A converters is given with the emphasize to the analog part of converters followed by analysis and design of low voltage second order $\Delta\Sigma$ modulator as well as analysis and design of 1 bit D/A converter and corresponding analog filters with the same low voltage and low consumption requirements. Simulation as well as measured results will be presented together with some practical considerations to achieve good crosstalk separation from digital to analog portion of the chip, low noise operation of analog blocks and thus the required resolution even with low operating voltage.

2. Overview of Oversampling Methods for A/D and D/A Conversion

2.1. Description of oversampling A/D converter

Figure 3 shows block diagram of a typical oversampled A/D converter. The first block is antialiasing filter which is necessary to attenuate out of band spectral components. It can be a simple first order passive filter which is integrated on the chip because the oversampling frequency is many times higher than the bandwidth of the signal $x(t)$. Modulator block performs many rough quan-

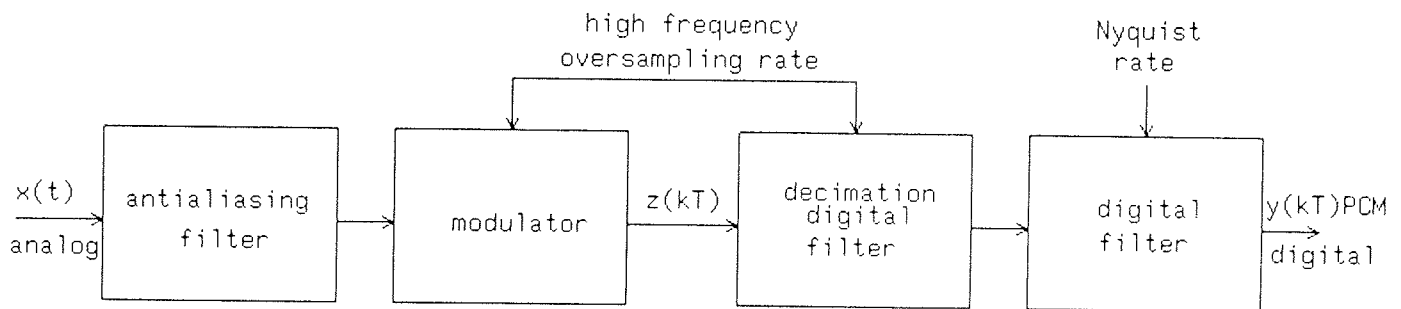


Figure 3: Oversampled A/D converter block diagram

tizations in one Nyquist period and the output signal is so called bits-stream $y(kT)$ which is processed by digital decimation filter. Its task is to attenuate out of band quantization noise and resample the signal with the Nyquist rate f_n . The most critical component in the chain is a modulator block which must be carefully optimized to reach required performances.

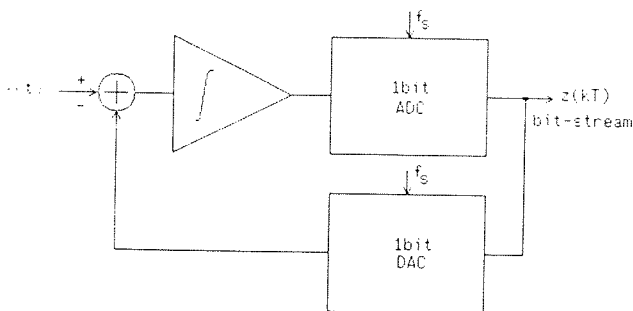


Figure 4: First order $\Delta\Sigma$ modulator - Noise-Shaping Coder

2.2. Modulator

Let us take a simple first order modulator shown on figure 4 to describe the principles of operation. The summing node adds input signal $x(t)$ and feedback signal which is coming from the D/A converter. The difference is integrated and the result is D/A converted (usually 1 bit). Output signal is a bit-stream whose average represent the input signal. The averaging process is performed by a decimation digital filter. In general the amplitude resolution of the converter increase when oversampling ratio is increased. Oversampling ratio D is defined as the ratio of oversampling frequency f_s to the Nyquist frequency f_n , $D = \frac{f_s}{f_n}$. The quantization noise in the baseband is reduced by the use of a feedback in the modulator.

Prediction modulators (figure 5) and noise shaping modulators (figure 4) are basically in use to reduce the quantization noise in baseband (1). The predictive or differential coder works in such a way that the value of the present sample is used to calculate the next value while the difference between actual value and the estimation is quantized by 1 bit converter. These quantized value is stored in $H(z)$ which is a simple integrator for

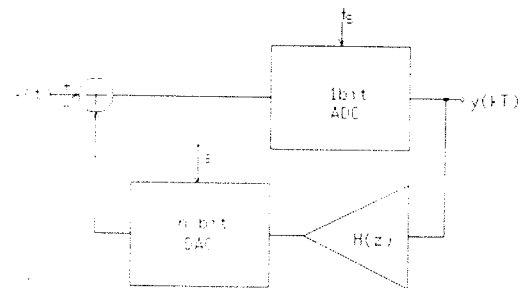


Figure 5: Predictive Coder

the first order modulator. In this way it really reduces the level of the quantization noise in the baseband.

The noise shaping coder shapes the power spectrum density of the quantization error and moves the noise energy towards the higher frequency. If the sampling frequency of the modulator is much higher than the Nyquist rate then this high frequency quantization noise can be attenuated by the use of digital filtering.

It seems that the number of analog components needed is smaller for predictive coders; in reality it requires multibit precision DAC (1) which is not easy to built, while nonidealities introduced by the integrators limit the linearity of such modulators. Besides these two problems, the decimation filter for the predictive coder requires multibit multiplier, while for simple noise shaping coder multiplier in decimation filter is not needed since the output of the modulator contains only 1 bit. All these reasons oblige the use of noise shaping modulator for A/D converter.

Higher order modulators can be built by the use of multiple integrators and appropriate feedbacks. Figure 6 shows comparison of quantization noise spectrum densities for the first and the second order modulator. It is evident that in the passband bigger S/N ratio can be achieved with a second order modulator for the same oversampling ratio. While higher than second order modulators would provide even further improvement in the S/N ratio in the passband these modulators are more sensitive to component inaccuracy, stability restrictions etc.

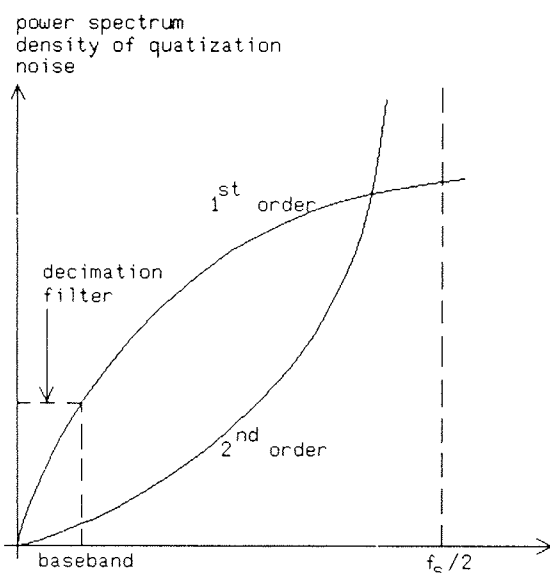


Figure 6: Power spectrum density for first and second order modulators

Theoretical simplified analysis of $\Delta\Sigma$ modulators can be performed with the assumption that quantizer can be modeled as a linear summing or gain element for which power spectrum density of the quantization noise is calculated. Simplified analysis of a second order modulator (figure 7) gives $Y(z)$ as a function of input samples and quantization noise: (equation 1)

$$Y(z) = \frac{X(z)k_1 k_2 + \varepsilon(z)(z-1)^2}{z^2 + z(k_2-1) + k_1 k_2 - k_2 + 1} \quad (1)$$

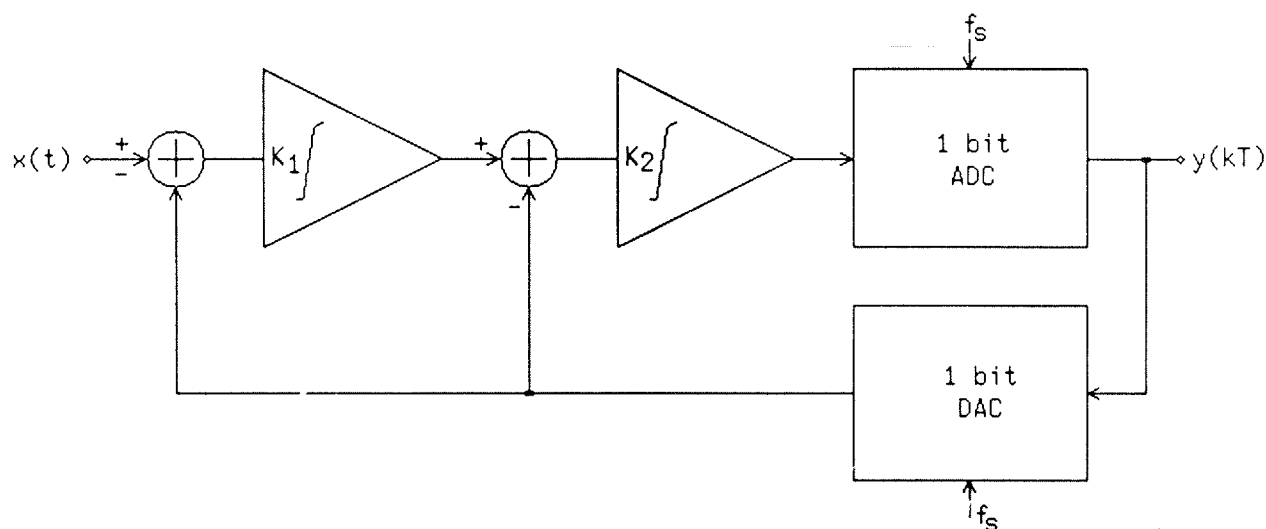


Figure 7: Second order modulator

The dynamic range of A/D converter is defined as the ratio of the output power for full scale sinusoidal input to the output power for a small input signal whose signal to noise ratio is 0 dB (1). If the quantizer is modeled as a linear gain element with the additive white noise source, then the dynamic range DR can be calculated by equation 2 (1).

$$DR = \frac{3}{2} \frac{2L+1}{\pi^{2L}} D^{2L+1} \quad (2)$$

where L is the order of $\Delta\Sigma$ modulator and D is the oversampling ratio f_s/f_n . The resolution or the number of bits can be calculated with:

$$N_{bits} = \frac{\frac{S}{N} [dB] - 1.76}{6.02} \quad (3)$$

Figure 8 shows the relation between oversampling ratio and resolution or the number of bits taking order of the modulator as a parameter for idealized first and second order modulator with the quantizer modeled as a linear gain element and quantization noise modeled as white noise source. This equation is valid for maximum input voltage. In reality these assumptions are too optimistic which will be shown in the next subsection. Multibit quantizer and/or D/A converters as well as several other higher order structures are possible.

2.3. Description of oversampling D/A converters

Figure 9 shows block diagram of a typical oversampled D/A converter. The sequence of N -bit digital words is processed by a digital interpolation filter with the Nyquist rate f_n . The interpolation filter performs filtering of image components, interpolation, and upsampling of the digital signal with the oversampling frequency. In this way the word length is reduced from N bits to M bits (usually $M = 1$), while sampling frequency is increased. The interpolation filter removes the sidebands which are the result of sampling with low frequency and interpolates

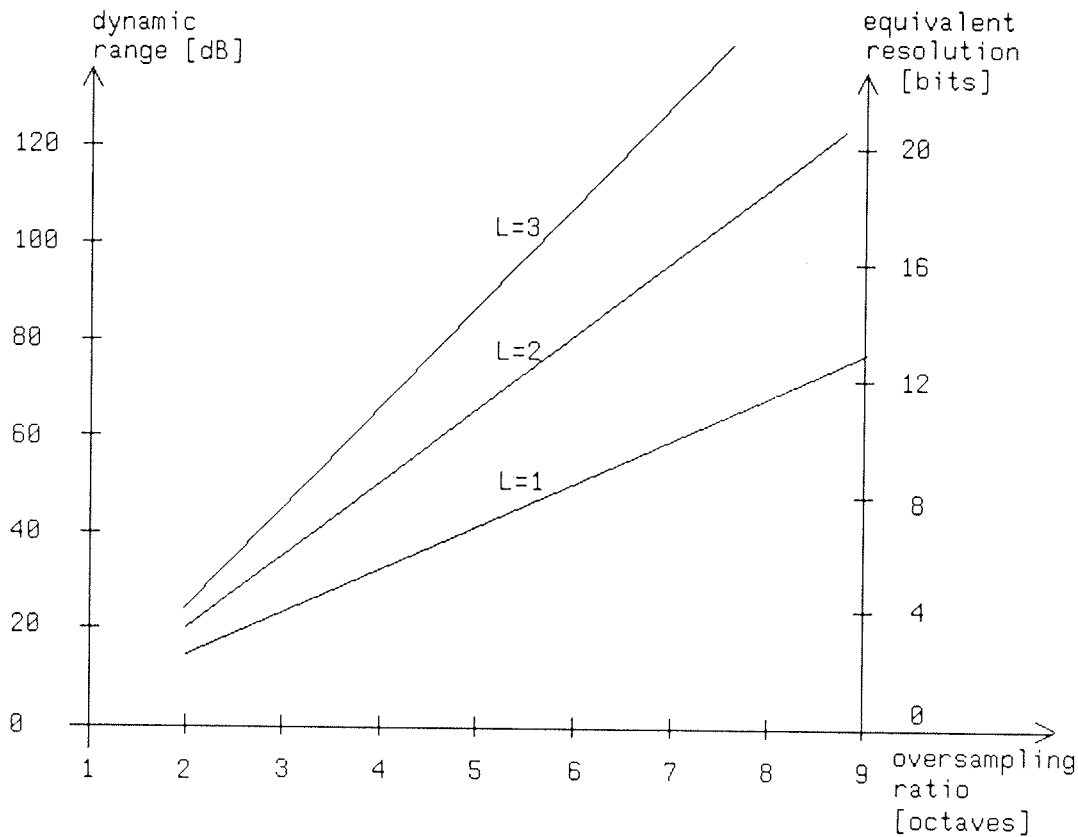


Figure 8: Dynamic range and number of bits

values between samples. The function of digital modulator is to reduce M bit oversampled signal to usually 1 bit signal and to shape the quantization noise to higher frequencies outside the baseband. The actual D/A conversion is performed by 1 bit D/A converter using charge packets generated by switched capacitor network or current sources. Last block in the chain is analog continuous time or sampled data filter whose task is to reduce the quantization noise. Although the performances are theoretically defined by the oversampling ratio and number of bits, the most critical component for the implementation are 1bit D/A converter and analog filter.

The design and implementation of these two blocks will be explained below.

Figure 10 shows simplified block diagram of digital demodulator which performs noise shaping and reduction of word length, while figure 11 interprets the principles of interpolation and upsampling of incoming stream of digital words.

The amount of filtering necessary to attenuate shaped out-of-band quantization noise is dependent on the application, but general rule of thumb is to have analog or

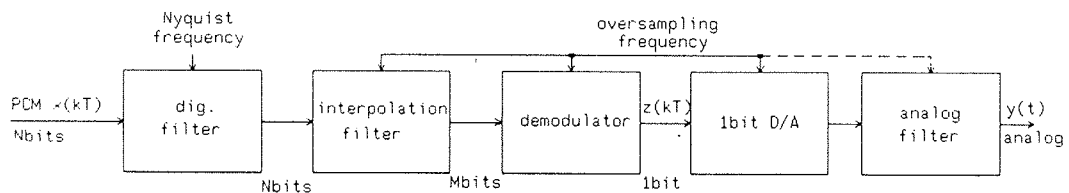


Figure 9: Oversampled D/A converter block diagram

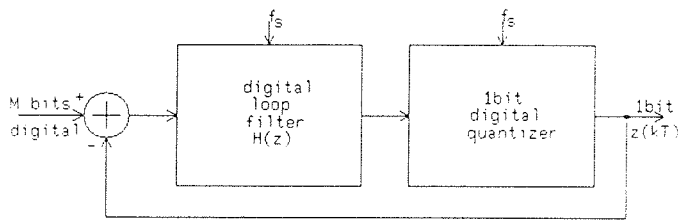


Figure 10: Block diagram of digital demodulator

sampled data filter which must be 1 order higher than the corresponding demodulator; for a second order demodulator 3rd order filter is recommended. For some applications lower order analog or sampled data filtering is sufficient. S-C filter is running with high oversampling frequency, followed by simple continuous time smoothing filter which attenuates images around f_s .

3. Analysis and Design of Low voltage Second Order $\Delta\Sigma$ A/D Converter

For the application of low voltage oversampling $\Delta\Sigma$ A/D converter second order modulator was chosen because the required resolution is 13 bits which can be achieved by the oversampling ratio of 128 and second order modulator topology. Figure 12 shows implementation of the second order modulator used in our converter. Because of the low voltage operation, a fully differential structure is needed to increase the $\frac{S}{N}$ ratio and to decrease coupling of digital noise from DSP part of the chip. The simulation of idealized modulator shows (figure 13) that maximum resolution which is possible to achieve for this design is close to 13 bits and not close to 15 bits as predicted by the theory. The reasons for a difference are the simplification of the quantizer and the white noise model of the quantization noise which is just an approximation.

Scaling of the modulator is possible because of the characteristics defined by capacitor ratios. Amplitude distribution of the signals in both integrators must be

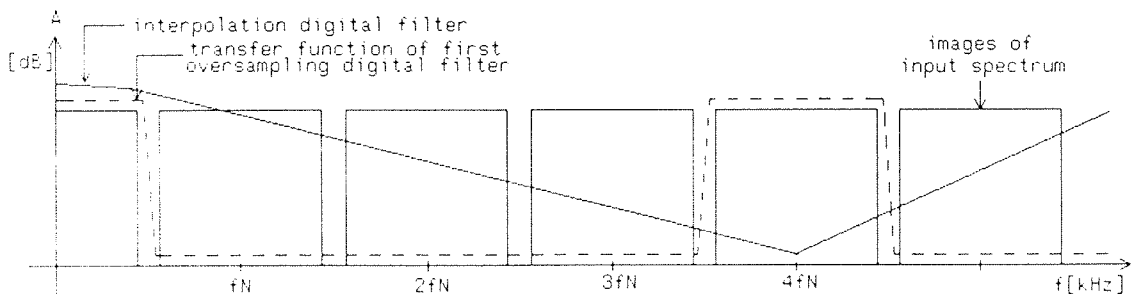


Figure 11: Function of interpolation filter

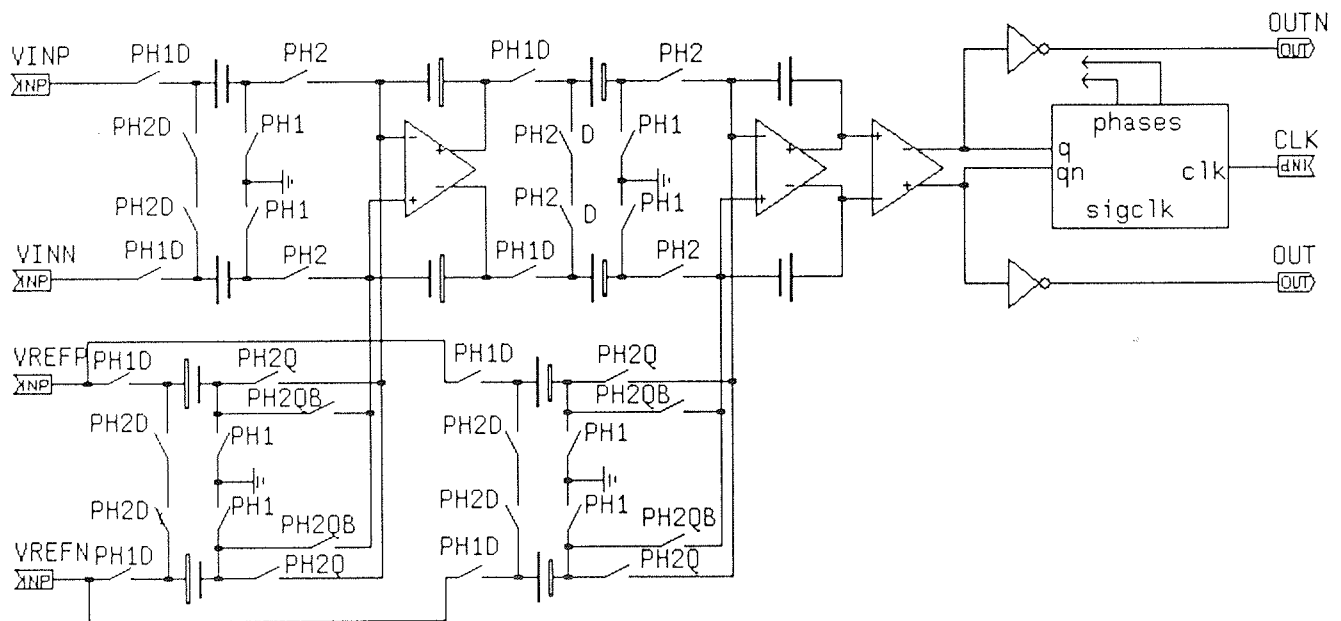


Figure 12: Simplified schematics of 2nd order modulator

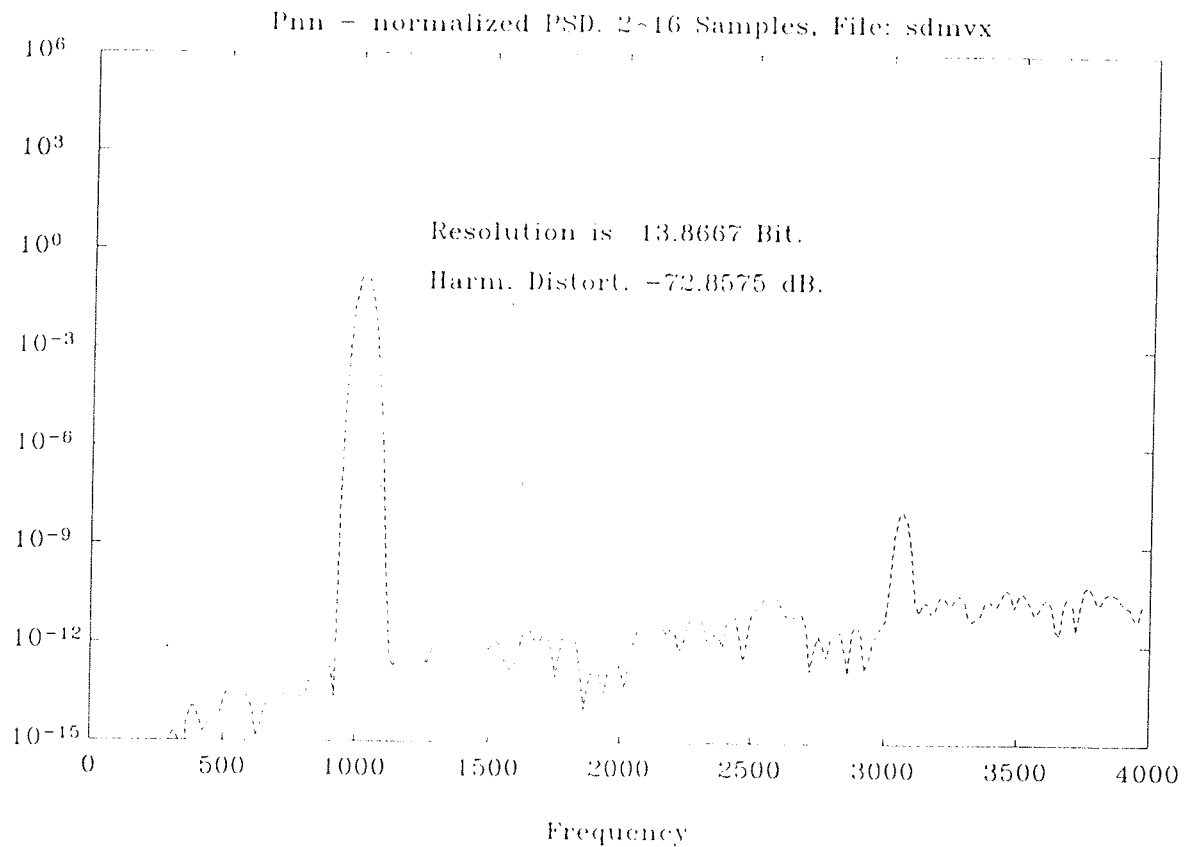


Figure 13: Spectrum of idealized modulator

such that the dynamic range of the converter can be maximum. The noise requirement is especially important for the first opamp because it's noise power enters the loop with no attenuation.

The operational amplifier used in these application is shown on figure 14 together with some of its important

characteristics: linearity, gain, offset, noise, settling time, slew rate and gain bandwidth. It was proved by the simulation that influence of nonidealities of the opamp as defined on figure 14 are negligible.

A very careful design is needed for the switches and the clock form generator (figure 15). The charge injection

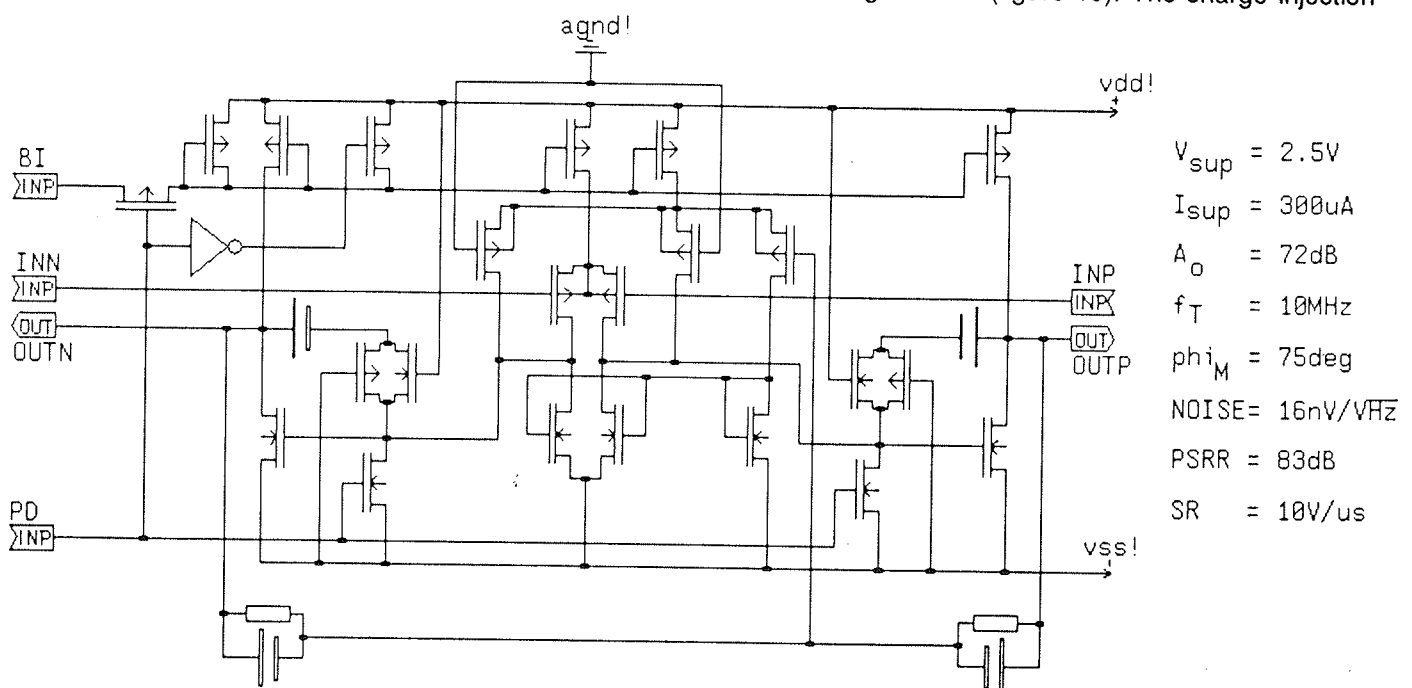


Figure 14: Opamp used in modulator and its parameters

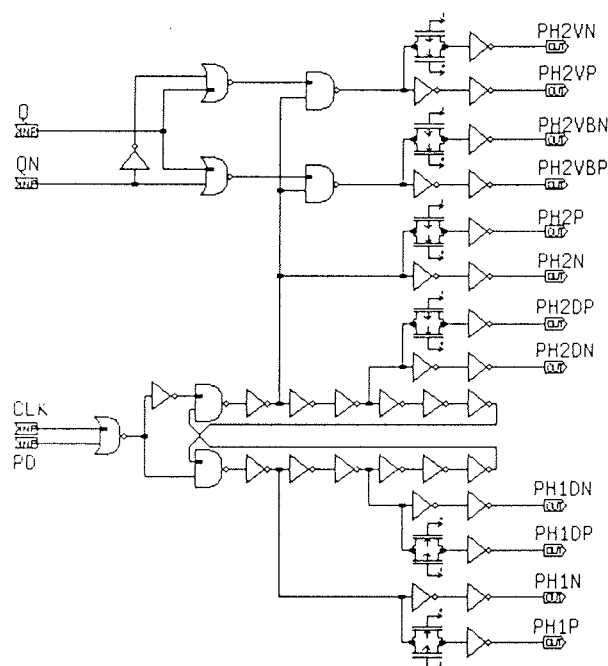


Figure 15: Clock form generator

adds common mode signal which is partially cancelled by the differential structure and the common mode feedback circuit. Signal dependent charge injection (8) is reduced by driving some of the switches with the delayed clocks marked with letter D in the figure 15.

The layout of analog and digital modules needs special technique to prevent coupling of digital noise into analog modules via common substrate and parasitic capacitances. It is reduced by separated connection of substrates and sources in analog and digital modules, and by the extensive use of shielding in sensitive analog nodes. Figure 20 shows layout of the second order modulator.

Figure 16 shows the typical measured power spectrum density as a function of frequency for a second order modulator which is used in the calculation of the number of effective bits of the A/D converter.

4. Analysis and Design of Low Voltage Oversampled D/A Converter

For the D/A conversion a digital modulator is used (figure 10) to perform noise shaping and reduction to 1bit bit-stream. This solution is used because of low supply voltage and inherent linearity of 1 bit D/A converters which is the most critical block of the whole D/A. It is built by a switched capacitor circuit as an input stage of a third order Chebishev S-C ladder filter, which was designed

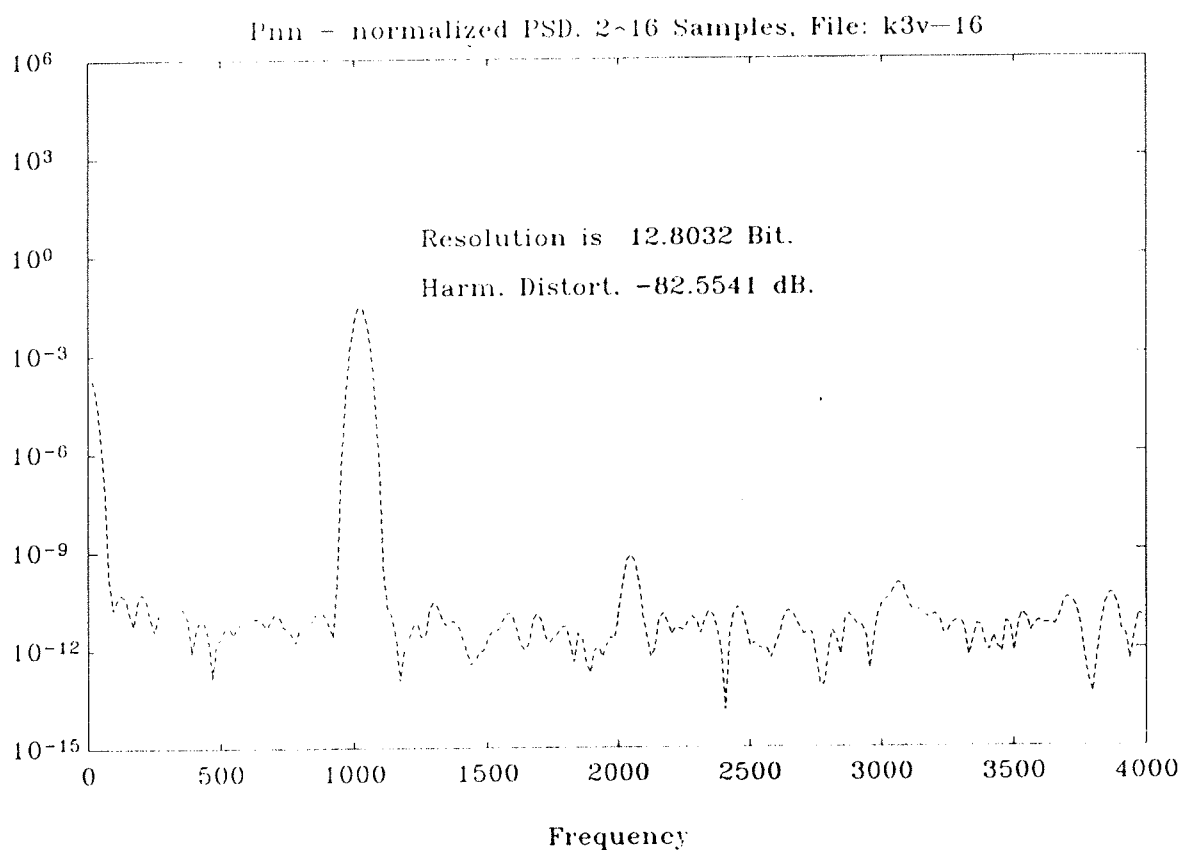


Figure 16: Power spectrum density of measured modulator

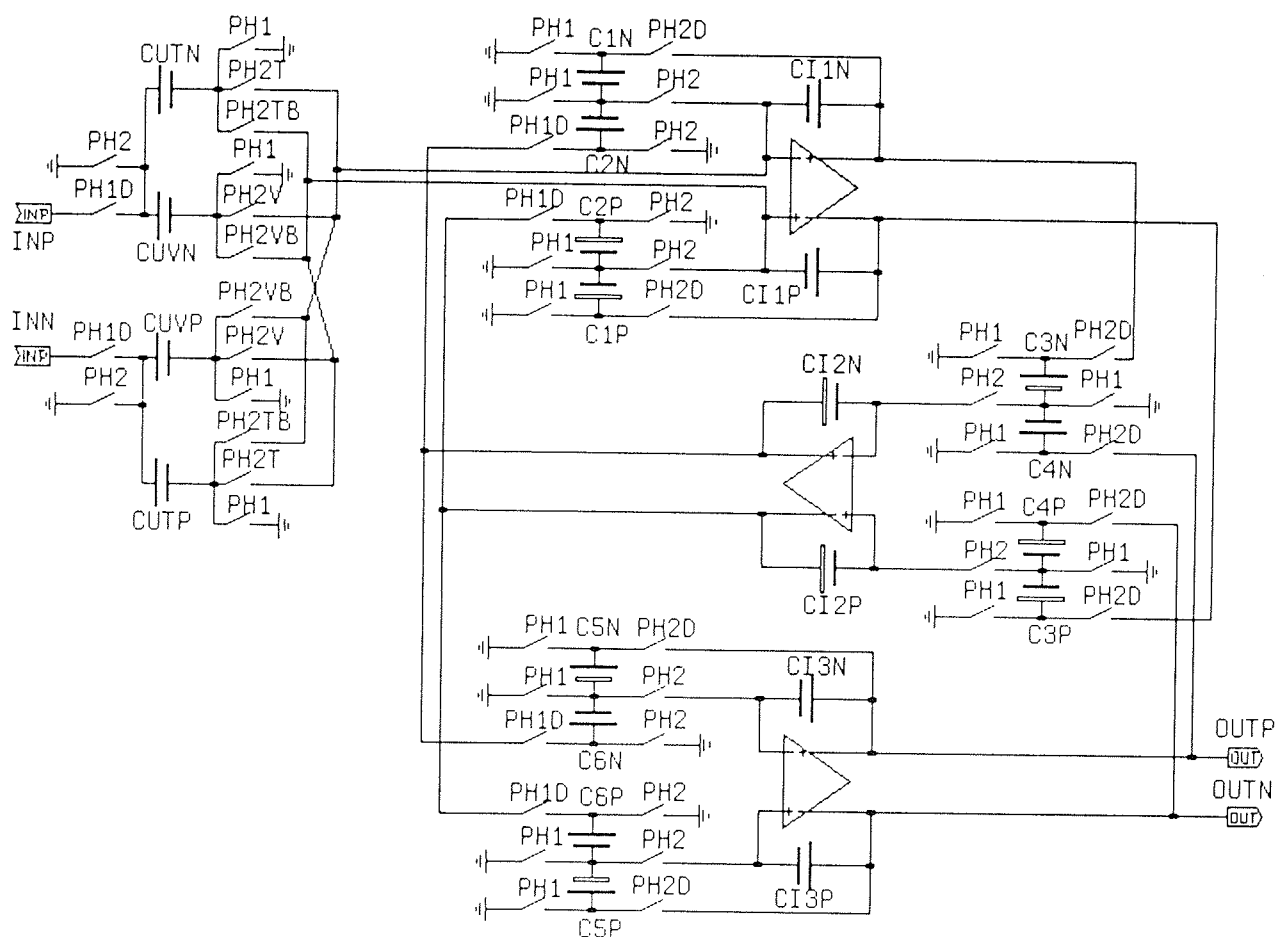


Figure 17: 1 bit D/A converter and filter circuit

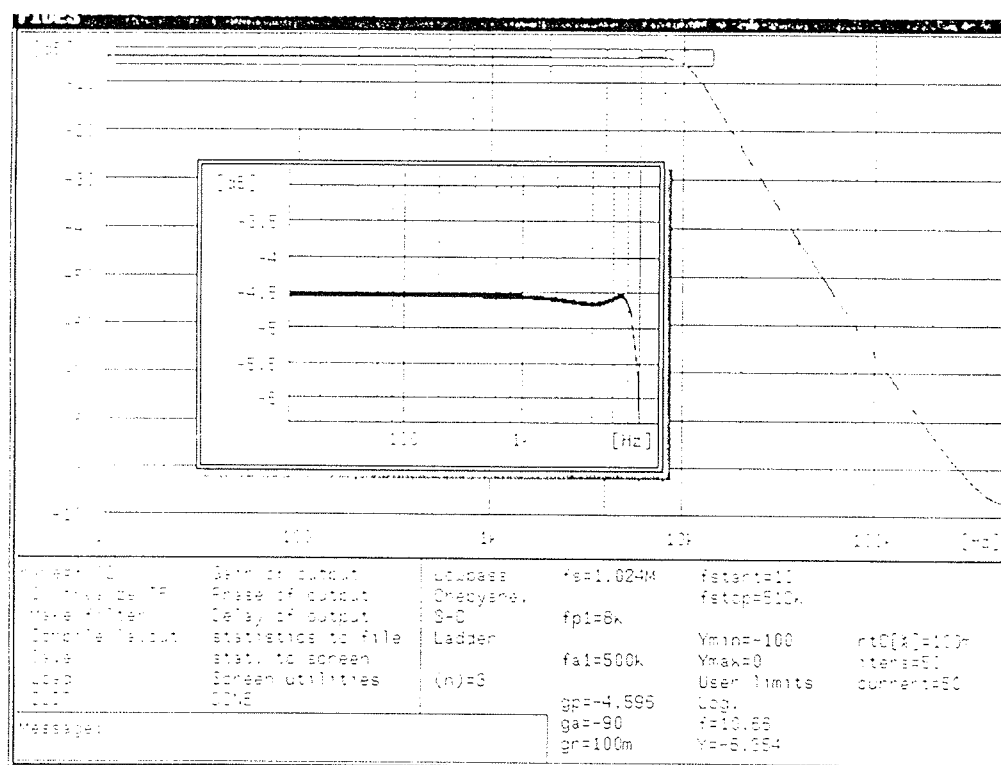


Figure 18: Frequency characteristics of Ladder filter

using FIDES (9). Figure 17 shows a schematic diagram of 1 bit D/A converter and corresponding S-C filter. Figure 18 shows frequency domain characteristics and the definition of filter requirements. Fully differential structure is used to reduce the common mode parasitics signal injection and to increase the dynamic range. A similar opamp as in modulator is used for S-C filter with the only difference in higher gain. The opamp is optimized for noise, which is less than $15 \frac{nV}{\sqrt{Hz}}$ at 100 Hz. The flicker noise is reduced by increasing the area of differential stage.

$\frac{KT}{C}$ noise of S-C filter is further reduced by the use of high capacitance of the unit capacitor of about 1pF. 1 bit D/A converter is built as a replacement for the input switched capacitor driven by the appropriate clocks. The circuit is actually composed of two 1-bit D/A converters whose bit-streams are added at the input of the S-C filter; one with the voice information and the other with the signaling information. Digital portion of the D/A converter uses a variation of the clock form generator shown on figure 15. The same circuit and layout design technique were used for D/A converter as for the modulator block.

Input bit-stream generated by digital demodulator is connected to the clock form generator which drives the 1 bit D/A converter and resulting signal is then filtered by the 3rd order Chebishev filter.

The signal to noise ratio in voice band is: $\frac{S}{N} = 85 \text{ dB}$ and is calculated from the figure 19 which represents the power spectrum density of the signal at the output of the filter.

Figure 20 shows a layout of analog portion of a second order modulator, 1bit D/A converter circuit and corresponding S-C filter.

Conclusions

In this article overview of oversampling technique used in A/D and D/A converters is given with necessary design steps for the analog portions of both converters to achieve required resolution of 13 bits and low voltage operation. Second order modulator was introduced along with some theoretical and simulation results. It was proved, that real resolution of second order modulator is slightly less than 13 bits and not 15 bits as predicted by the theory and the reasons are shortly explained. The required resolution is possible for oversampling ratio of 128 if basic modules are designed appropriately. The results of measurements of test-chip modulator are in good agreement with the predictions.

1 bit D/A S-C converter and 3rd order S-C filter followed by first order smoothing filter was used for the analog portion of the D/A converter chip. The simulation shows

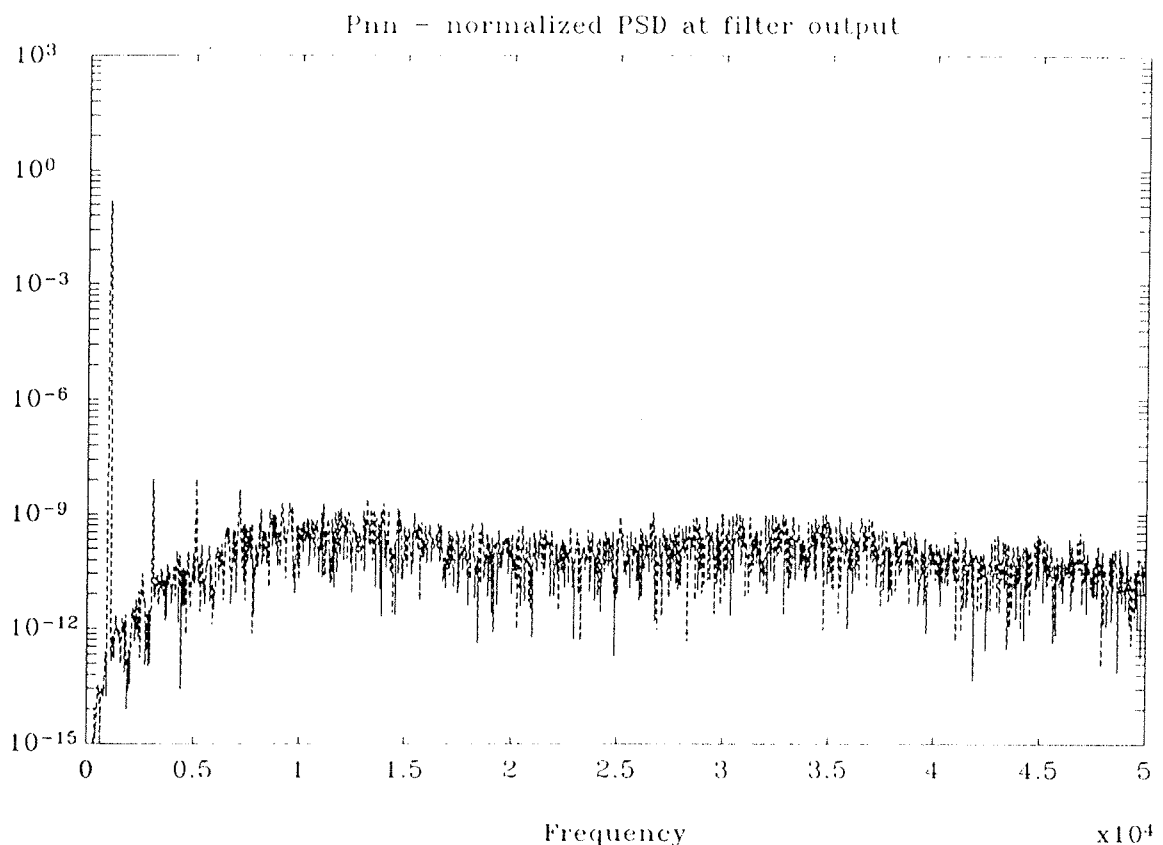


Figure 19: Power spectrum density at the output of the filter

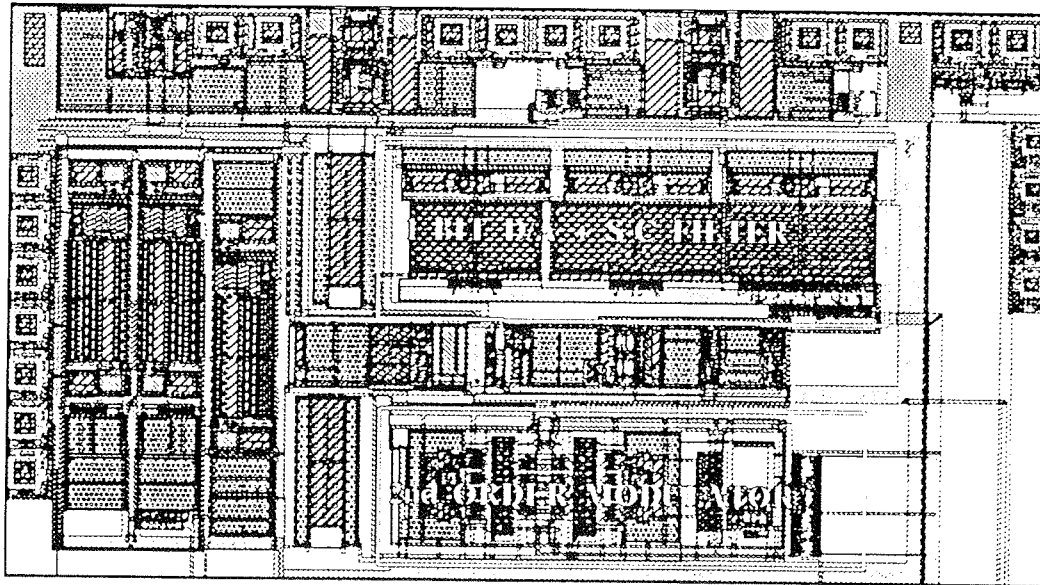


Figure 20: Layout of analog part of A/D and D/A converter

a good differential linearity. Measured results were not available at the time of publication of this article.

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UPORABA DIFUZIJSKEGA PROCESA ZA IZDELAVO KOLEKTORSKEGA VLOŽKA V BiCMOS VEZJIH

Boštjan Gspan

KLJUČNE BESEDE: CMOS, integrirana vezja, BiCMOS, difuzija, difuzijski postopki, kolektorski vložek, simulacija procesov, simulacijski programi, SUPREM-4

POVZETEK: V članku je opisan način izdelave kolektorskega vložka z uporabo difuzije. Namen tega procesa je dopolnitev obstoječega proizvodnega procesa integriranih vezij CMOS (osnovni gradnik vezja je par n in p kanalnega tranzistorja) s procesom BiCMOS (vezjem CMOS dodanimi bipolarnimi tranzistorji). Za kolektorski vložek se zahteva kar najnižja upornost (1.5 do $2.5 \Omega \text{ cm}$) silicija in kar največja globina (okrog $5 \mu\text{m}$) spoja med n in p tipom polprevodnika. Meritve kažejo, da so globine spojev med 5.2 in $5.4 \mu\text{m}$. Koncentracija primesi na površini rezine je bila od 4×10^{19} do $1 \times 10^{20} \text{ cm}^{-3}$, kar zagotavlja ustrezno upornost plasti.

Simulacija difuzijskega postopka je bila narejena z dvodimenzionalnim simulatorjem procesa proizvodnje integriranih vezij Suprem-4.

USE OF DIFFUSION FOR MAKING COLLECTOR PLUGS IN BiCMOS INTEGRATED CIRCUITS

KEY WORDS: CMOS, integrated circuits, BiCMOS, diffusion, diffusion processes, collector plug, process simulation, simulation program, SUPREM-4

ABSTRACT: A way of making collector plugs used in BiCMOS integrated circuits with use of existing production steps (diffusion) for CMOS integrated circuits is described. Doped silicon for collector plug should have resistivity in range from $1.5 \Omega \text{ cm}$ to $2.5 \Omega \text{ cm}$. Junction of n and p type silicon should be at least $5 \mu\text{m}$ below the surface. Measured depths of n-p junction are in range from $5.2 \mu\text{m}$ to $5.4 \mu\text{m}$. Measured surface dopant concentrations are in range from 4×10^{19} to $1 \times 10^{20} \text{ cm}^{-3}$. Measured values assure targeted resistivity of the layer.

The simulation of production process was made by two-dimensional simulator of production process Suprem-4.

1. UVOD

Ena od možnih poti za doseg hitrejšega delovanja vezij je dodajanje bipolarnih tranzistorjev osnovni strukturi CMOS, kar imenujemo tehnologija BiCMOS. Tehnologija BiCMOS omogoča izdelavo integriranih vezij, ki imajo podobne lastnosti (velika hitrost, velik fan-out) kot družina bipolarnih ECL (emitter coupled logic) logičnih integriranih vezij, ob veliki gostoti realiziranih logičnih funkcij in majhni statični porabi energije, kar omogoča CMOS del vezij. V primerjavi s tehnologijo CMOS je tehnologija BiCMOS mnogo bolj kompleksna za simulacijo delovanja. Tudi v tehnologiji izdelave integriranih vezij se pojavijo problemi, ko moramo izdelati bipolarni tranzistorje s procesnimi koraki tehnologije CMOS. Možne so tudi modifikacije proizvodnih procesov bipolarnih tranzistorjev, kar pa je redkost, ker je izdelava vezij CMOS mnogo bolj razširjena.

Izhodišče v nekem procesu BiCMOS je silicijeva rezina p tipa. Na p tipu rezine je najbolj enostavno narediti vertikalni bipolarni tranzistor npn tipa. Ker ne želimo izgub signala mora imeti kolektorski vložek majhno upornost.

Modifikacija procesa je obsežno delo in optimiranje koraka difuzije je le eno od potrebnih del. V članku opismemo poskuse izdelave kolektorskega vložka za npn bipolarni tranzistor z minimalnimi modifikacijami postopkov v standardnem CMOS procesu. Ker smo uporabili obstoječ proces, smo za izdelavo kolektorskega vložka uporabljali difuzijo, ki sicer ni najbolj primeren postopek za izdelavo tega elementa. Med vsemi možnimi procesi je bil izbran ta, ker smo pričakovali, da bodo imeli bipolarni tranzistorji izdelani v modificiranem procesu, še zadovoljive električne lastnosti. Rezultati optimizacije difuzije so v danem trenutku odločali o izbiri nekega procesa. Rezultate difuzije smo izmerili tudi z metodo SRA (metoda porazdeljene upornosti), po kateri smo zanesljivo izmerili profil primesi.

Poleg praktične izdelave difuzije za kolektorski vložek smo naredili tudi simulacijo izdelave z računalniškim programom Suprem-4. Na ta način smo želeli preveriti vrednost računalniške simulacije pri načrtovanju procesnih korakov tehnologije BiCMOS, saj so simulacije mnogo cenejše in tudi hitrejše kot izdelava rezin.

2. OPIS PROCESA MOS, ZA KATEREGA RAZVIJAMO DIFUZIJSKI POSTOPEK

Za modifikacijo smo izbrali procesne korake iz postopka za izdelavo vezij CMOS, ki daje v redni proizvodnji zadovoljiv odstotek uporabnih vezij in ga uvajamo v laboratoriju za mikroelektroniko na Fakulteti za elektrotehniko in računalništvo. Proces karakteriziramo tudi z osnovno najmanjšo dimenzijo, ki jo načrtovalci vezij lahko uporabljajo pri načrtovanju vezij in je pri izbranem postopku $1.2\ \mu\text{m}$.

Obstoječi proces upošteva spoznanja iz konca 80-ih let. Vhodna surovina je rezina silicija z epitaksijsko plastjo p-tipa silicija. Uporabljeni so distančniki. Za vnašanje primesi v silicij uporabljamo pretežno ionsko implantacijo, ki vnaša natančno določeno količino primesi na točno določena področja na rezini. Termična obdelava kristalnega silicija po implantaciji je nujna, da se sprostijo mehanske napetosti in poškodbe, ki nastanejo zaradi implantacije. Po implantaciji, ko silicij oksidiramo ali drugače termično obdelamo, pride na vrsto difuzija primesi. V želji, da bi pri nezmanjšani kritični dimenziji z vezjem uresničili več logičnih funkcij, uporabljamo dve plasti aluminija. Krmilne elektrode na vratih tranzistorjev so narejene iz dopiranega polikristalnega silicija. Pogosta je uporaba plazemskih postopkov za jedkanje in depozicijo plasti, saj so to nizkotemperaturni postopki, ki ne povzročajo velikih neželenih difuzij primesi.

Dober način za približno in hitro oceno kompleksnosti proizvodnega procesa integriranih vezij je število potrebnih mask. Za omenjeni proces je potrebnih 11 mask. Število mask v procesu je tudi direktno povezano z njegovim izkoristkom, saj večje število mask zmanjšuje verjetnost za visoke odstotke dobrih vezij. Ker obstajajo tudi CMOS procesi z več maskami, je izbrani proces tudi po tem kriteriju primeren za nadaljnje modifikacije.

3. OPIS DIFUZIJSKEGA POSTOPKA

Raziskovali smo, kako bi naredili kar se da globok spoj med n in p tipom polprevodnika, hkrati smo želeli imeti čim manjšo upornost materiala (od $1.5\ \Omega\ \text{cm}$ do $2.5\ \Omega\ \text{cm}$), ki bi ga v BiCMOS procesu uporabili za kolektorski vložek. Ti dve zahtevi določata močno dopiran silicij. Ker smo delali modifikacijo postopka v okviru standardnega procesa, smo uporabljali pretežno standardne procesne korake.

Pri načrtovanju poskusov smo uporabili spoznanja iz atomskih modelov mehanizma difuzije. Pri nizkih koncentracijah primesi (pod $10^{16}\ \text{atomov/cm}^3$) v siliciju se rezultati meritev dobro ujemajo z izračunanimi razporeditvami primesi v polprevodniku po difuzijski enačbi (1) in zato nas podrobno ne zanima mehanizem premikanja atomov primesi po kristalni mreži silicija. Boljše ujemanje pri visokih koncentracijah primesi (nad $10^{20}\ \text{atomov/cm}^3$) med izračunanimi in izmerjenimi vrednostmi dobimo, če namesto difuzijskega koeficienta vpe-

ljemo difuzivnost, ki je odvisna od koncentracije primesi (2). Ko število atomov primesi preseže število termično generiranih nosilcev naboja v čistem siliciju pri temperaturi difuzije, je opazno razhajanje med izračunanimi in izmerjenimi vrednostmi, če ne upoštevamo koncentracije primesi. V številu atomov primesi moramo upoštevati tudi število atomov primesi, ki so vgrajeni v substratu. Pri visokih koncentracijah dobimo zadovoljive rezultate, če upoštevamo atomski model difuzije. Če difuzijsko enačbo razstavimo na dva dela, ki upoštevata različni difuzivnosti za donorske in akceptorske atome, se rezultati izračunov dobro ujemajo z meritvami (3). Seveda moramo upoštevati tudi vpliv vgrajenega električnega polja v kristalu, temperaturno odvisnost difuzivnosti in oženje prepovedanega pasu (4, 5).

Na mikroskopskem nivoju opišemo difuzijo atomov primesi v siliciju kot posledico interakcije med točkastimi defekti v kristalni mreži silicija in atomi primesi. Točkasti defekti (intersticijski in vakance) imajo lahko različne električne naboje.

3.1 Opis modificiranega procesnega koraka

Izbrali smo p-tip rezine, ker smo želeli s poskusom dokazati možnost izdelave npn bipolarnega tranzistorja. Običajen postopek izdelave BiCMOS vezij vključuje epitaksijsko rast silicija p tipa nad pokopano plastjo n tipa (6). Ker v proizvodnji ni na voljo epitaksijskega reaktorja, smo poskusili problem rešiti z difuzijo. Za kolektorski vložek želimo, da se ne bi preveč razlezel v lateralni smeri, zato smo izbrali zmerno temperaturo in čas difuzije. Visoka koncentracija primesi, ki smo jo želeli doseči, je narekovala uporabo implantacije za vnos primesi v silicij. Implantiranim primesem smo dodali še izvor primesi v dopiranem polikristalnem siliciju, ki smo ga na rezino deponirali pred difuzijo. Implantacijo primesi smo delali z največjo pospeševalno napetostjo, ki jo je zmožal implanter v proizvodnji ($150\ \text{keV}$). Doza primesi ni odstopala od običajnih ($8 \times 10^{12}\ \text{ionov/cm}^2$). Podatke za nastavitve difuzijskih peči smo dobili iz kalibracijskih krivulj peči, ker so nekatere želene lastnosti difundirane plasti kazale, da jih ni mogoče doseči z običajnimi difuzijskimi recepti. Polikristalni silicij smo deponirali pri 1150°C v inertni (dušikovi) atmosferi. Primesi smo difundirali v oksidacijskem koraku pri 1130°C , ki je sledil. Oksid smo odjedkali in naredili še eno difuzijo pri 1000°C v inertni atmosferi, ki je trajala 240 minut. Da bi dosegli želene upornosti silicija, smo časa depozicije polikristalnega silicija in oksidacije spreminjali v skladu s kalibracijskimi krivuljami. Zadnji difuziji sledile obsežne meritve na rezinah.

4. MERITEV REZULTATOV DIFUZIJE

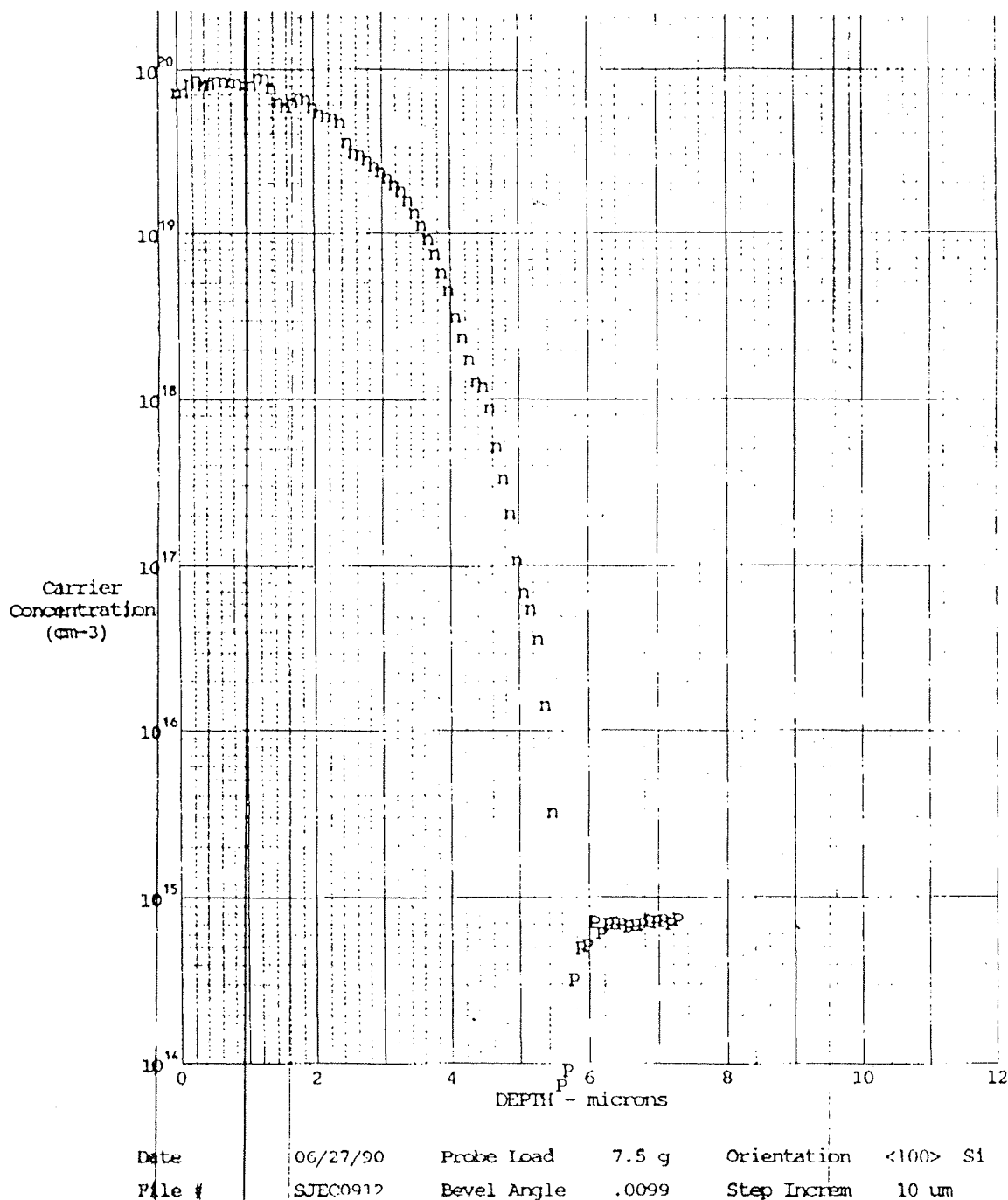
Profile dopantov so na naših vzorcih izmerili s SRA metodo (7) v firmi Solecon Laboratories Inc. Koncentracijo atomov dopanta pri SRA metodi merimo preko upornosti.

Meritve na naših rezinah pa so bile opravljene pri sledečih pogojih: sila s katero sta kontakta pritiskala na vzorec je bila 7.5×10^{-2} N, korak med točkami v katerih so merili upornost je bil $10 \mu\text{m}$, vzorec pa je bil zbrušen pod kotom 1° .

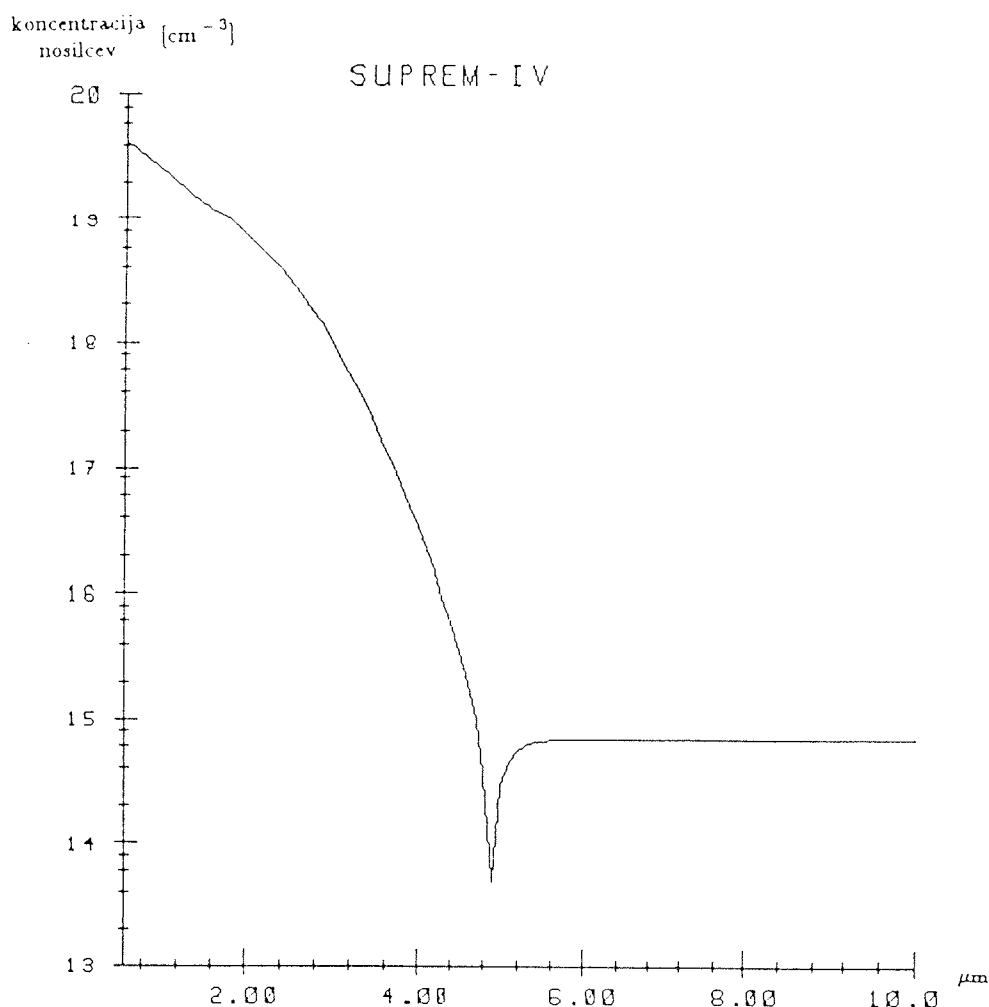
Merjeni vzorci so bili za navadne MOS tehnologije neobičajni. Površinska koncentracija dopantov je bila izredno visoka, p-n spoj pa izredno globoko; v takih razmerah so le rezultati SRA meritev profila dopantov zanesljivi. Na sliki 1 vidimo, da je površinska koncentracija dopantov 9×10^{19} atomov/ cm^3 , globina p-n spoja je $5.6 \mu\text{m}$ pod površino silicija.

5. RAČUNALNIŠKA SIMULACIJA DIFUZIJE

Suprem-4 je program, ki omogoča dvodimenzionalno simulacijo različnih procesnih korakov za izdelavo integriranih vezij in diskretnih elementov na silicijevi rezini (8). Matematični model difuzije v programu Suprem-4 obsega sistem desetih sklopljenih difuzijskih enačb (9). Zmanjšanje planarnih razdalj med aktivnimi področji modernih integriranih vezij narekuje uporabo dvodimenzionalnega simulatorja Suprem-4, ki je zaenkrat edino računalniško simulacijsko orodje, sposobno dovolj natančno opisati procese, uporabljene pri izdelavi modernih silicijevih integriranih vezij. Končni cilj uporabe



Slika 1: Profil primesi na prvi rezini (difuzija 1: 32.0 min., difuzija 2: 14.5 min.)



Slika 2: Rezultati prve simulacije (difuzija 1: 32.0 min., difuzija 2: 14.5 min.)

Suprema-4 je omogočiti modeliranje fino stopenjskih (fine-scale) integriranih vezij. Rezultat simulacije izdelave kolektorskega vložka je prikazan na sliki 2.

6. KOMENTAR REZULTATOV

Rezultate dela ilustrirata sliki 1 in 2, na katerih so rezultati meritev oziroma simulacij za iste procesne podatke. Površinski koncentraciji, simulirana in izmerjena, sta enakega reda velikosti in izračunana globina spoja tudi odstopa od izmerjene za manj kot 10%. "Potlačenost" profila primesi na simulaciji je potrjena tudi z meritvami. Tako lahko trdimo, da se simulirani in izmerjeni profil ujemata v bistvenih lastnostih. Ujemanje ni povsem pričakovano, ker večina simulacije poteka za koncentracije primesi med 10^{16} in 10^{20} atomov/cm³, kjer je v matematičnih modelih difuzije mejno področje med visokimi in nizkimi koncentracijami primesi in zato simulacije običajno niso zanesljive.

7. ZAKLJUČEK

Želeli smo narediti kolektorski vložek, ki bi imel upornost med 1.5 in 2.5 Ω cm. Uspeli smo narediti difundirane plasti, ki imajo upornosti med 1.7 in 2.1 Ω cm. Dosežene globine spoja med p in n tipom polprevodnika so med 5.2 in 5.6 μ m, kar je dovolj za kolektorski vložek.

Rezultati simulacije izdelave kolektorskega vložka s programom Suprem-4 in izmerjeni profili koncentracije difundiranih primesi so enaki v vseh bistvenih parametrih. Dobro ujemanje simulacij z izmerjenimi rezultati nas utrjuje v prepričanju, da lahko s simulacijami dobro napovemo rezultate poskusov na siliciju. Ker so simulacije na računalniku mnogo cenejše kot poskusi na silicijevih rezinah, imamo v rokah orodje za razvoj tehnologije z zmernimi stroški. Pričakujemo, da bo šel del razvoja integriranih vezij na siliciju v smer vezij, na katerih bo na enem čipu uporabljena bipolarna in tehnologija CMOS, zato je pomembna ugotovitev, da kolektorski vložek lahko izdelamo z difuzijo. Vrednost ugotovitve je v tem, da smo uporabili stroje in postopke, ki jih poznamo in obvladamo, kar omogoča, da se laboratorij za mikroelektroniko vključi v razvoj procesov BiCMOS.

8. ZAHVALA

Za pomoč pri praktični izvedbi poskusov in meritev se zahvaljujem sodelavcema Andreju Beliču in dr. Zoranu Krivokapiču. Iskreno se zahvaljujem dr. Radku Osredkarju za mnogo koristnih nasvetov in napotkov pri obdelavi zbranih rezultatov.

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LASERSKI ULTRAZVOČNI DEFEKTOSKOP

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KLJUČNE BESEDE: ultrazvočni defektoskopi, detekcija ultrazvoka, lasersko vzbujanje ultrazvoka, NdYAG laserji, senzorji malih pomikov, Michelsonov interferometer, brezkontaktno merjenje, neporušne preiskave, uporaba laserjev, laserska ultrasonika, eksperimentalne raziskave

POVZETEK: V članku je prikazana zgradba in način delovanja dveh sistemov za brezdotično interferometrično detekcijo lasersko generiranih ultrazvočnih pomikov. Odziv obeh sistemov je proporcionalen dejanskim odmikom na površini materiala, z njim pa lahko detektiramo pomike reda velikosti 0.1 nm. V eksperimentalnem delu predstavljamo odzive teh sistemov na lasersko vzbujen ultrazvok pri različnih parametrih, hkrati pa razčlenjujemo vplive na obliko in širjenje ultrazvočnega vala.

LASER ULTRASONIC DEFECTOSCOPE

KEY WORDS: ultrasonic defectoscopes, detection of ultrasound, NdYAG lasers, small displacement sensors, Michelsons interferometer, contactless measurement, nondestructive evaluation, laser application, laser ultrasonics, experimental research

ABSTRACT: The construction and the basic operating principles are presented for two interferometric systems for noncontact laser induced ultrasonic displacement measurements. Both system responses are proportional to the displacements on material surface and amplitudes down to the order of magnitude of 0.1 nm can be detected. In this paper experiments with varying excitation parameters are discussed while different effects on the ultrasonic wave shape are analyzed.

1. UVOD

Laserske metode vzbujanja in detekcije ultrazvoka v materialih se uveljavljajo pri neporušnem preizkušanju materiala /1,2/, pri določevanju kvalitete površin in materialnih konstant /3,4/, metode detekcije pa lahko uporabimo pri določanju kvalitete laserskih obdelovalnih procesov /5,6/ in kalibraciji senzorjev malih pomikov (mikrofoni, hidrofon) /7/.

Najvažnejša odlika laserskih metod je brezdotičnost postopka, kar nam omogoča njihovo uporabo v težavnih okoljih (radioaktivnost, korozivna okolja, visoke temperature). Poleg tega na stiku med preizkušancem in senzorjem ne prihaja do modulacije valovanj, kar nam zagotavlja direkten vpogled v dogajanje na površini vzorca.

Težave, s katerimi se soočamo pri uporabi teh metod, nastopijo pri vzorcih, kjer je odboj sondirnega žarka slab, pa naj bo to zaradi previsoke absorpcije na preizkušancu, ali pa zaradi prevelike hrapavosti na njegovi površini /8,9/. Poleg tega uporaba laserja zahteva upoštevanje varnostnih predpisov. Nenazadnje je tu še razmeroma visoka cena sistema.

Tovrstni sistemi so sestavljeni iz vzbujevalnega dela, močnostnega pulznega laserskega izvora in sondirnega dela. Ultrazvočne pomike na površinah materialov lahko detektiramo z modulacijo od snovi odbitega žarka. Pri tem izkoriščamo bodisi odklon žarka /4,10/, bodisi tunnelski efekt /11/ ali pa interferenco /1,12/.

V tem članku predstavljamo možnosti interferometrične detekcije ultrazvoka z dvema izboljšanima verzijama Michelsonovega interferometra. V eksperimentalnem delu so prikazani odzivi na aluminijastih vzorcih pri različnih parametrih vzbujanja ultrazvoka. Hkrati analiziramo posamezne vplive na širjenje in obliko ultrazvočnih valov.

2. PRINCIP DELOVANJA

2.1. Lasersko vzbujanje ultrazvoka v kovinah

Lasersko vzbujanje ultrazvoka temelji na optoakustičnem pojavu, do katerega pride ob interakciji nestacionarnega svetlobnega toka in površine kovine. Mehanizem tega pojava je v grobem naslednji: snov se pri lokalni absorpciji svetlobe segreje in termično raztegne. Nastalo neravnovesno stanje se v obliki mehanskih valov razširi po celotnem vzorcu. Dinamika tega pojava je odvisna od časovnega poteka svetlobnega toka, optičnih in termoelastičnih konstant materiala ter robnih pogojev na meji med absorbirajočo kovino in prozornim okoliškim medijem. Iz množice lasersko vzbujenih valov običajno za analizo uporabimo longitudinalne, transverzalne in nekatere od površinskih valov.

Ultrazvok običajno vzbujamo z laserskimi pulzi. Glavni vpliv na dogajanje na površini in s tem povezan časovni potek ultrazvočnih valov ima intenziteta vpadle laserske svetlobe. Pri nizkih intenzitetah govorimo o termoelas-

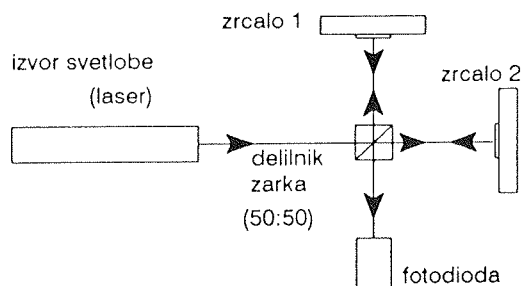
tičnem mehanizmu. Pri tem maksimalne temperature ne dosežejo tališča, zato ekspanzijo lahko dinamično popišemo z linearno teorijo kot termoelastični val /15/. Kvalitativna analiza nam pokaže, da v tem primeru zaradi geometrije toplotnega izvora transverzalni val amplitudno prevlada nad longitudinalnim.

Drugače pa so razmere pri visokih intenzitetah, kjer pride do odparevanja površinske plasti in do nastanka plazme. Takšen ablativni mehanizem vzbujanja ultrazvoka ima za posledico prevlado longitudinalnega vala, ki ga povzroči odzivna sila, transverzalni val pa spremeni fazo. Teoretično so te razmere težje popisljive, zato se navadno zatekamo k eksperimentalnim rezultatom.

Za defektoskopijo so najugodnejši longitudinalni valovi. Optično jih je možno vzbujati v ozkem območju intenzitet, pri katerih se prispevka k transverzalnemu valu zaradi termične ekspanzije in ablacije medsebojno izničita.

2.2. Interferometrski detekcija ultrazvoka

Klasični Michelsonov interferometer za merjenje pomikov (sl. 1) deluje na principu štetja interferenčnih peg, ki se pojavljajo pri spreminjanju optičnih poti v krakih interferometra. Njegova ločljivost je zato omejena na četrtno valovne dolžine svetlobe. Z izboljšanjem števnice elektronike je ločljivost možno izboljšati še za faktor 10, vendar tudi to ne zadošča za meritve ultrazvočnih pomikov na površini kovin.



Slika 1: Shema Michelsonovega interferometra

Za takšen interferometer velja, da se intenziteta svetlobe I na fotodiodi pri spreminjanju dolžine x enega od krakov spreminja kot

$$I(x) = 4 \cdot \epsilon_0 \cdot c \cdot E_0^2 \cdot \cos^2\left(\frac{2\pi x}{\lambda}\right). \quad (1)$$

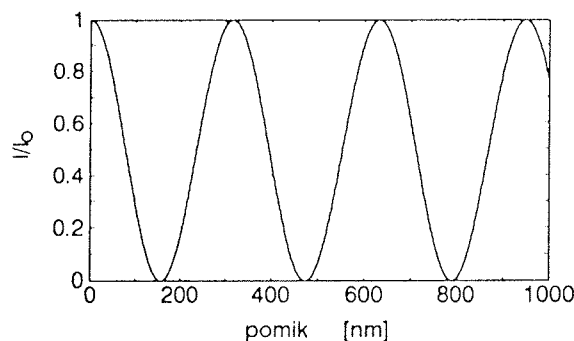
Pri tem je ϵ_0 influenčna konstanta, c hitrost svetlobe, E_0 amplituda električnega polja in λ valovna dolžina. Iz enačbe 1 in slike 2 je razvidno, da se s pomikom spreminja tudi občutljivost interferometra $Z(x)$, ki jo definiramo kot

$$Z(x) = \frac{dI}{dx} \cdot k = -8 \cdot \epsilon_0 \cdot c \cdot E_0^2 \cdot k \cdot \frac{\pi}{\lambda} \cdot \sin\left(\frac{4\pi x}{\lambda}\right), \quad (2)$$

kjer je k konstanta fotodiode (Vm^2/W). Občutljivost je največja pri $x = \lambda/8 \pm m\lambda/4$, torej na polovici amplitude

intenzitete (sl.2), če zahtevamo še pozitiven odvod pa pri $x = 3\lambda/8 \pm m\lambda/2$, kjer znaša

$$Z_{\max} = 8 \cdot \epsilon_0 \cdot c \cdot E_0^2 \cdot k \cdot \frac{\pi}{\lambda} \quad (3)$$



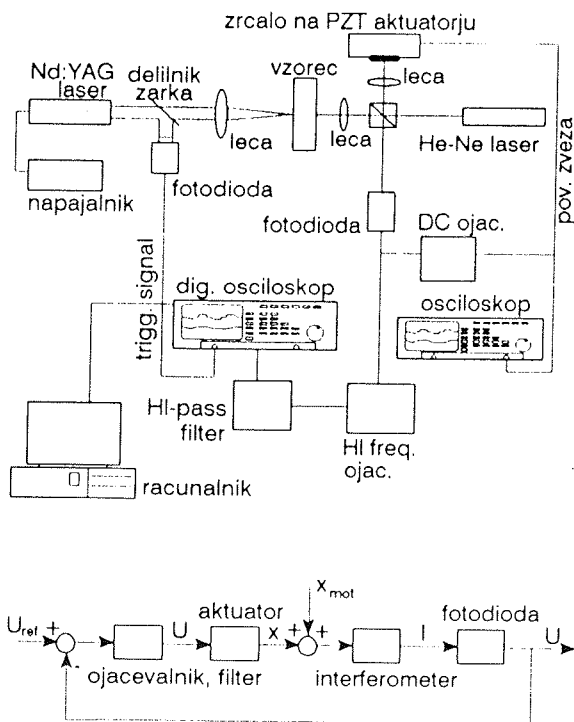
Slika 2: Intenziteta v odvisnosti od razlike dolžin krakov ($\lambda = 632.8 \mu\text{m}$)

Za meritev zelo majhnih pomikov je potrebno interferometrski sistem nastaviti tako, da visokofrekvenčni ultrazvočni pomik detektiramo takrat, ko je njegova občutljivost največja. Pri tem se je treba izogniti okoliškim motnjam (vibracije, temperaturne fluktuacije), v frekvenčnem območju do 1 kHz. Nalogo je možno rešiti na več načinov, od katerih sta dva podrobneje opisana v nadaljevanju.

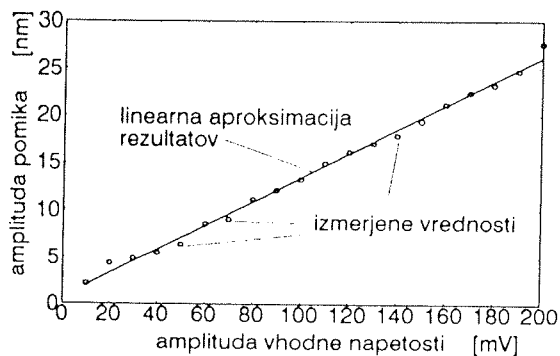
2.2.1. Kompenziran Michelsonov interferometer

V praksi se je najprej uveljavil stabiliziran interferometer /12/. Rešitev problema temelji na zaprtem detekcijskem sistemu, ki motnje eliminira s povratno zanko. Če zrcalo v referenčnem kraku Michelsonovega interferometra premikamo v nasprotni smeri motnje okolice, lahko eliminiramo tako temperaturno motnjo kot tudi vibracije. Ker sta motnja in pričakovani signal frekvenčno dobro ločena, z vstavitvijo filtra v povratno zanko dosežemo selektivno eliminacijo zunanje motnje. Frekvenčno območje mehanskih vibracij in temperaturnih fluktuacij sega do približno 1 kHz, medtem ko pričakujemo signal v območju od enega do nekaj deset MHz. Shema takšnega merilnega sistema predstavlja slika 3.

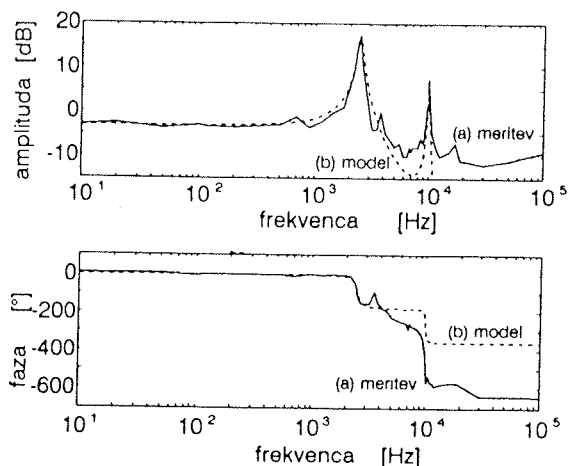
Kot aktuator smo uporabili polovični bimorfni piezoelektrični element, ki izkorišča uklon plošče /13,14/. Na medeninasto ploščo prilepljena piezoelektrična ploščica je radialno polarizirana. S takšnim aktuatorjem je možno doseči pomike prek $1 \mu\text{m}$ v centru ploščice že pri napetostih pod 5V. Meritev linearnosti (sl. 4), je dala zadovoljive rezultate. Meritve frekvenčne karakteristike (sl. 5) pa so pokazale, da aktuator lahko obravnavamo kot dvojni sistem drugega reda. Tej karakteristiki smo prilagodili tudi oblikovanje povratne zveze, ki je sestavljena iz dveh filtrov 1. reda, dveh ojačevalnih stopenj in stopnje za nastavljanje referenčne točke delovanja interferometra.



Slika 3: Sistem s kompenziranim Michelsonovim interferometrom in kibernetska shema stabilizacije interferometra.



Slika 4: Linearnost aktuatorja pri različnih amplitudah vhodne napetosti

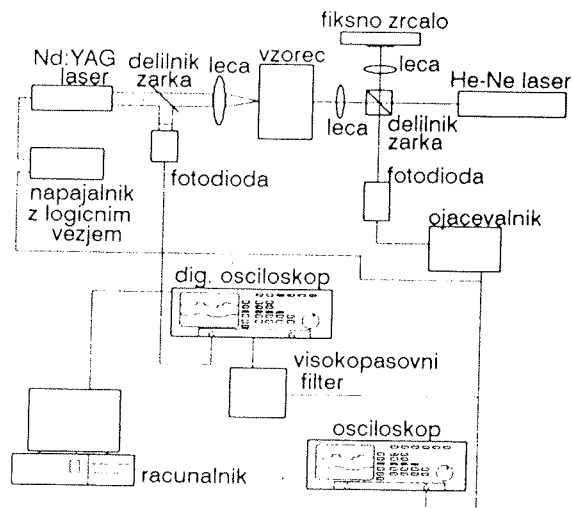


Slika 5: Frekvenčna karakteristika sistema aktuator interferometer-fotodioda: (a) izmerjena karakteristika in (b) sistem modeliran z dvojnim sistemom drugega reda.

2.2.2. Sistem s sinhronim proženjem

Drugi način je novost, ki je v literaturi še nismo zasledili, deluje pa na principu kontroliranega proženja vzbujevalnega laserja.

Motnje iz okolice vseskozi premikajo interferometer iz najboljčujivejše točke, zato se jim z vzbujanjem prilagodimo tako, da ultrazvočni val vzbudimo v trenutku, ko je zaznavnost največja. Signal iz fotodiode vodimo v logično vezje (sl.6) in ko doseže točko maksimalne občutljivosti, sprožimo pulz iz vzbujevalnega laserja. Sama logika tega vezja temelji na vnaprejšnjem predvidevanju položaja interferometra. Predhodno nastavimo dve točki, skozi kateri naj bi potekal signal, povzročen z okoliško motnjo. Z njima definiramo gradient motnje. Pričakujemo, da bo motnja v naslednjih 140 μ s, kolikor je potrebno od signala za proženje laserja do laserskega pulza, obdržala takšen naklon. S smiselno postavitvijo obeh točk in nastavitvijo toleranc pri drugi dosežemo, da vzbujevalni laser proži dejansko v trenutku maksimalne občutljivosti.



Slika 6: Interferometerski sistem za detekcijo ultrazvoka s sinhronim proženjem vzbujevalnega laserja.

Ta metoda je vezana na možnost dovolj hitrega kontroliranega vzbujanja ultrazvoka. Za nastavitve sistema je potrebno delno poznavanje motnje. Metoda je dovolj enostavna, tako da jo lahko realiziramo že s preprostim elektronskim vezjem. Nekaj težav nastopi pri velikih motnjah (amplitude nad 160 μ m), kjer prihaja do prehodov prek enega interferenčnega vrha. Pri vzorčenju signalov s sprotnim povprečenjem zato položaj interferometra nadziramo z dodatnim osciloskopom, tako da ugotovimo takšne prehode.

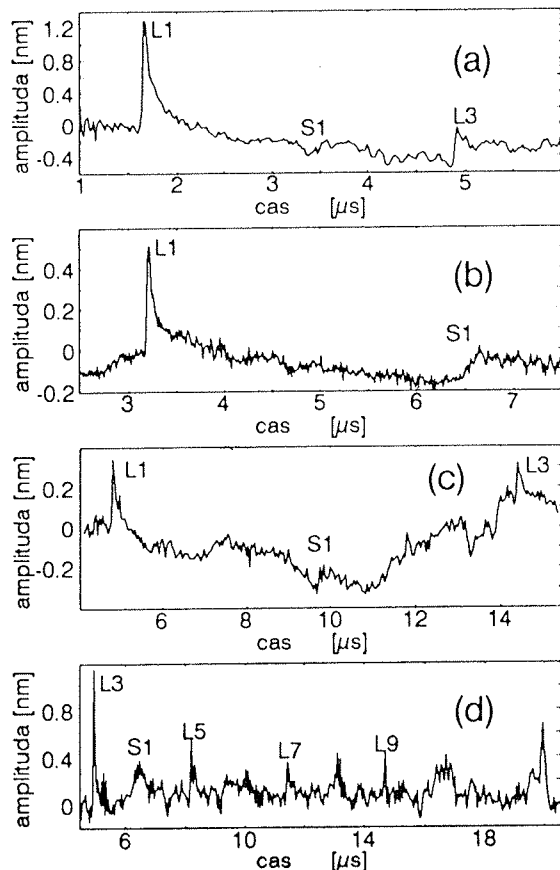
Optično se oba interferometra od klasične postavitve Michelsonovega interferometra razlikujeta po vstavljenih enakih konveksnih lečah v oba kraka, kar nam omogoča lažje justiranje izhodnih žarkov. Pri manjši izvenfokusni poziciji obeh zrcal uporabimo za justiranje koncentrične interferenčne kroge. S tem izgubimo pri-

bližno 20% vidnosti, vendar pa je bistveno olajšano pozicioniranje vzorcev.

Fotodioda na izhodu interferometrov je prirejena tako, da je izhod iz primarnega senzorja (fotodiode) ojačan za faktor od 7 do 50, kar je odvisno od nastavitve potenciometra (trenutno 10), nato se odcepi veja za nizkofrekvenčno povratno zanko, oz. za nadzor nizkofrekvenčne motnje. Visokofrekvenčna veja je filtrirana z visokopasovnim ($f_m = 150$ kHz) filtrom in ojačana s faktorjem 10. Izhodna pasovna širina detektorja je od 150 kHz do 60 MHz, zgornja meja je odvisna od faktorja primarnega ojačanja. Občutljivost za $1 \mu\text{W}$ pri 650 nm in skupnem ojačanju 100 znaša 89.6 mV. Skupni šum na izhodu je ocenjen na $1.7 \text{ mV}_{\text{rms}}$, kar približno ustreza amplitudi pomika 0.1 nm .

3. EKSPERIMENTI

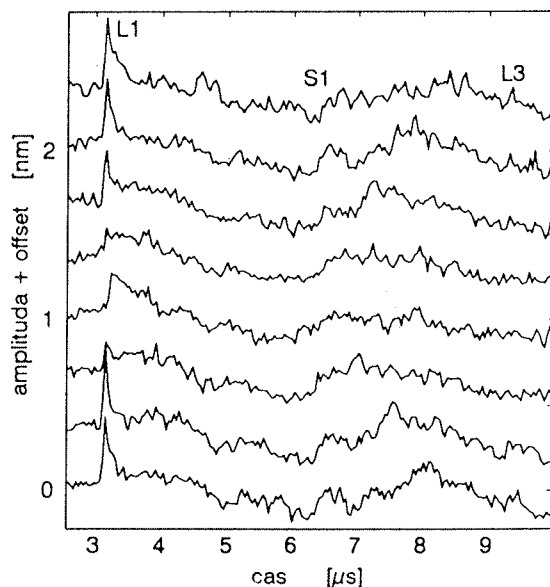
Z opisanimi interferometroma smo detektirali ultrazvočne valove v aluminijastih vzorcih. Vzbujaali smo jih z NdYAG laserjem, z dolžino pulza 11 ns (FWHM). Energija in s tem intenziteta vpadlega pulza sta se spreminjali. Na sliki 7 so prikazani odzivi interferometra pri različnih debelinah vzorca in večkratni odboji ultrazvočnega vala v vzorcu, z debelino 10 mm. Energija vzbujevalnega laserja je pri teh eksperimentih znašala 11 mJ, žarek pa je bil fokusiran na površino vzorca. Pri



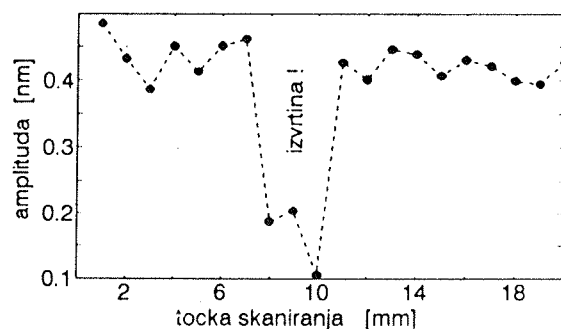
Slika 7: Odzivi interferometra na vzorcih debeline (a) 10 mm, (b) 20 mm in (c) 30 mm (10 x povprečno), in (d) večkratni odboji longitudinalnega vala na vzorcu debeline 10 mm.

teh pogojih prevladuje ablativni mehanizem generacije ultrazvoka, kjer se del materiala upari. Ugotovili smo linearno odvisnost pozicije ultrazvočnih valov v odvisnosti od debeline vzorca. Hkrati smo opazili tudi upadanje amplitud z večanjem debeline vzorca.

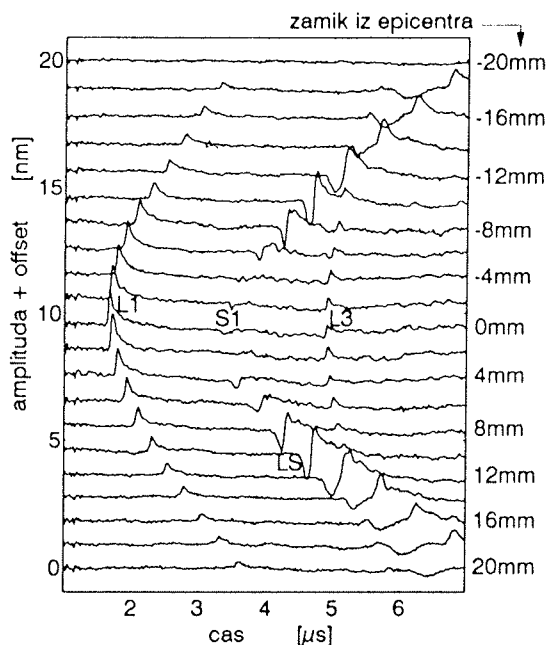
Na širjenje in s tem na obliko ultrazvočnega vala vplivajo možne napake v materialu, po katerem se val širi. Te vplive smo analizirali na vzorcu debeline 20 mm, v katerega smo bočno izvrtali dve luknji s premerom 3 mm. Vzbujanje je bilo v tem primeru enako kot v prvem eksperimentu. Metoda določevanja defekta je enaka kot pri klasični presevalni defektoskopiji, le da gre tu za drugačne vrste vzbujanja in detekcije ultrazvočnih valov. Pri premikanju obeh žarkov prek izvrtine smo opazili znatne spremembe v signalu (sl. 8). Kot merodajno cenilko smo izbrali amplitudo prvega longitudinalnega (L1) vala, katere spreminjanje med skeniranjem je prikazano na sliki 9. Ugotovili smo, da število odzivov z manjšo amplitudo odgovarja dimenziji izvrtine. Na tej osnovi je možno razviti novo metodo določanja lege in dimenzije defektov v notranjosti vzorcev.



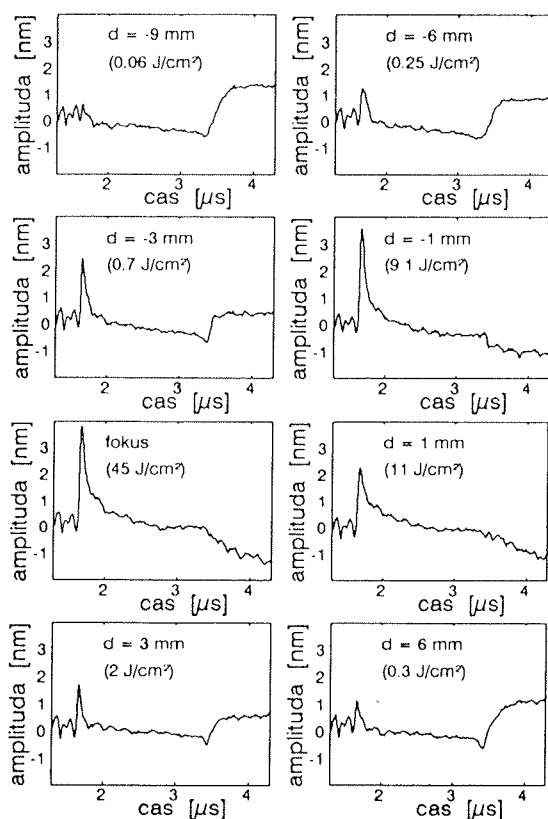
Slika 8: Odzivi interferometra pri premikanju žarkov preko izvrtine. Korak med posameznimi signali je 1 mm.



Slika 9: Spreminjanje amplitude longitudinalnega vala pri premikanju žarkov prek izvrtine.



Slika 10: Spreminjanje ultrazvočnih odzivov pri zamikanju vzbujevalnega in sondirnega žarka.



Slika 11: Odzivi interferometra pri različnih intenzitetah vpadle svetlobe. Ob posameznih primerih navajamo izvenfokusno razdaljo, v oklepaju pa gostoto energije vzbujevalnega žarka.

Naslednji vpliv na obliko odziva je posledica detekcije vala izven epicentra vzbujanja. Eksperimente za analizo tega vpliva smo opravili na vzorcu debeline 10 mm, tako da smo izvor ultrazvočnega pulza premikali glede na točko detekcije ultrazvoka. Odzivi so prikazani na sliki 10. Opazimo spreminjanje pozicije posameznih valov, zaradi spremenjenih poti. Poleg tega se med longitudinalnim (L1) in transversalnim (S1) valom pojavi še takoi-menovani čelni val. To je strižni val, ki nastane pri širjenju longitudinalnega vala po površini /15/ in se od začetnega strižnega vala odlepi pri kritičnem kotu:

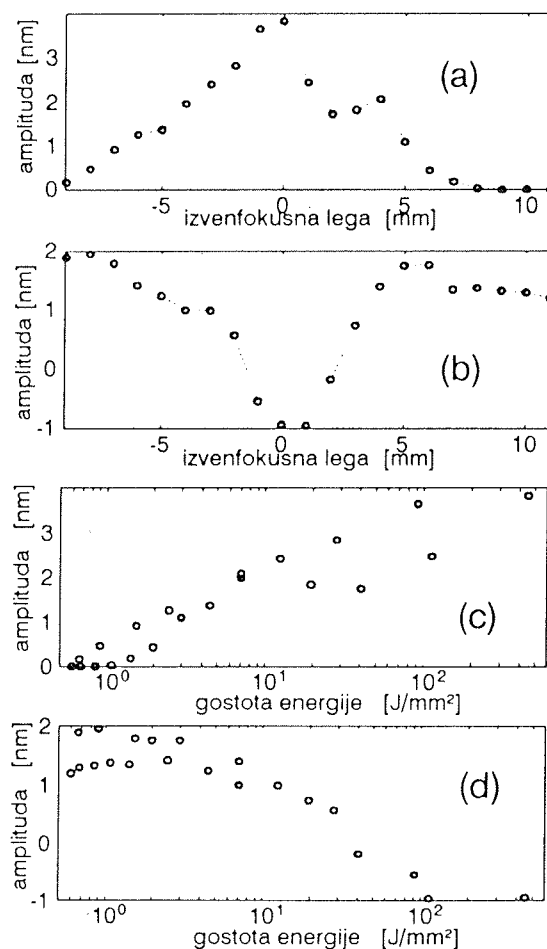
$$\sin \Theta_c = \frac{C_S}{C_L} \quad (4)$$

C_S ... hitrost širjenja transversalnega vala

C_L ... hitrost širjenja longitudinalnega vala

Časovna razlika med strižnim in čelnim valom je pri tem eksperimentu majhna, njuno ločevanje pa otežuje še površinski val, ki se pojavi pri konverziji longitudinalnega vala ob odboju na zadnji površini.

Pomemben vpliv na obliko ultrazvočnega vala ima mehanizem vzbujanja ultrazvoka. Pri termoelastičnem



Slika 12: Spreminjanje amplitude (a) longitudinalnega vala in (b) transversalnega vala v odvisnosti od izvenfokusne lege vzorca, ter odvisnosti (c) longitudinalnega in (d) transversalnega vala od intenzitete vzbujevalnega žarka.

vzbujanju se material lokalno hitro segreje brez faznih sprememb. To ima za posledico ekspanzijo predvsem v radialni smeri. Longitudinalni val tako predstavlja zažemek, ki se pojavi ob ekspanziji in je orientiran nasprotno smeri širjenja. Ablativni mehanizem generacije ultrazvoka pa temelji na uparjanju materiala in pojavu plazme. Zaradi mehanske odzivne sile je longitudinalni val močnejši in pozitivno orientiran. Vpliv obeh mehanizmov je možno spreminjati s premikanjem goriščne ravnine glede na površino vzorca. Pri tem se spreminja tudi prerez vzbujevalnega laserskega žarka. Uporabili smo lečo z goriščno razdaljo 25 mm, povprečna energija vzbujevalnih pulzov pa je znašala 18 mJ. Nekaj odzivov je prikazanih na sliki 11. Spreminjanje amplitud longitudinalnega in strižnega vala ter njuno odvisnost od intenzitete ponazarja slika 12. Sipanje v zadnjem diagramu je posledica nenatančnosti določanja površine vpadlega žarka. V bližini gorišča opazimo naglo povečanje amplitude longitudinalnega vala in zmanjšanje amplitude transversalnega vala. Opisani pojav je razen v defektoskopiji možno s pridom uporabiti pri nadzoru pulznih laserskih obdelovalnih procesov /5/.

4. ZAKLJUČKI

V prispevku je predstavljen razvoj dveh sistemov za detekcijo ultrazvoka. V začetku navajamo teoretične osnove interferometrične detekcije, v nadaljevanju pa je opisana eksperimentalna postavitev sistema s kompenziranim Michelsonovim interferometrom in sistema s krmiljenim proženjem vzbujevalnega laserja.

Z obema sistemoma je možno vzbujati in detektirati ultrazvočne pomike na kovinskih vzorcih. Sistema predstavljata novost, ki se uspešno kosa z metodami konvencionalne detekcije ultrazvoka. V marsičem jih celo prekaša, saj neposredno detektira odmik površine v normalni smeri. Njuna frekvenčna karakteristika zagotavlja informacijo o odkikih brez popačenj zaradi prenosne funkcije sistema. Amplitudno sta dovolj občutljiva, kar smo pokazali v eksperimentalnem delu, kjer prikazujemo odzive sistema na pomike reda velikosti do 0.1 nm. Tako lahko detektiramo pomik vala, ki smo ga na prednji strani 10 mm debele aluminijaste plošče vzbudili z laserskim pulzom, potem pa se je še devetkrat odbil od stene. Pri vsakem odboju val izgubi približno 10% amplitude, ki se v odvisnosti od poti dodatno zmanjšuje približno s kvadratom poti.

Uporabnost sistema pri defektoskopskih preiskavah je razvidna iz predstavljenih odzivov na ultrazvočne pomike, ki so se širili skozi umetno poškodovan material.

Defekte smo simulirali z izvrtinami, v tem prispevku pa prikazujemo le odzive pri premikanju vzbujevalnega in sondirnega žarka prek takega defekta. V prispevku so prikazani še vplivi debeline vzorca, zamaknitve točke vzbujanja in točke detekcije in vpliv vzbujevalnega mehanizma ultrazvočnih valov na njihovo širjenje in časovni potek.

Odlike predstavljenih sistemov se pokažejo v razmerah, ki so neugodne za klasične metode. To so agresivna atmosfera, temperaturno obremenjeni vzorci in radioaktivno okolje.

5. LITERATURA

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THERMALLY TREATED COLD SPUTTERED YBaCuO FILMS BY TRIODE SPUTTERING

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KEY WORDS: superconductive films, YBaCuO films, MgO substrates, amorphous films, cold sputtering, triode sputtering, thermal treatment, experimental research, experimental results

ABSTRACT: Superconductive YBaCuO films were sputtered onto (100) MgO substrates in a triode system. Stoichiometric target was used in reactive DC mode. Low temperature depositions were followed by various heat treatments in nitrogen and/or oxygen atmosphere. In the as deposited state the films were amorphous. Fast heating in nitrogen caused grains to grow up to 2 μm while oxygen would reduce the grain growth to average size below 0.4 μm . Raman spectra as well as XRD confirm the presence of orthorhombic YBa₂Cu₃O₇ phase but indicate also traces of BaCuO₂. The transition temperature to superconducting state ($R=0$) was 80 K. Films annealed in nitrogen were porous.

TOPLITNO OBDELANE HLADNO TRIODNO NAPRŠENE YBaCuO PLASTI

KLJUČNE BESEDE: superprevodne plasti, YBaCuO plasti, MgO substrati, amorfne plasti, hladno naprševanje, triodno naprševanje, toplotna obdelava, eksperimentalne raziskave, eksperimentalni rezultati

POVZETEK: Superprevodne YBaCuO plasti smo napršili na (100) MgO podlage v triodnem sistemu. Uporabili smo stehiometrično tarčo in enosmeren način naprševanja. Nizkotemperaturni depoziciji se sledile različne toplotne obdelave v dušiku in/ali kisiku. Napršene plasti so bile amorfne. Hitro segrevanje v dušiku je povzročilo rast zrn do velikosti 2 μm , v kisiku pa je znašala povprečna velikost zrn le do 0.4 μm . Ramanski spektri, kot tudi rentgenski spektri potrjujejo prisotnost ortorombske YBa₂Cu₃O₇ faze ob sledovih BaCuO₂. Temperatura prehoda v superprevodno stanje ($R=0$) je znašala 80 K. Plasti pregrete v dušiku, so bile porozne.

INTRODUCTION

Since the discovery of the superconductivity at temperatures above liquid nitrogen boiling point in some ceramic materials in 1986 /1/ an enormous amount of research efforts was put into both the scientific understanding and application of the phenomenon. Several thin film deposition methods for high temperature superconducting (HTSC) materials have been established, including PVD techniques (sputtering, evaporation, laser ablation), all giving films with superconductive transition temperature around 90 K. The superconducting quality of films made by different methods is similar because the postdepositional annealings are usually similar. However, the significance of annealing details (temperature, time, heating and cooling rates, atmosphere, etc.) has been generally accepted although not well understood. Usually, the deposition method is chosen depending on the available facility and then optimized.

The triode sputtering system is known for its ability of transferring multicomponent materials from the target to the substrate without changing the composition. Therefore it should be adequate for sputtering from the stoichiometric YBa₂Cu₃O₇ target. Additionally, due to large target to substrate distance, such arrangement is efficient when one wants to avoid the detrimental effect of

negative ions during the deposition of YBaCuO films. Triode sputtering system has already been used by the Phillips group /2,3/ who successfully prepared Hall structures with 0.25 μm YBa₂Cu₃O₇ thin films on SrTiO₃, while their films on other substrates were reported to be of inferior quality.

Several materials have been considered for potential use as a substrate. The most important properties include the structure (lattice constants), temperature coefficient of expansion, dielectric constant and the sensitivity to film-substrate interface reactions. So far, the best results have been obtained on expensive substrates such as SrTiO₃ or LaAlO₃. Somewhat less successful were films on cheaper MgO substrates. Regarding the temperature expansion, MgO substrate may be an appropriate choice with its temperature coefficient of $13 \cdot 10^{-6} \text{ K}^{-1}$ while YBa₂Cu₃O₇ is anisotropic having the corresponding temperature coefficients between 10 and $15 \cdot 10^{-6} \text{ K}^{-1}$ for a and b directions of the unit cell, respectively /4/.

At present the majority of research groups are dealing with in situ PVD thin film preparation methods. These methods give better film quality (controlled orientation, epitaxy, high J_c and T_{co} , weaker film-substrate reaction) and are faster than two step ex situ methods. Their

drawback is, on the other hand, that they are limited to rather small areas with homogenous temperature. Ex situ methods will offer potentially larger deposition areas and larger substrates if adequate deposition and annealing conditions are defined and fulfilled.

In 1989 Nagata and his group /5/ have noticed that rapid heating of YBCO thin film in nitrogen atmosphere acts in favour of crystal grain growth. The aim of this study was to confirm this occurrence and determine the influence of the atmosphere, heating rate and temperature during film annealing and oxidation after deposition onto (100) MgO substrates.

EXPERIMENTAL DETAILS

All depositions were performed in a plasma beam apparatus Sputron (Balzers, Liechtenstein) which permits DC as well as RF operation in inert or reactive atmosphere. The system geometry with its 15 cm target to substrate distance is similar to that during evaporation and minimizes the detrimental effects of negative oxygen ions /6/.

Both home made /7/ and original Balzers targets with nominal stoichiometric composition were used in our experiments. According to Balzers specification, the source contains 99.9% of the superconducting phase and very little impurities (less than 250 ppm Sr, 30 ppm Na, 25 ppm K, 10 ppm Ca; Al, Fe, As, Ni, Zn below 5 ppm). Control Raman spectra revealed excellent target homogeneity and possible presence of BaCuO₂ phase. Fig.1 shows Raman spectra from Balzers and home made targets. The oscillations are due to surface roughness, nevertheless clear peaks at 342 and 505 cm⁻¹ can be found. The home made target was less homogeneous than Balzers target and gave poorer deposition repeatability. Its Raman spectrum is presented on figure 1b.

Stoichiometric targets were sputtered in argon DC plasma (800 V, 0.65 A, $5 \cdot 10^{-3}$ mbar). To obtain reproducible results, we cleaned the targets through presputtering for 10 min before each deposition. One possible source of compositional changes in the film can be in the segregation on the target surface. To stabilize the target surface, $5 \cdot 10^{-5}$ mbar of oxygen was introduced into the working chamber. This can hardly be considered as reactive deposition since "ordinary" reactive process would require about ten times higher oxygen partial pressure /8/. 1 μ m thick films were sputtered at 2.5 nm/min deposition rate onto 100°C substrates.

Sapphire, ZrO₂, SrTiO₃ and MgO substrates were used. However, we present here only the results obtained with (100) MgO crystals. Both polished and air cleaved surfaces were used. After polishing the substrates were cleaned in mild detergent, distilled water and etanol.

Several postdepositional annealing procedures were tested. The samples were treated in 1 atm flowing nitrogen and/or oxygen following the experience of Nagata et al. /5/. The treatment can be divided into three (or four) stages: heating up, annealing at high temperature and cooling down (with or without additional oxidation above 450°C). In the warm up stage, heating rates between 1 and 10°C/min were used. Annealing temperature was varied between 750 and 850°C. Tests were made with annealing times between 1 and 60 min and 10 min annealing was chosen as optimum. Slow cooling down rates of 1°C/min in oxygen were used to improve the oxidation process and the transition from tetragonal to orthorhombic phase. In early runs the cool down stage included also the 7 h oxidation at 450°C, whereas later this step was omitted.

Gold contacts were sputter deposited onto the heat treated films and wired with the conductive paste (Epo-tek, Poliscience AG). Conventional DC four point probe was used for measuring electrical characteristics. The temperature was measured with platinum thermometer in the range 300 to 25 K and varied slowly (0.5 to 1

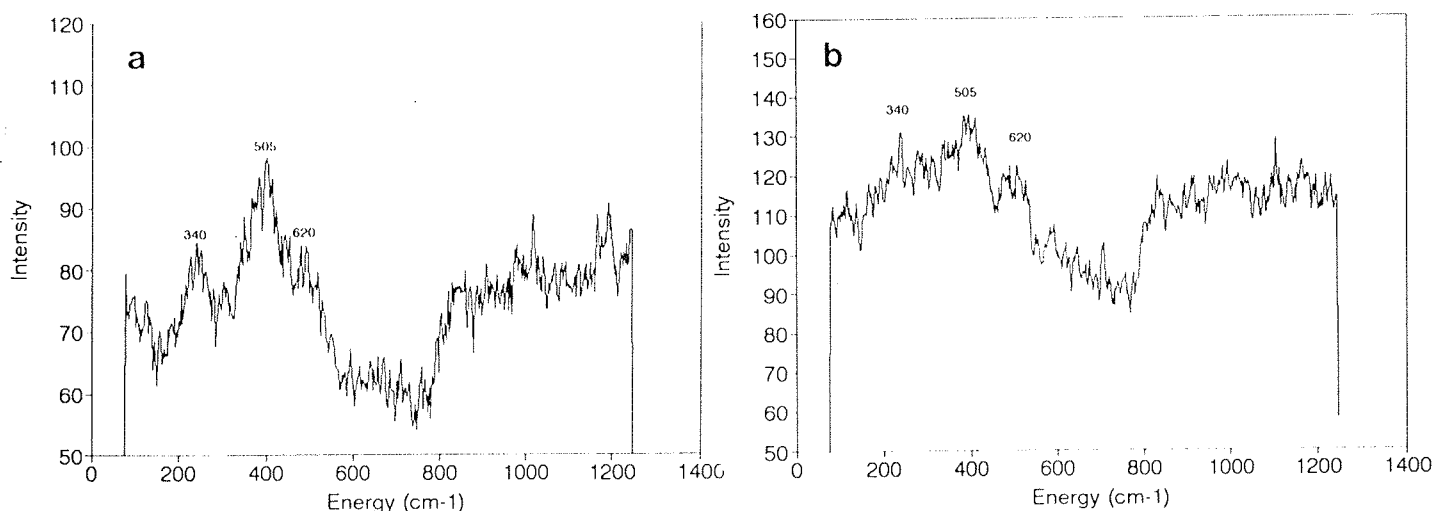


Fig. 1: Raman spectra of Balzers (a) and home made (b) target.

K/min) to compensate the influence of poor thermal contact between the sample and the thermometer and reduce the hysteresis around the critical temperature.

Films were analyzed before and after heat treatment using several techniques. Raman light scattering was measured in triple spectrometer with carefully normalized response of the detector. Argon ion laser ($\lambda = 514.5$ nm) was used with 40 mW beam (30 μm in diameter).

X-ray diffraction was made in the Enraf Nonius 591 apparatus with 40 kV / 26 mA generator and Huber thin film diffractometer having a Seemann-Bohlin geometry. The wavelength of the $\text{CuK}\alpha$ source was 0.154 nm).

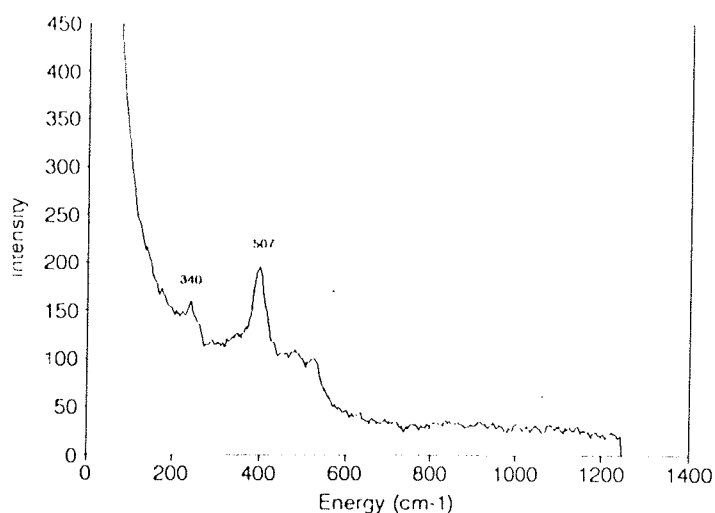


Fig. 2: Raman spectrum of 1 μm thin YBCO film on MgO, heated up and annealed for 10 minutes in nitrogen and cooled in oxygen at a rate $1^\circ\text{C}/\text{min}$.

For Auger electron spectroscopy (AES) depth profile we have used a Perkin Elmer PHI SAM 745 A spectrometer.

RESULTS AND DISCUSSION

The as deposited films were amorphous and insulating with sheet resistivity in the $\text{M}\Omega$ range. During the cool down to 25 K they would not exhibit the transition to superconductive state. Sheet resistivity after annealing can be rough indication of film quality for selection and detailed analysis. A $1\mu\text{m}$ films had room temperature sheet resistivities larger than 0.16Ω . This corresponds to ρ above $18\mu\Omega\text{cm}$. Individual parameters of the thermal treatment and their influence on the film structure were tested. Heating rates between 1 and 10 $^\circ\text{C}/\text{min}$ were tried, the latter giving best results. Although rapid heating may cause holes to appear in the films which were grown on sapphire, we had no such problems with MgO substrates. Films on MgO which had been annealed at 750°C had no transition to superconductive state. The best results on MgO were obtained when annealing at 850°C . It is known that slow cooling down improves the oxidation process and the transition from tetragonal to orthorhombic phase. Also, it is often recommended to perform an additional oxidation at 450°C for several hours. Our experience shows that the oxidation at 450°C would not be necessary if the film was heated up in nitrogen.

After heat treatment the samples were analyzed at room temperature by Raman light scattering. Compared to Fig.2a spectrum from Fig.2b with its clear peak at 505 cm^{-1} indicates composition $\text{YBa}_2\text{Cu}_3\text{O}_{6.9}/9/$. However, BaCuO_2 phase is probably present as indicated by the peaks at 600 cm^{-1} and confirmed by X-ray spectra (eg. Fig.3) and temperature dependence of resistivity. Ac-

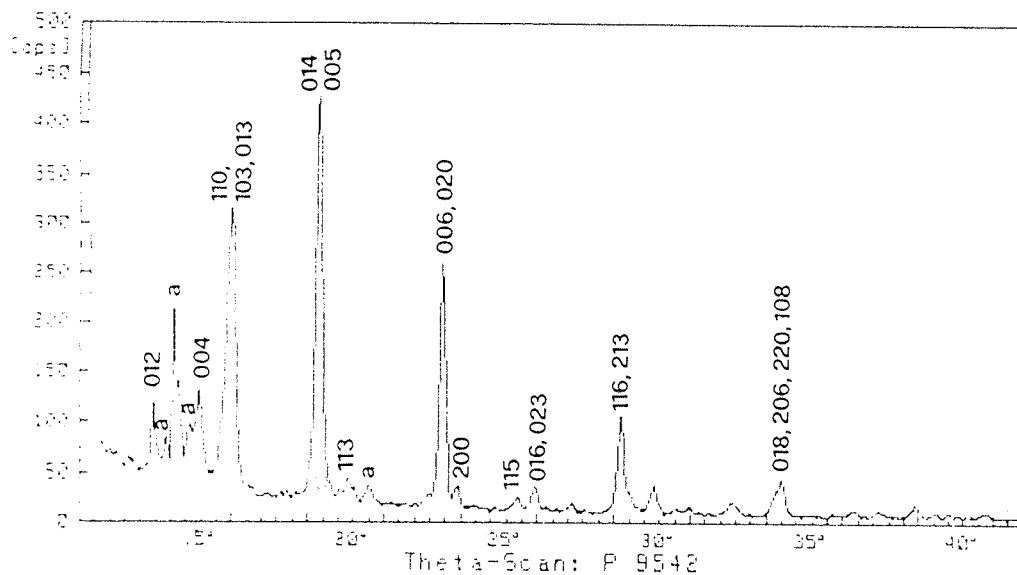


Fig. 3: X-ray diffraction of 1 μm thin YBCO film on MgO, heated up and annealed for 10 minutes in nitrogen and cooled in oxygen at a rate $1^\circ\text{C}/\text{min}$. Peaks marked by "a" are BaCuO_2 peaks.

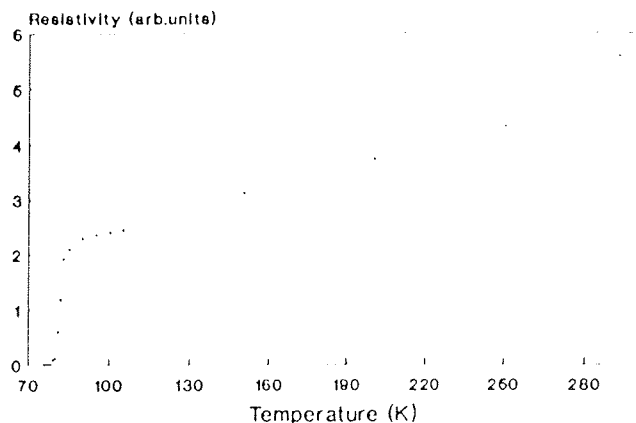


Fig. 4: Resistivity vs. temperature for 1 μm YBCO film on MgO

cording to X-ray diffraction peaks (013), (103) and (110) the films are randomly oriented. Peaks around $\vartheta = 13^\circ$ belong to BaCuO₂ phase. In some cases poor correlation was found between the Raman spectrum and the resistance characteristic. The reason for this lies in the difference of the signal origin. Light is scattered from the

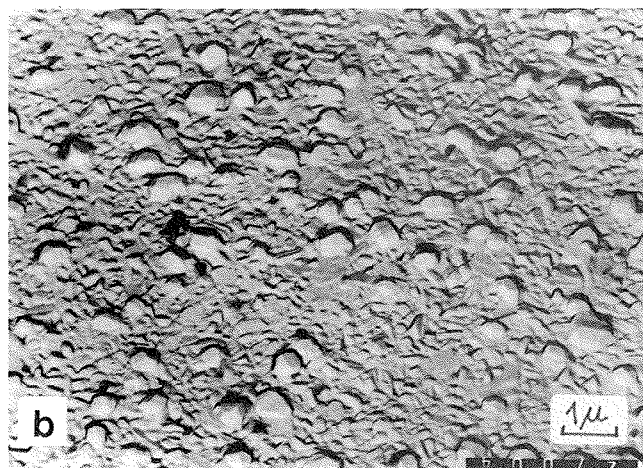
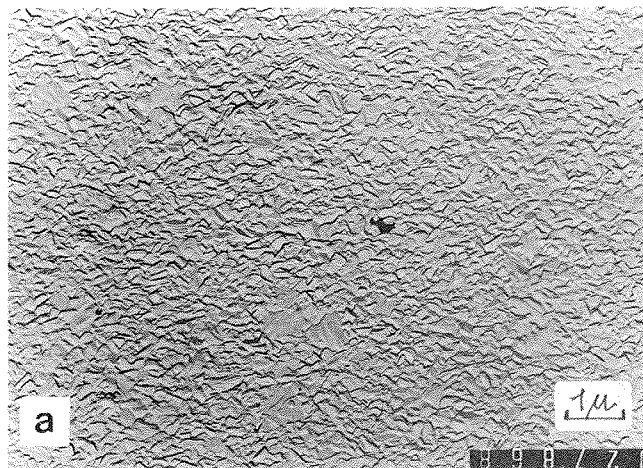


Fig. 5: Electron micrographs of surface replicas from 1 mm thick films completely treated in oxygen (a), and heated in nitrogen, then treated in oxygen (b).

surface while the whole thickness is important for resistivity.

Various heat treatments result in very different temperature characteristics. Annealing in oxygen with additional oxidation at 450°C resulted in relatively broad transition as measured through temperature dependence of resistivity. The resistivity began to drop at 80 K with $R = 0$ below 25 K for the sample which was heated at 2°C/min in oxygen. Negative temperature coefficient of resistivity in the normal state indicated the presence of tetragonal phase. Rapid heating (10°C/min) of the sample in nitrogen moved the transition start point between 85 and 90 K and end point ($R = 0$) to 60 K. Also, the temperature coefficient became positive in the normal state. In contrast to many authors who reported the benefits of oxidation above 400°C for several hours, our experience

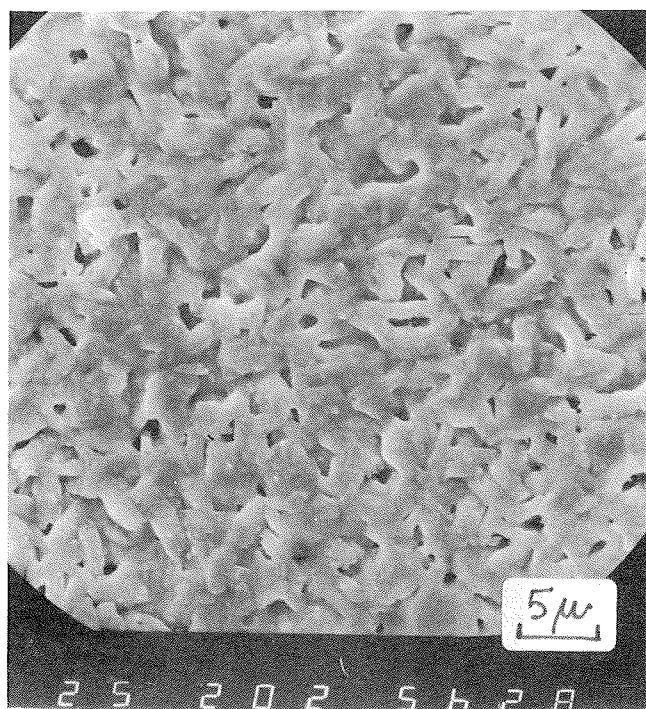


Fig. 6: SEM micrograph of YBCO film on MgO, annealed at 850°C in nitrogen and cooled down in oxygen.

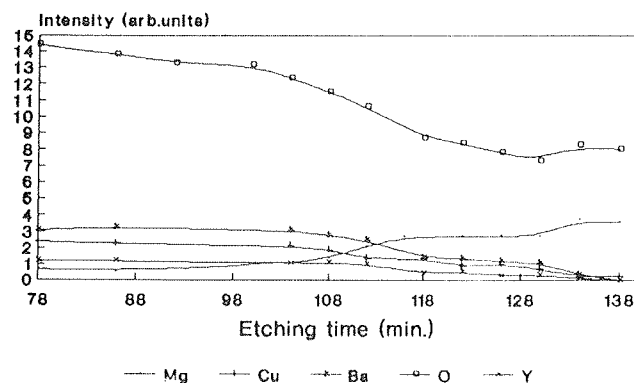


Fig. 7: AES film depth profile of YBCO/MgO junction after 850°C annealing in nitrogen and cool down in oxygen.

suggests to abandon this step - the slow cooling ($1^{\circ}\text{C}/\text{min}$ in oxygen) alone moved the transition end point to 80 K. Fig.4 shows temperature dependence of resistivity for different annealing procedures.

Surface replicas were taken to look at the grain size. For the films that were heat treated in oxygen only the grain size was in the range around $0.4\text{ }\mu\text{m}$, while fast heating in nitrogen caused the grains to grow up to $2\text{ }\mu\text{m}$, on the average, as illustrated in Figs. 5a, 5b and 6.

Optical inspection of films under microscope revealed, that films heated in nitrogen were porous. In some cases the nucleation process was so strong, that a $1\text{ }\mu\text{m}$ film thickness was not satisfactory to enable full substrate coverage after the furnace annealing process. On the other hand, films full time annealed in oxygen were homogenous what is in agreement with above mentioned differences in grain sizes.

CONCLUSIONS

Various heat treatments were tested for Y-Ba-Cu-O films sputter deposited onto (100) MgO substrates. Raman light scattering spectra and X-ray diffraction patterns were taken for heat treated films together with temperature dependence of resistivity. As deposited films were amorphous and insulating (at room temperature their resistivity was in $\text{M}\Omega$ range). Rapid heating ($10^{\circ}\text{C}/\text{min}$) in nitrogen enhances the grain growth to about $2\text{ }\mu\text{m}$ compared to $0.4\text{ }\mu\text{m}$ when heated up in oxygen. The taken spectra indicate the dominance of orthorhombic $\text{YBa}_2\text{Cu}_3\text{O}_{7\pm 0.1}$ phase but also the presence of BaCuO_2 phase. The resulting resistivity characteristics were improved considerably. Our best films had critical temperature around 85 K and transition width of

5 K. The temperature coefficient of resistivity in normal state was positive.

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T9000 - A NEW GENERATION TRANSPUTER (It's architecture and applications) Part II

Zlatko Bele

KEY WORDS: transputer, T9000, multiprocessing, embedded computer systems, Virtual Channel Processor, programmable memory interfaces, communications subsystems, application

ABSTRACT: In this two part article a new generation transputer T9000 is described. Part I deals with it's basic concept and architecture, while Part II describes main areas of it's applications.

T9000 - TRANSPUTER NOVE GENERACIJE (Zgradba in uporaba) II.del

KLJUČNE BESEDE: transputerji, T9000, multiprocesiranje, sistemi z računalnikom, virtualni kanalski procesorji, programabilni pomnilniški vmesniki, komunikacijski podsistemi, uporaba

POVZETEK: Omenjeni članek v dveh delih opisuje transputer nove generacije T9000. V prvem delu je podan osnovni koncept in zgradba T9000, v drugem pa so opisana glavna področja in načini njegove uporabe.

INTRODUCTION

In terms of applications the T9000 has been specifically designed for embedded applications, which make special demands on a processor in terms of its ability to switch context efficiently when responding to system interrupts or time slices between tasks.

The T9000 provides direct hardware support for context switching and process scheduling with sub-microseconds response time for multiple level interrupts. Furthermore, its unique virtual channel communications model provides direct hardware support for message passing. The ability to handle a single task error such as overflow without resetting the system is an exclusive feature of the T9000. There is no other microprocessor which is able to achieve this attributes in a single design.

Main three applications areas for which the T9000 has been specifically developed are:

- imaging
- computing
- communications

IMAGING APPLICATIONS

The imaging market covers a broad spectrum of applications ranging from printers to image processing systems. These applications require the generations, manipulation and transmission of image data, high performance processing for tasks such as image compression, and Postscript interpretation. These applications demand efficient communication links for I/O and a high level of system integration for minimal system size and cost. The current range of transputers effectively supports imaging applications with a range of performance options and multiprocessing capabilities. The T9000 offers, in addition to its high performance, single cycle bit and byte manipulation for fast image data handling and a fast 2-D block move function for image movement.

* Page printers

System cost and software support are key elements in any high volume laser printer design and consequently the choice of the CPU is the focus for laser printer designers. The T9000 has all the necessary characteristics for mid-range and high-performance laser printers not only as a uniprocessing solution but also as a truly scalable element within a multiprocessing system. It provides the raw processing power essential for image manipulation, and has the added benefit of an efficient Postscript interpreter.

Typical characteristics for this kind of applications are :

- 200 MIPS peak integer performance
- 25 MFLOPS peak integer performance
- Postscript support available
- C-Exec real time kernel available
- 10X raster image performance of current single processor laser solutions
- High speed DMA link technology working concurrently with CPU for image data transfer to main memory, print engine and host interfaces
- Low memory interface costs, direct interface to 8 Mbytes DRAM (including on-chip refresh logic)

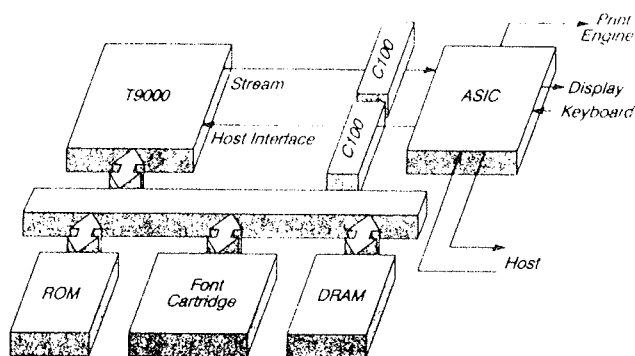


Fig. 1: Page printer application

X - Terminals

Having a workstation dedicated to a single user can be an expensive solution. X - Terminals bring the features of a workstation to the desktop: local intelligence, processing power and communications at a price of a standard personal computer. The transputer family offers a variety of solutions from low and monochrome systems using the T4 family to high-end, high-resolution colour systems using T9000.

Typical characteristics for this kind of applications are :

- Industry software including full port of X11R4 and TCP/IP
- Scalable performance
- System level solution - T9000 and IMS G3XX Colour Video Controller
- Fast single cycle bit manipulation for graphics operation
- 2-D block move instruction
- Hardware concurrency to support communications, local computation and display management simultaneously
- Direct support for 8 Mbytes of DRAM (on-chip refresh logic)

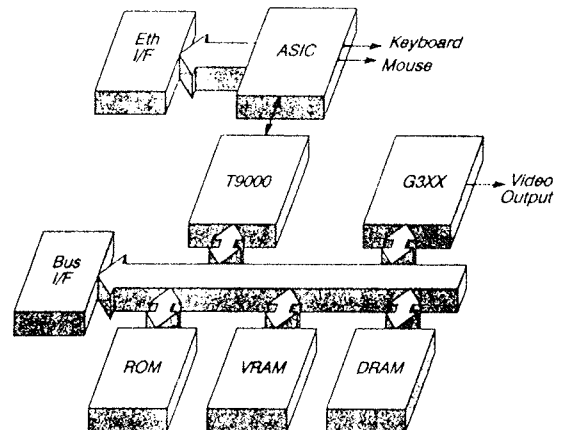


Fig. 2: X-terminal application

* Scanners

Similar in application to laser printers, but with an emphasis on data stream manipulation, scanners present designers with several problems: high speed data stream routing, image compression and optical character recognition. The T9000, unlike most microprocessors, has the processing power to cope with all these areas.

Typical characteristics for this kind of applications are:

- High performance for optical character recognition and image compression algorithms
- Link concurrency with CPU for simultaneous image manipulation and data transfer
- High integration for low cost and size
- 80 Mbytes/serial data transmission capability

COMPUTING

The T9000 offers many ways of increasing system performance. The T9000's 200 MIPS peak execution rate and 25MFLOPS peak floating point performance, coupled with the ability to build multiprocessor systems, means that thousands of MIPS and hundreds of MFLOPS can be employed to achieve almost unlimited real-time performance. Alternatively, system performance can be increased by employing the T9000 in subsystems such as disk arrays, application accelerators etc.

*Disk arrays

Whatever the power of the central processor in a main-frame or workstation, a major bottleneck is in the data storage subsystem. System down-time in many cases

can be narrowed down to failure of a hard disk drive within the infrastructure. The way ahead lies with an array of disks rather than one single large capacity drive. The speed of data retrieval has become a major issue in disk system design and a fault tolerant architecture has become a necessity. The T9000, along with the rest of the transputer family, is suitable for disk array design in mainframe, workstation or PC.

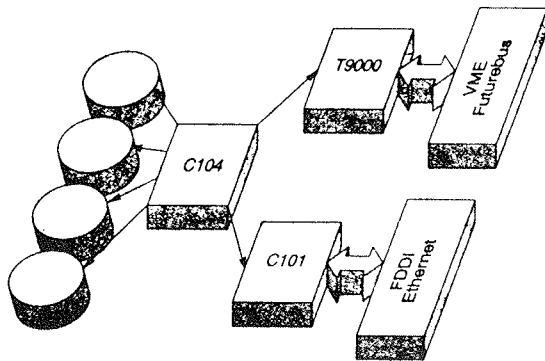


Fig. 3: Disk array application

Typical characteristics for this kind of applications are:

- Link technology operating at 5 times the speed of SCSI.
- Fault tolerant design capability without external arbitration logic
- Scalable architecture allows any configuration
- CRC error checking algorithms can be executed as a concurrent process

* Application accelerators

Used as an embedded processor in application accelerators, the transputer provides transparent processing power to overcome the problems of increased performance requirements. From PCs to mainframes there will always be a need for more processing power, regardless of the application running or the number of users.

Transputer-based application accelerators speed up dedicated software such as financial modelling packages, relational data bases and complex numerical algorithms, leaving the host CPU to concentrate on the system tasks for which it was intended.

Typical characteristics for this kind of applications are:

- Scalable solutions for performance upgrades to main frames/PCs/workstations etc.
- Links to parallel interface chips
- Standard range of motherboards and modules for many hosts
- Driver software availability

Supercomputers

Natural, scientific, engineering and commercial tasks are inherently parallel. Sequential processors are often unable to perform complex calculations such as finite element analysis, computational fluid dynamics and geographical survey analysis efficiently. The transputer offers almost limitless performance through its modular, scalable architecture and parallel and multi processing capabilities. The virtual channel concept of the T9000 and the dynamic configurability of the C104 packet routing switch allow supercomputer designers to incorporate various network topologies- N-cube, hypercube, tree, mesh, ring, toroid etc. -within the same system. A key requirement for any large parallel computer is the ability for each individual node to communicate with others. In T9000/C104 networks, wormhole routing techniques ensure that message latency is minimised and transmission is continuous, allowing the construction of large systems with full node connectivity.

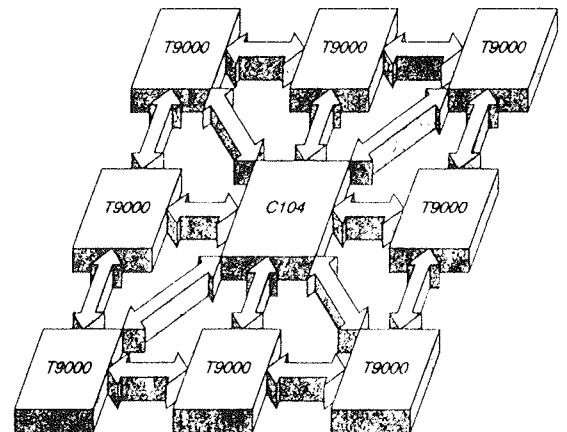


Fig. 4: Supercomputer application

Typical characteristics for this kind of applications are:

- Exceptional performance - 200 MIPS, 25 MFLOPS (peak)
- Minimal link latency
- Dynamically configurable network topologies using C104 routing switch
- Modular, scalable, parallel architecture
- Virtual channel message passing capability in hardware

Robotics

From spot-welders to automotive production line installation, real time control of machinery is vital to efficient production. Communications capability is essential in a

control system since processing nodes in remote locations often need to relay information about their status to a central control unit. The numerous axes of a robotic arm can now communicate and relay position and attitude data to each other for accurate and fast positioning through the use of transputer's link technology. The ability to build fault tolerant systems with ease is also important; sub-microseconds response time is crucial for safety-critical systems.

The transputer family provides the essential communications and multiprocessing capability for large and complex control systems. The T9000's unique ability to pre-emptively schedule and reschedule interrupts to the pipeline, and to use the interrupts as outputs, gives flexible real-time responsiveness.

Typical characteristics for this kind of applications are:

- Multitasking kernels available for real-time control-VRTX and C-Exec
- Sub microsecond pipelined interrupt scheduling
- Integrated Floating point Unit for accurate positional control
- Ability to mix current and T9000 family members for optimum system efficiency
- Pre-emptive scheduling of interrupts

COMMUNICATIONS

The worldwide telecommunications market is going through a period of tremendous change, with new communications standards and technologies creating new growth markets. Digital computer networking and network interconnection, the digitisation of telephone networks, and new markets like cellular radio all place greater reliance on processing performance and software than previous analog systems.

*Internetworking

The market for the equipment that interconnects different networks together, bridges, routers, gateways, etc., has experienced rapid growth as corporations seek to unify their networking operations. Increasingly sophisticated protocols and higher data rates, particularly with 100 Mbit/s FDDI standard, raise the processing performance required significantly. The shared-bus architecture adopted in many of these multi-processing systems becomes a significant bottleneck as data rates increase, resulting in a reduction in performance and network throughput.

Using the T9000 with its high-speed communications capability, for the interface card controllers to token-ring, ethernet, FDDI, etc. and the low latency C104 packet routing switch, bridges routers and gateways can be constructed using the dynamic message routing architecture which naturally fits the application.

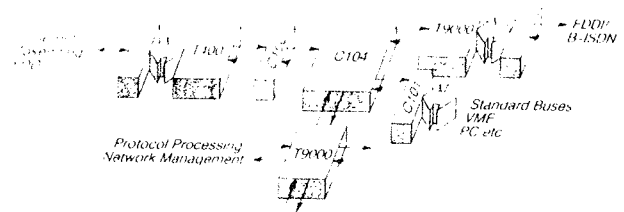


Fig. 5: Internetwork application

Typical characteristics for this kind of applications are:

- Single CPU performance up to 200 MIPS for fast, efficient protocol processing
- Scalable, multi-processing architecture supports flexible, modular equipment design
- Serial link speeds up to 100Mbits/s provide fast, flexible interprocessor communications
- Sophisticated message-passing architecture avoids limitations of bus-based systems

*Switching

Telephone switches, from small digital PABXs to large Central Office exchanges, are classic examples of real-time, distributed multiprocessing systems. The message-passing architecture of the transputer family provides an ideal foundation for switch control systems, offering a close match to the message-passing requirements of these applications. A choice of interfacing techniques through links or bus-based cards like VME, offers a smooth migration path for the large systems that, of necessity, must evolve. At the same time, the latest generation of transputers and routing chips offers new opportunities for smaller systems to avoid the performance bottlenecks of conventional bus-based systems.

Typical characteristics for this kind of applications are:

- High speed protocol processing
- Sub microsecond message routing latency using wormhole algorithms in hardware
- 32 way virtual channel Packet Routing Switch C104 allows nondirectly connected processors to communicate with minimal latency
- High speed interface between exchange and network using the new 100 Mbaud T9000 links

*Network Interfacing

Building cost-effective interfaces to today's high performance networks makes exceptional demands on the microprocessor at the heart of the interfacing system.

Higher data rates and increasingly sophisticated protocols require considerable processing performance, for today's networks and for emerging communications standards. At the same time, user demand for lower prices places greater pressure on the interface designer to minimise system cost.

Whatever the system, from low speed 64 kbit/sec ISDN through Ethernet to FDDI and Broadband ISDN interfaces, from single processor add-in cards to distributed multiprocessing systems such as telephone switches, the transputer family satisfies all communications systems requirements.

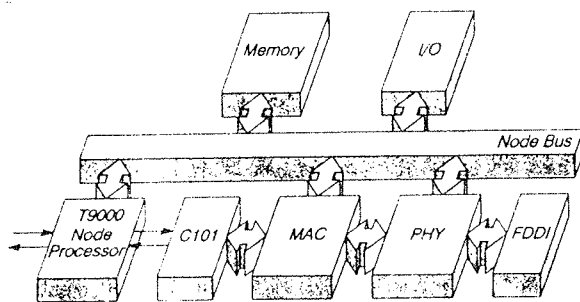


Fig. 6: Network interfacing application

Typical characteristics for this kind of applications are:

- High performance interfacing to high speed digital networks, e.g. ISDN, FDDI, Ethernet/token ring
- High integration for low system cost
- 200 Mbytes/Programmable Memory Interface to all types of memory with minimal external logic. (No external circuitry for up to 8Mbyte DRAM).
- VRTX and Chorus (distributed UNIX) software available)

*Mobile communications

Cellular radio has seen spectacular success since its introduction in the early 1980s. New digital cellular standards like the PAN-European 'GSM', new systems such as Personal Communications Network(PCN), and the next-generation 'Digital European Cordless Telephones '(DECT) set the scene for further growth.

The massive scale of these new networks and the speed with which they have to be installed make it even more important to keep infrastructure investment as low as possible. With base station and handset processing requirements rapidly increasing as the networks go all-digital, the transputer family offers performance, and a flexible upgrade path at the lowest possible price.

Typical characteristics for this kind of applications are:

- Simple multiprocessing for flexible, modular base station design
- Low component cost+high integration=low system cost
- Low cost control of 'RF line cards'
- Base station control and management functions
- High performance protocol processing for call set-up/clearance

*Satellite communications

There is no more demanding environment for any type of system than Space. Transputer is also here found as an ideal mean for the on-board processing systems of orbital vehicles and probes.

Typical characteristics for this kind of applications are:

- High integration/low system cost means space saving design and low mass
- Good intrinsic radiation tolerance
- Multiprocessing capability means easy to build multiple-redundant fault tolerant system

*Global positioning

The T9000's fast, autonomous serial links, high performance CPU and low-cost package provide all the elements necessary for building a complete GPS receiver. All signal processing can be performed in software by the CPU, eliminating a costly ASIC, whilst interfacing to the RF front-end is simplified enormously through the use of the serial links.

The range of devices in the transputer family means the designer can easily make the right cost/performance decision. T4/T8 transputers provide an ideal performance level for the commercial GPS 'P'-code products, whereas the T9000 can satisfy the demanding requirements for 'Y'-code system.

Typical characteristics for this kind of applications are:

- Economical single processor solution
- Low system cost
- Fast acquisition time
- Low power requirements
- No custom hardware required
- Global positioning software availability
- High accuracy positional determination
- Powerful enough for both 'P' and 'Y' code implementations

*Military

Imaging, communications and control are all applicable to the military market.

All transputer products are compliant to the high quality Mil- Std-883C, and the T9000 brings a new level of processing capability to the military segment. The high speed core of T9000 allows the use of a general purpose processor in applications as diverse as phased array radar and fault tolerant control system. Its integer and floating point capability mean that is an ideal vehicle for signal analysis applications such as image processing and data acquisition. The high I/O capability enables the T9000's use in control applications for fast reaction to transducer input for ultimate real-time response. The

T9000 is also supported by verified software in the form of ANSI C and the military standard ADA.

Po interni dokumentaciji SGS-THOMSON/INMOS priredil:

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MIKROIKS d.o.o.
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SLOVENIJA

Prispelo: 08.09.92

Sprejeto: 18.09.92

PRIKAZI DOGODKOV, DEJAVNOSTI ČLANOV MIDEM IN DRUGIH INSTITUCIJ

Mednarodni sistem ocenjene kakovosti elektronskih elementov IECQ

UVOD

Vključevanje nacionalnih gospodarstev v mednarodno delitev dela zahteva od vsake države sistematičen in koordiniran nastop.

Odpravljanje fizičnih, tehničnih in fiskalnih meja, postopno zbliževanje zakonodaj, poenotenje predpisov, harmonizacija standardov ipd., so le zunanji okviri, ki pospešujejo to zbliževanje.

Zato so izjemno pomembna prizadevanja, da bi se tudi Slovenija čimprej pridružila sodobnim integracijskim procesom, ki v Evropi in svetu že potekajo ter si s tem zagotovila pogoje za polnopravno vključevanje in sodelovanje, oz. odstranila vse ovire, ki takšna prizadevanja kakorkoli zavirajo.

Med obetavnejša znamenja in kot potrditev upravičenosti večletnih prizadevanj lahko uvrstimo tudi vključevanje Slovenije v Sistem ocenjene kakovosti elektronskih elementov IECQ (IEC Quality Assessment System for Electronic Components), vključitev v enega od dveh sistemov preskušanja in certificiranja proizvodov vzpostavljenih v okviru Mednarodne elektrotehniške komisije IEC (International Electrotechnical Commission).

V prispevku je osrednja pozornost namenjena seznanjanju s sistemom IECQ kot vzpodbuda za hitrejše uvajanje sistema v Sloveniji. Seveda pa predstavitev sistema ocenjene kakovosti elektronskih elementov ne bi bila ustrezna brez vzporednega opisa splošne filozofije kakovosti, sistemov kakovosti in dejavnosti Mednarodne elektrotehniške komisije IEC.

Opozoriti je treba na dejstvo, da je sistem IECQ primer, ki zgovorno kaže, kako se vprašanja kakovosti sistematično rešujejo v svetovnem merilu.

POMEN KAKOVOSTI

Kakovost proizvodov je pri vključevanju na zahtevne in konkurenčne trge ključnega pomena. Minimalna zahteva pri tem je gotovo, da naj bo kakovost proizvodov primerljiva s kakovostjo sorodnih, konkurenčnih proizvodov.

Zagotavljanje kakovosti postaja prioriteta narodno-gospodarska naloga, ki se na izvedbeni ravni sooča z

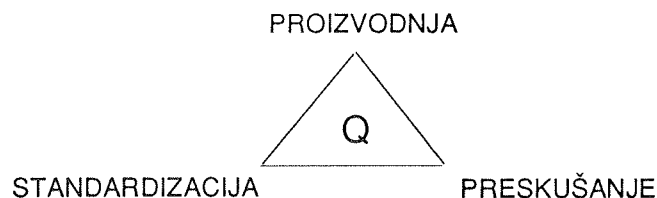
vrsto konfliktnih situacij, še zlasti z vprašanji optimiranja med težnjami po vrhunski kakovosti in konkurenčnosti na eni ter ekonomskimi možnostmi, tehniško-tehnološko usposobljenostjo in vzporedno se porajajočimi ekološkimi in zdravstvenimi problemi na drugi strani.

Na nivoju posamičnega nacionalnega gospodarstva, oz. sektorja gospodarstva, je mogoče zahteve po visoki kakovosti sistematično izpolnjevati le v kolikor je zagotovljena učinkovita povezava treh bistvenih vitalnih funkcij vsakega gospodarskega sistema: standardizacije, proizvodnje in preskušanja (glej sliko št. 1).

Za optimalno delovanje sistema nacionalnega gospodarstva je važno, da so cilji in naloge vsakega od navedenih elementov kar najbolj jasno postavljeni.

Tako je ena najpomembnejših nalog standardizacije v tem, da oblikuje sistem harmoniziranih standardov, ki naj bo v celoti skladen s sistemi mednarodnih standardov. Vzporedno s tem mora vzpostaviti nacionalne sisteme preskušanja in certificiranja, ki naj omogočijo neposredno vključevanje v mednarodne sisteme (sheme) preskušanja in certificiranja; pri tem velja poudariti, da vključevanje in sodelovanje v omenjenih sistemih temelji na principih recipročnega priznavanja rezultatov preskusov in potrdil (certifikatov) o ustreznosti.

Ena od ključnih usmeritev slovenske standardizacije mora biti kar najbolj aktivno delovanje v Mednarodni organizaciji za standardizacijo (International Organization for Standardisation - ISO) ter spremljanje dela Evropskega komiteja za standardizacijo CEN (Comité Européen de Normalisation), ki povezuje članice Evropske gospodarske skupnosti (EGS) in članice Evropskega sporazuma o svobodni trgovini in prometu (EFTA). Na področju elektrotehnike pa je pomembno delovati v telesih in tehniških odborih Mednarodne elektrotehniške komisije IEC ter spremljati delo Evropskega komiteja za elektrotehniko CENELEC (Comité Européen de Normalisation Electrotechnique).



Slika 1: Elementi sistema kakovosti na nivoju (sektorja) nacionalnega gospodarstva

Proizvajalci bi morali pri proizvodnji v kar največji možni meri upoštevati minimalne zahteve, izražene v harmoniziranih nacionalnih in mednarodnih standardih ter v podjetjih vzpostaviti sisteme kakovosti v smislu zahtev skupine standardov s področja vodenja in zagotavljanja kakovosti. Nacionalni standardi s področja sistemov kakovosti naj bi bili vsklajeni z mednarodnimi standardi skupine ISO 9000 (Quality management and quality assurance standards), oz. standardi skupine EN 29000.

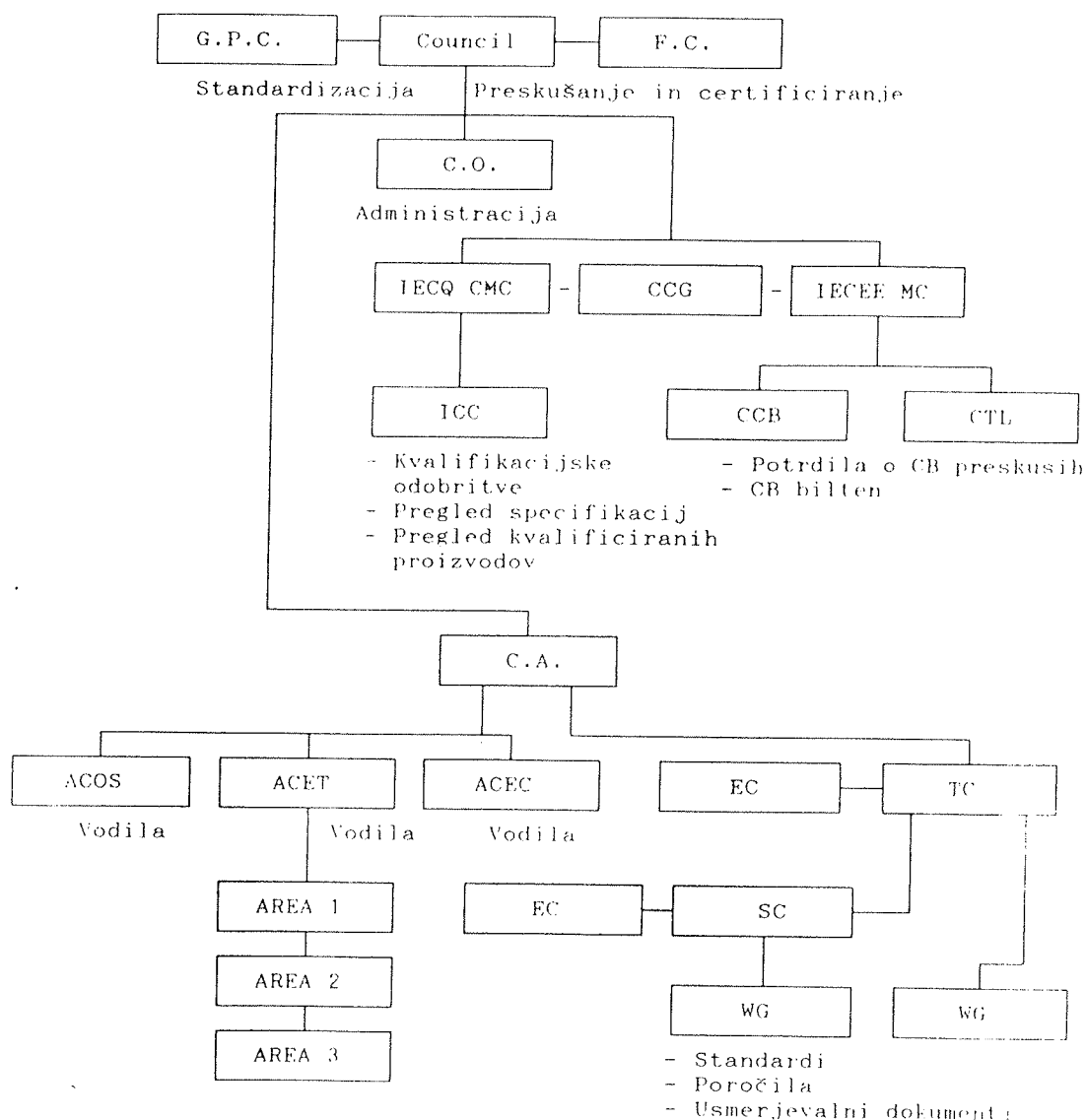
Podjetja bi si morala prizadevati doseči status odobrenih proizvajalcev, usposobljenih za proizvodnjo v sistemih ocenjene kakovosti.

Mednarodno priznana neodvisna preskuševališča pa bi morala biti v kar največji možni meri usposobljena za izvajanje preskusov in postopkov v smislu zahtev nacio-

nalnih in mednarodnih standardov ter za izdajanje listin o ustreznosti, to je certifikatov in atestov.

DEJAVNOST MEDNARODNE ELEKTROTEHNIŠKE KOMISIJE IEC

Dejavnost Mednarodne elektrotehniške komisije IEC pokriva široko problematiko mednarodne standardizacije na področju elektrotehnike in elektronike ter tako dopolnjuje dejavnost Mednarodne organizacije za standardizacijo ISO, ki pokriva vsa ostala področja. Obe organizaciji, ISO in IEC, tvorita specializiran sistem svetovne standardizacije in sodelujeta na vseh področjih, ki zadevajo skupne cilje mednarodne standardizacije.



Slika 2: Organizacija Mednarodne elektrotehniške komisije IEC

Dejavnost Mednarodne elektrotehniške komisije pokriva v glavnem dve področji: področje standardizacije ter področje preskušanja in certificiranja (glej sliko št.2).

Mednarodna elektrotehniška komisija izdaja standarde IEC, ki izhajajo kot dvojezične publikacije istočasno v francoščini in angleščini. Standarde pripravljajo mednarodni sekretariati tehniških odborov, oz. pododborov, katerih sedeže prevzamejo zainteresirani nacionalni komiteji.

Sedež Mednarodne elektrotehniške komisije je v Ženevi, kjer je centralni urad, ki ga vodi generalni sekretar, ki ga imenuje svet načelno za neomejeno dobo. Najvišji organ Mednarodne elektrotehniške komisije je Svet, ki ga sestavljajo predsedniki nacionalnih komitejev vseh držav članic. Delo tehniških odborov usmerja akcijski komite, ki ga sestavljajo predsedniki 12 nacionalnih komitejev.

Na področju standardizacije danes v nad 200 tehniških odborih in pododborih, sodeluje nekaj deset tisoč specialistov iz 42 držav članic, v katerih sicer živi 80 % svetovnega prebivalstva.

V okviru dejavnosti preskušanja in atestiranja sta vzpostavljena dva sistema: Sistem IECQ (IEC sistem ocenjene kakovosti elektronskih elementov) in sistem IECEE (IEC sistem za preskušanje ustreznosti standardom za varnost električnih izdelkov).

Pomen kratic:

Council = Svet

G.P.C. - General Policy Committee = Komite za splošno politiko

F.C. - Finance Committee = Finančni komite

C.A. - Committee of Action = Akcijski komite

ACOS - Advisory Committee on Safety = Svetovalni komite za varnost

ACET - Advisory Committee on Electronics and Telecommunications = Svetovalni komite za elektroniko in telekomunikacije

ACEC - Advisory Committee on Electromagnetic Compatibility = Svetovalni komite za elektromagnetno kompatibilnost

TC - Technical Committee = tehniški komite

EC - Editing Committee = uredniški komite

SC - Sub-Committee = podkomite

WG - Working Group = delovna skupina

C.O. - Central Office = Osrednji urad

IECQ - IEC Quality Assessment System for Electronic Elements = EC sistem za ugotavljanje kakovosti elektronskih elementov

CMC - Certification Management Committee = Komite za vodenje certificiranja

ICC - Inspectorate Co-Ordination Committee = Komite za koordinacijo inšpektoratov

IECEE - IEC System for Conformity Testing to Standards for Safety of Electrical Equipment = IEC sistem za preskušanje ustreznosti standardom za varnost električnih izdelkov

MC - Management Committee = Vodilni komite

CCB - Committee of Certification Bodies = Komite organov za certificiranje

CTL - Committee of Testing Laboratories = Komite preskusnih laboratorijev

CCG - Certification Consultative Group = Svetovalna skupina za certificiranje

AREA 1 - Electronic elements = Elektronski elementi

AREA 2 - Measurement and Control, including control of power flow by electronic means (equipment and systems) = Meritve in nadzor, vključno z nadzorom pretoka energije s pomočjo elektronskih sredstev (naprav in sistemov)

AREA 3 - Telecommunications, information technology and associated electronic equipment = Telekomunikacije, informacijska tehnika in pripadajoča elektronska oprema

SISTEM IECQ

Ker slovenskemu gospodarstvu po letu 1992 ne bo mogoč direkten vstop na skupno evropsko tržišče, ker nismo člani ES niti EFTA, moramo poiskati možnosti, da prek drugih priznanih sistemov certificiranja izdelkov našemu gospodarstvu omogočimo pristop na skupni evropski trg po letu 1992.

Za proizvajalce elektronskih in elektromehanskih elementov je za to najprimernejši sistem za zagotavljanje kakovosti elektronskih elementov - IECQ, ki deluje v okviru dejavnosti preskušanja in certificiranja pri Mednarodni elektrotehniški komisiji (IEC) kot svetovni sistem.

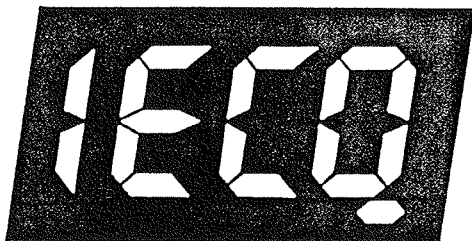
Cilj IECQ je olajšati mednarodno menjavo elektronskih elementov na temelju recipročnosti priznavanja rezultatov preskušanj in certifikatov o ustreznosti posameznim standardom.

Ključni cilj sistema IECQ, proizvodnja in distribucija elektronskih elementov, naj bi bil dosežen z opredelitvijo postopkov ocenjevanja kakovosti tako, da bi bili proizvodi proizvedeni in distribuirani v skladu z zahtevami in standardi, ki so sprejemljivi za vse udeležence v procesu menjave. Kupec lahko elemente, ki so bili izdelani in distribuirani s strani odobrenih proizvajalcev in distributerjev, uporablja, ne da bi jih moral ponovno preskušati. S sistemom IECQ je vzpostavljen nov nivo zaupanja med proizvajalcem in uporabnikom elektronskih elementov, ki temelji na preverjeni in ocenjeni kakovosti.

Statut in poslovnik sistema IECQ sta bila po nekajletnih pripravah, upoštevajoč izkušnje CECC (Komite za elektronske elemente) in ECQAC (Odbor za zagotavljanje kakovosti elektronskih elementov) v okviru CENELEC, sprejeta na zasedanju sveta v Montreuxu leta 1981. Tedaj so bili izvoljeni tudi organi sistema, ki deluje v okviru IEC z lastnim finančnim proračunom.

Statut in poslovnik skupaj z osnovnimi pravili (Basic Rules) in pravili postopkov (Rules of Procedure) sistema IECQ, ki jih je skupaj z dopolnili sprejel svet IEC kot publikaciji QC001001 in QC001002, opredeljujejo tudi možnosti in način za sodelovanje v sistemu IECQ. Sistem IECQ je zasnovan tako, da ima država udeleženka (participating country) dve možnosti za sodelovanje. Z vstopom v sistem si pridobi pravico za sodelovanje v Komiteju za vodenje certificiranja (Certification Management Committee - CMC) in v Komiteju za koordinacijo inšpektoratov (Inspectorate Co-Ordination Committee - ICC), vendar pri sodelovanju v slednjem obstajata dve možnosti: lahko sodeluje kot svetovalna članica z omejeno pravico glasovanja ali kot polnopravna članica s pravico glasovanja v vseh zadevah komiteja, kar je odvisno od stopnje, do katere je v državi urejeno certificiranje elektronskih elementov in ali v njej obstaja potrjeni nadzorni inšpektorat.

Logotip sistema IECQ je predstavljen s pomočjo črk digitalnega prikazalnika s tekočimi kristali.



Slika 3: Logotip sistema IECQ

Za vključitev v sistem IECQ morajo v državi, deželi udeleženki, obstajati:

- nacionalni komite Mednarodne elektrotehniške komisije (National Committee of the IEC),
- pooblaščen institucija za vodenje sistema, (National Authorized Institution - NAI),
- organizacija za standardizacijo, ki izdaja standarde in druge listine, potrebne za delovanje sistema, (National Standards Organisation),
- nadzorni inšpektorat, ki odgovarja za nadzor postopkov za ugotavljanje kakovosti in potrjevanje ustreznosti, (National Supervising Inspectorate - NSI),
- organizacija za preverjanje merilnih instrumentov, (Calibration Service).

Ustrezno temu je potrebno doseči:

- odobritev nadzornega inšpektorata v državi udeleženki,
- odobritev proizvajalcev in njihovih laboratorijev,
- odobritev neodvisnih distributerjev, kadar ti obstajajo,
- odobritev neodvisnih preskusnih laboratorijev,
- določitev odgovornosti glavnega kontrolorja,
- izdajanje standardov, oz. specifikacij za delo v sistemu.

Za vstop v članstvo v CMC in ICC je treba predložiti predpisano dokumentacijo, za priznanje nadzornega inšpektorata pa je dodatno potreben obisk predstavnikov treh že obstoječih nacionalnih nadzornih inšpektoratov, ki morajo preveriti, ali nadzorni inšpektorat v državi udeleženki izpolnjuje vse zahteve v pogledu organizacije, opreme in kadrov.

Standardi in specifikacije v sistemu morajo biti obdelani po enotni strukturi, opisani v IEC Guide 102 (Specification structure of the quality assessment of electronic components), po kateri obstajajo naslednje stopnje specifikacij za elemente:

- osnovne specifikacije (basic specifications),
- rodovne specifikacije (generic specifications),
- področne specifikacije (sectional specifications),
- okvirne podrobne specifikacije (blank detail specifications),
- podrobne specifikacije (detail specifications).

Proizvajalci, distributerji in neodvisni preskusni laboratoriji iz dežel neudeleženk sistema imajo omogočen dostop do sistema IECQ po postopku, ki je opredeljen v publikaciji QC001002 tako za članice kakor za nečlanice Mednarodne elektrotehniške komisije.

Iz poročila predsedujočega v komiteju za vodenje certificiranja CMC (Junij 1989) lahko razberemo, da je tedaj v sistemu sodelovalo 23 držav s 14 potrjenimi nacionalnimi inšpektorati. Potrjenih je bilo 122 proizvajalcev, 32 distributerjev, 21 preskusnih laboratorijev in 99 elektronskih elementov.

V razvoju sistema je poleg težnje po vključevanju vse večjega števila držav udeleženk zaznaven tudi napredek v pogledu učinkovitega sodelovanja in povezovanju s sorodnimi sistemi in organizacijami, pri čemer velja omeniti zlasti naslednje primere:

a) Vključitev pravil standardov ISO 9000 med pravila IECQ,

kar naj odrazi skladnost zahtev v obeh sistemih. Pooblaščen institucija (NAI) bo lahko, na predlog nadzornega inšpektorata (NSI) v deželi udeleženki, potrdila skladnost sistema kakovosti proizvajalca, distributerja in neodvisnega preskuševališča z zahtevami standardov

ISO 9000. Določila o povezanosti pravil omenjenih sistemov bodo vnešena v dokumente obeh sistemov. V obravnavi na zadnjem zasedanju IECQ CMC in IECQ ICC o kompatibilnosti sistema ISO 9000 in pravil IECQ sistema, je bilo ugotovljeno, da razen dveh, večina v sistemu IECQ odobrenih proizvajalcev že izpolnjuje hkrati tudi zahteve sistema ISO 9000.

V tem pogledu je diskrecijska pravica nacionalne pooblaščenice institucije za vodenje sistema IECQ, da deklarira, da je sistem kakovosti, proizvajalcev, distributerjev in neodvisnih preskusnih laboratorijev v sistemu IECQ usklajen tudi z zahtevami standardov ISO 9000 (ISO 9001, 9002 ali 9003).

b) Postopek o privzemu CECC specifikacij v IECQ,

ki naj omogoči pooblaščenici instituciji (NAI) v deželi udeleženci, da privzame specifikacije CENELEC odbora za elektronske elemente CECC po podrobni primerjavi specifikacij CECC in IECQ, ugotovljena odstopanja pa poda CMC skupaj z dokumentom "IECQ obvestilo o privzemu CECC specifikacij", ki se nato obravnava po postopku, ki velja začasne specifikacije (Provisional Specifications) sistema IECQ.

V sistem CECC so vključene države EGS in EFTA, kar daje sistemu IECQ še večji poudarek.

c) Sporazum med IEC in CODUS Ltd.,

ki predvideva, da lahko banka podatkov Codus uporablja in dobavlja podatke, ki so last IEC. V to računalniško vodeno banko podatkov se zdaj, med drugim, vnašajo podatki o elektronskih elementih, ki so odobreni v okviru sistemov BS 9000, CECC in IECQ.

d) IEC se prav tako povezuje z organizacijo EXACT

(International Exchange of Authenticated Electronic Components Performance Test Data). Ta organizacija zbira in distribuira poročila o overjenih preskusih kakovosti in zanesljivosti elektronskih elementov; v organizaciji EXACT je zastopal Jugoslavijo Institut za kakovost in metrologijo (IKM) iz Ljubljane s statusom priznanega preskuševališča.

e) Povezovanje sistemov IECQ in CECC,

ki temelji na medsebojnem priznavanju certifikatov o ustreznosti.

SISTEM IS 9000 - PRVA LASTOVKA SISTEMA IECQ

V letu 1984 je bil v SOZD Iskra vzpostavljen sistem zagotavljanja kakovosti elektronskih elementov za profesionalno rabo po sistemu IS 9000. Zastavljen in izdelan je bil na osnovi pravil britanskega sistema BS

9000 in je v prvi stopnji harmoniziran ter kompatibilen s sistemi CECC in IECQ, v njem pa so se uporabljali standardi IEC in ISO.

Namenjen je bil uporabi v SOZD Iskra, dopuščal pa je možnost, da se vanj, po predhodnem soglasju vključijo tudi druge organizacije in skupnosti, proizvajalci in uporabniki elektronskih elementov, do vzpostavitve (v tedanji Jugoslaviji) mednarodnega sistema IECQ.

Sistem IS 9000, ki opredeljuje splošne zahteve za elektronske elemente, vsebuje dva dela:

- del I : Splošne značilnosti in osnovna pravila
- del II: Zagotovitvene standarde

V prvem delu so poleg predstavitve in definicij opisani tudi sistem standardov, postopki ocenjevanja, zahteve za odobritev organizacije kontrole in sposobnosti kontroliranja proizvajalcev, zahteve za odobritev preskusnih laboratorijev in distributerjev, naloge in pooblastila nadzornega inšpektorata, postopki kvalifikacijske odobritve elementov, prevzemnega vzorčenja, kontrole kakovostne ustreznosti. Na koncu so opredeljene zahteve, ki zadevajo potrdila o ustreznosti (Certificates of Conformity) in overjene zapise o preskusih (Certified test records - CTR).

V drugem delu je opisan sistem zagotovitvenih standardov, njihova struktura, preskusni postopki in zahteve za izdelavo podrobnih standardov.

Sistem standardov sestavljajo osnovni (temeljni in splošni) ter zagotovitveni (rodovni, področni in podrobni) standardi.

Temeljni standardi nosijo oznake IS 9100 do IS 9999, splošni standardi od IS 9000 do IS 9099, rodovni standardi od IS-Q.00.00 do IS-Q.01.99, področni od IS-Q.02.00 do IS-Q.04.99, podrobni standardi pa od IS-Q.05.00 do IS-Q.09.99. Podrobni standardi, ki jih pripravi proizvajalec v primeru, da ustreznega podrobnega standarda v sistemu IECQ ni (obstaja pa okvirni podrobni standard) nosijo oznake od IS-Q.10.00 do IS-Q.89.99.

Za pripravo in izdelavo podrobnih specifikacij (standardov) za posamezne elemente je v povezavi s proizvajalci zadolžena Iskra Standardizacija, uporabo standardov pa odobrava Nadzorni inšpektorat sistema IS 9000. Funkcijo neodvisnega preskusnega laboratorija opravlja Institut za kakovost in metrologijo, funkcijo proizvajalčevih preskusnih laboratorijev pa merilnice/preskuševalnice pri proizvajalcih.

Sistem IS 9000 je kompatibilen s sistemom IECQ, tako da je na ta način omogočen lažji prehod v mednarodni sistem.

SISTEM IECQ V SLOVENIJI

Za čimprejšnjo vključitev Slovenije v mednarodni sistem zagotavljanja kakovosti elektronskih elementov je v skladu z mednarodnimi pravili podana organizacijska shema IECQ v Sloveniji.

V tej shemi IKM namerava odigrati vlogo nacionalne pooblaščenice institucije, sodelovati pri formiranju nacionalnega nadzornega inšpektorata in biti neodvisni preskusni laboratorij. Dosedanje in bodoče povezave IKM z IECQ ter drugimi organizacijami, ki se na to navezujejo, so razvidne iz naslednjih shem, na slikah št.4 in št.5.

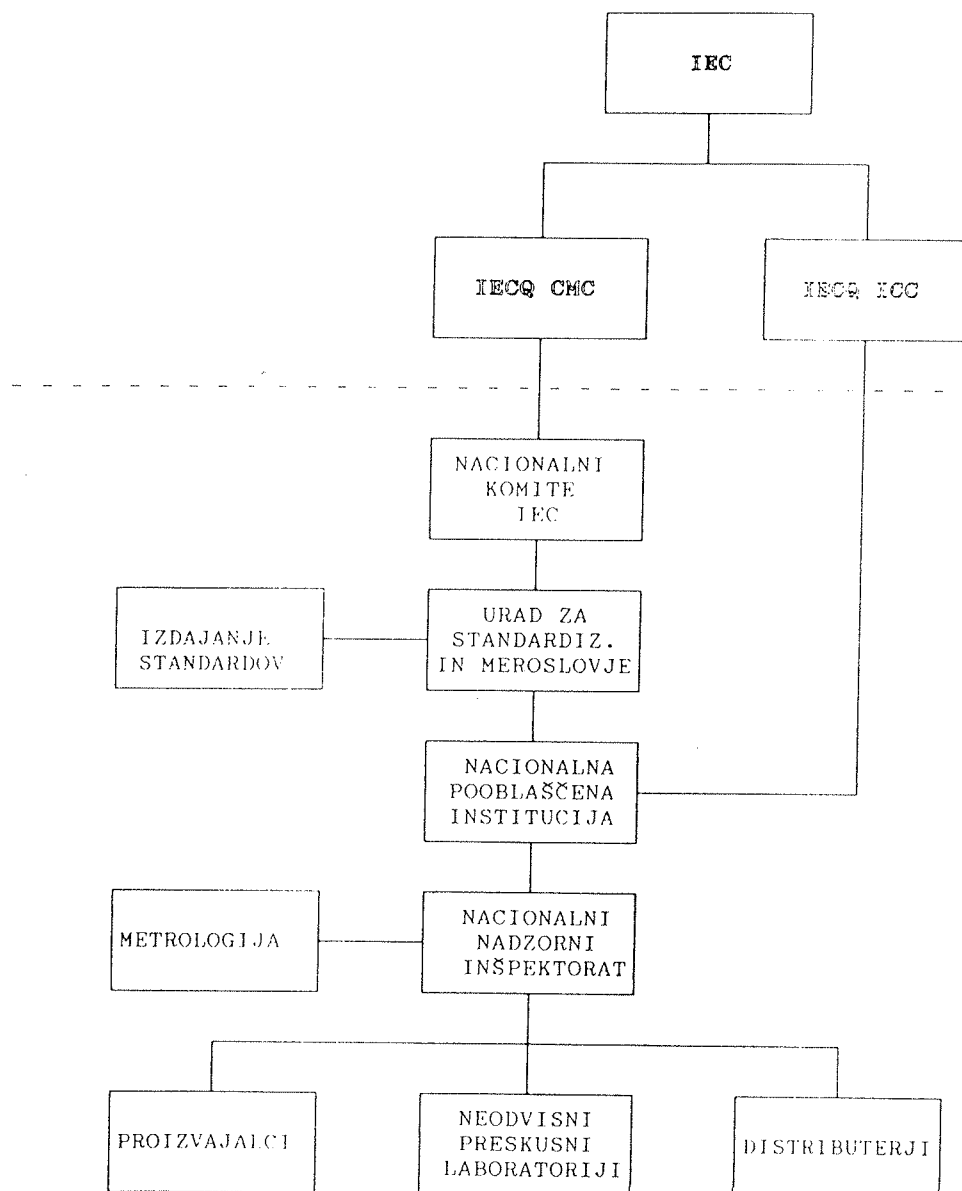
Kot prva institucija Slovenije s tega področja je bil pri Ministrstvu za znanost in tehnologijo ustanovljen Urad za standardizacijo in meroslovje (USM). Urad je pobudnik za ustanavljanje vseh ostalih institucij, potrebnih za vključitev v ta mednarodni sistem, pri čemer je nujno

potrebna vsa podpora zainteresiranih dejavnikov, zlasti še proizvajalcev elektronskih elementov, katerim je sistem IECQ prvenstveno namenjen. Zato je pričakovati, da bodo proizvajalci elektronskih elementov poslali na USM preliminarne prijave za svoje proizvode, s katerimi nameravajo stopiti v sistem IECQ.

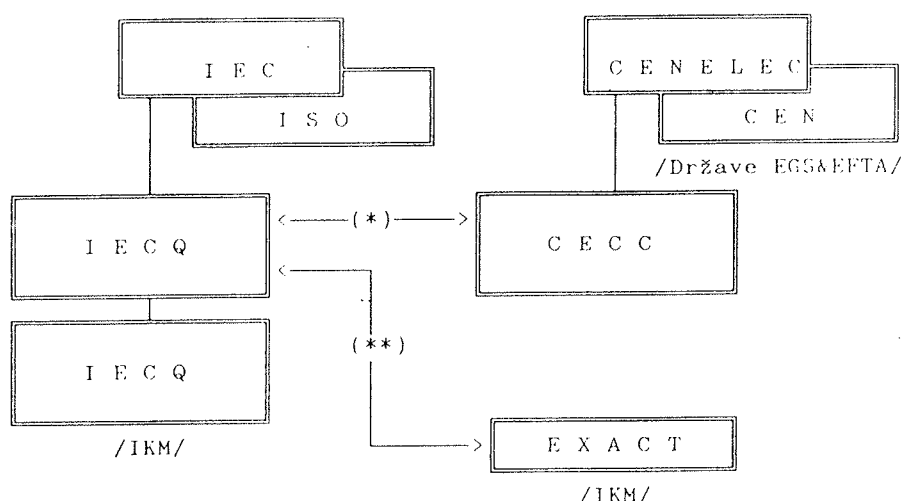
Splošna shema povezanosti mednarodnih, evropskih in državnih (nacionalnih) sistemov standardizacije, (tipskega) preskušanja (kakovosti) in certificiranja ustreznosti proizvodov s poudarkom na sistemih ocenjene kakovosti elektronskih elementov IECQ in CECC.

(*) Akcije za zблиžanje: zasedanje v Parizu 17.05.1991 in dokument IECQ-CMC WG23A.

(**) Poročilo o razvoju EXACT: dokument IECQ-CMC/Secretariat/253, marec 1989



Slika 4: Organizacija sistema IECQ v Republiki Sloveniji



Slika 5: Organizacija sistema IECQ v Republiki Sloveniji

Pomen kratic:

ISO: Mednarodna organizacija za standardizacijo
(International Organisation for Standardisation)

IEC: Mednarodna elektrotehniška komisija
(International Electrotechnical Commission)

CEN: Evropski komite za standardizacijo
(Comite Europeen de Normalisation)

CENELEC: Evropski komite za elektrotehniško standardizacijo
(Comite Europeen de Normalisation Electrotechnique)

CECC CENELEC komite za elektronske elemente
(CENELEC Electronic Components Committee)

EGS: Evropska gospodarska skupnost (12 držav)

EFTA: Evropsko združenje za svobodno trgovino (6 držav)
(European Free Trade Association)

EXACT: Mednarodna organizacija za izmenjavo overjenih podatkov o preskusih kakovosti elektronskih elementov (International Exchange of Authenticated Electronic components Performance Test Data)

IKM si je še v okviru Jugoslavije prizadeval za vzpostavitev ustreznega sistema na nacionalni ravni in za pridobitev statusa pooblaščenega laboratorija. V lanskem letu smo v okviru razvojno- raziskovalnih projektov pri MZT izvajali projekt IECQ, katerega cilj je bil postavitev

osnov za delovanje sistema IECQ v Sloveniji. V letošnjem letu delo na projektu nadaljujemo.

Laboratorij za elektronske elemente ima že dolgoletno tradicijo in izkušnje na področju preskušanja elektronskih elementov. Preskusna in merilna oprema, ki jo laboratorij poseduje za izvajanje tovrstnih preskusov, pokriva zelo širok spekter proizvodov.

Naša preliminarne prijava za pooblastilo kot preskusni laboratorij v sistemi IECQ zajema naslednja področja splošnih standardov:

- nespremenljivi kondenzatorji (QC 300000),
- nespremenljivi upori (QC 400000),
- potenciometri (QC 410000),
- diskretni polprevodniki (QC 700000),
- elektromehanski elementi (QC 960000).

S tem je hkrati tudi nakazana pot proizvajalcem elektronskih elementov za vključevanje v mednarodno gospodarstvo.

Po osnovnem članku avtorjev:

M. BORKO

F. MLAKAR

T. TEKAVEC

priredil in dopolnil T. Tekavec, IKM

Tržaška 2, Ljubljana

PREDSTAVLJAMO PODJETJE Z NASLOVNICE

GORENJE POINT DRUŽINA OSEBNIH RAČUNALNIKOV DIALOG

DIALOG 286, DIALOG 386SX, DIALOG 386, DIALOG 486 IN DIALOG NB - notesnik sestavljajo družino osebnih računalnikov DIALOG.

Raznovrstnost konfiguracij, ergonomske rešitve, visoka zmogljivost in kakovost so odlike majhne, toda uspešne družine osebnih računalnikov DIALOG. Člani družine se med seboj razlikujejo po procesorju na osnovni plošči. S številnimi dodatnimi opcijami vam v podjetju Gorenje Point omogočimo, da računalnik prilagodite izbranim nalogam. Ponujamo vam različne grafične kartice z ustreznimi monitorji, trde diske različnih kapacitet, tiskalnike, kasetne tračne enote, mrežne kartice, miške...

Osebne računalnike DIALOG na vašo željo opremimo s preiskušeno programsko opremo uveljavljenih programskih hiš, ali pa vam v podjetju Gorenje Point izdelamo programske pakete po vaših zahtevah.

Če želite osebne računalnike DIALOG povezati v učinkovito računalniško mrežo, vam bomo pomagali pri njenem načrtovanju, izgradnji in vzdrževanju. Gorenje Point je uradni pooblaščen prodajalec (Authorized Reseller) računalniških mrež Novell.

Predstavitev članov družine osebnih računalnikov DIALOG pričnimo z najmočnejšim - DIALOGOM 486. Intelov 486 mikroprocesor z internim vmesnim pomnilnikom in matematičnim koprocetorjem mu daje moč, ki je primerljiva z zmogljivimi mini računalniki.

DIALOG 486 EISA

je najmočnejši računalnik izmed DIALOGOV 486. Zaradi vse bolj razširjenega in zelo zmogljivega 32 bitnega EISA (Extended Industry Standard Architecture) vodila, ga bo mogoče razširjati in dograjevati tudi v prihodnje. Istočasno pa ohranja združljivost z zelo razširjenimi ISA moduli. Nakup tega računalnika ne more biti zgrešena investicija, uporabljene najmodernejshe tehnične rešitve bodo dolgo ohranile njegovo aktualnost. Ker temelji na najnovešem 32 bitnem vodilu, je osebni računalnik DIALOG 486 EISA zmogljivejši od večine mini računalnikov.

V DIALOG 486 EISA je vgrajen Intelov i486 mikroprocesor. Poleg internega vmesnega pomnilnika (8K zlogov) in z 80387 združljivega koprocetorja nudi 64K ali 256K zlogov zunanega vmesnega pomnilnika. Omogoča tudi dograditev še močnejšega koprocetorja Weitek 4167. Pomnilnik je od 4MB mogoče razširiti do 64MB. Prostorno ohišje omogoča vgradnjo največ osmih diskovnih

pogonov polovične višine. Tako je mogoče računalnik opremiti z diski kapacitete od 200MB do 2GB.

DIALOG 486 EISA je kot grafična delovna postaja, večuporabniški sistem ali mrežni strežnik gotovo prava izbira.

DIALOG 486 ISA

S trikratno hitrostjo 386-33MHz računalnika je DIALOG 486 ISA idealen zelo zmogljiv mrežni strežnik ali grafična delovna postaja. Tudi vanj je vgrajen Intelov i486 mikroprocesor s taktom 33MHz, internim vmesnim pomnilnikom in koprocetorjem ter 64K ali 256K zlogi zunanega vmesnega pomnilnika. Omogoča dograditev še močnejšega koprocetorja Weitek 4167. Pomnilnik je od 4MB mogoče razširiti do 32MB. Prostorno stolp ohišje, ki ga lahko postavite ob svojo delovno mizo, omogoča vgradnjo največ šestih diskovnih pogonov polovične višine. Uporabljeno najbolj razširjeno ISA vodilo pa zagotavlja, da boste v DIALOGU 486 ISA lahko uporabili vse krmilnike, ki so zasloveli v svetu 386 računalnikov.

Z vgrajenim večjim številom serijskih vmesnikov in pod Unix operacijskim sistemom lahko postane DIALOG 486 večuporabniški računalnik, ki se lahko meri z večino mini računalnikov.

DIALOG 486

	EISA	ISA
procesor	i486/33MHz	i486/33MHz
- interni vmesni pomnilnik	8KB	8KB
- interni koprocetor	80387	80387
- zunanji vmesni pomnilnik	64KB ali 256KB	64KB ali 256KB
vodilo	EISA	ISA
koprocetor (opcija)	Weitek 4167	Weitek 4167
pomnilnik	4MB do 64MB	4MB do 32MB
BIOS	AWARD EISA	AMI
razširitvena mesta	6 32-bitnih EISA 2 16-bitni ISA	6 16-bitnih ISA 2 8-bitni ISA
vmesniki	2 serijska 1 paralelni	2 serijska 1 paralelni

gibki disk	1,2MB in 1,44MB	1,2MB in 1,44MB
trdi disk	od 120MB do 2 GB	od 120MB do 1GB
monitor	monokromatski ali barvni 14"	monokromatski ali barvni 14"
tipkovnica	SLO - 101 ali 102 tipki	SLO - 101 ali 102 tipki
ohišje	stolp	stolp

DIALOG 386

je namenjen predvsem poslovnim in statističnim uporabam, zelo primeren pa je tudi kot mrežni strežnik. Za vse, ki od računalnika pričakujejo veliko, je DIALOG 386 pravi osebni računalnik. Vanj je vgrajen vse bolj razširjeni 386 mikroprocesor s taktom 40MHz, ki mu ob veliki zmogljivosti zagotavlja sprejemljivo ceno.

Velika izbira grafičnih krmilnikov, monitorjev in diskov pa zagotavlja, da bo DIALOG 386 res izpolnil vsa vaša pričakovanja.

Napredna zgradba DIALOGA 386 s 64K zlogi vmesnega pomnilnika zagotavlja moč 9,7 MIPS ali več. Za pospešitev matematičnih operacij s plavajočo vejico lahko dodate 80387 ali Wietek 3167 matematični koprocesor. Pomnilnik je od 4MB razširljiv do 16MB. Ohišje omogoča vgradnjo največ osmih diskovnih pogonov polovične višine - od trdih in gibkih diskov do optičnih diskov ali tračnih enot.

Uporaba 386 procesorja zagotavlja veliko zmogljivost tudi pri delu pod 32-bitnim operacijskim sistemom, pa naj je to Novell NetWare 386, Unix ali OS/2.

DIALOG 386 je kot grafična delovna postaja ali mrežni strežnik gotovo najboljša izbira po zmerni ceni.

DIALOG 386

procesor	386/40MHz
- zunanji vmesni pomnilnik	64KB ali 256KB
vodilo	ISA
koprocesor (opcija)	80387 ali Wietek 3167
pomnilnik	4MB do 64MB
BIOS	AMI
razširitvena mesta	6 16-bitnih ISA 2 8-bitni ISA
vmesniki	2 serijska 1 paralelni
gibki disk	1,2MB in 1,44MB
trdi disk	od 80MB do 1GB
monitor	monokromatski ali barvni 14"

tipkovnica	SLO - 101 ali 102 tipki
ohišje	stolp ali namizno

DIALOG 386SX

omogoča učinkovito izvajanje vse bolj razširjenih 32-bitnih programskih rešitev. Njegovo srce je 386SX najcenejši izmed 32 bitnih mikroprocesorjev, ki teče s taktom 25MHz.

V običajni konfiguraciji opremimo DIALOG 386SX z 1MB pomnilnika in trdim diskom 105 MB. Pomnilnik lahko razširimo do 8MB, dovolj prostorno ohišje zagotavlja ustrezen obseg zunanega pomnilnika, na voljo pa so tudi različni monitorji in številni dodatki od miške do mrežnih kartic vseh vrst.

Kljub izredno nizki ceni je uporabnost DIALOGA 386SX skoraj neomejena: od poslovnih in administrativnih uporab do namiznega založništva in preprostejših grafičnih postaj. Gotovo bo zadovoljil večino najrazličnejših potreb in pričakovanj.

DIALOG 386SX

procesor	386SX/25MHz
vodilo	ISA
koprocesor (opcija)	80387SX
pomnilnik	1MB do 8MB
BIOS	AMI
razširitvena mesta	5 16-bitnih ISA 1 8-bitno ISA
vmesniki	2 serijska 1 paralelni
gibki disk	1,2MB in 1,44MB
trdi disk	od 40MB do 400MB
monitor	monokromatski ali barvni 14"
tipkovnica	SLO - 101 ali 102 tipki
ohišje	namizno ali mini stolp

DIALOG 286

je najpreprostejši in najcenejši osebni računalnik v družini DIALOG. Namenjen je za splošno uporabo pri delu, v šoli ali doma.

DIALOG 286 temelji na 286 mikroprocesorju, ki teče s taktom 20MHz ali 16 MHz. Delo s pomnilnikom brez čakalnih stanj in aparaturno realizirana funkcija EMS 4.0 povečujeta njegovo učinkovitost.

Pri delu s programskimi paketi od Lotusa do Venture boste učinkovito presegli zloglasno mejo 640K zlogov in uporabili ves pomnilnik. Standardna konfiguracija DIALOGA 286 vsebuje 1MB pomnilnika in 40 MB trdi disk. Pomnilnik lahko razširimo do 5MB, na voljo pa so tudi različni monitorji in številni dodatki od miške do mrežnih kartic vseh vrst. Kot osebni računalnik ali kot mrežna delovna postaja bo DIALOG 286 vedno vaš neutrudni pomočnik.

DIALOG 286

procesor	286/20MHz ali 16MHz
vodilo	ISA
koprocisor (opcija)	80287
pomnilnik	1MB do 5MB

BIOS	AMI
razširitvena mesta	5 16-bitnih ISA 1 8-bitno ISA
vmesniki	2 serijska 1 paralelni
gibki disk	1,2MB in 1,44MB
trdi disk	od 40MB do 400MB
monitor	monokromatski ali barvni 14"
tipkovnica	SLO - 101 ali 102 tipki
ohišje	namizno ali mini stolp

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VESTI

BiCMOS Technology extends the AMS ASIC Spectrum

Dr. Conrad F. Heberling, AMS

Within the last few years CMOS has become the dominating and leading technology in semiconductors. The reasons: lower power consumption, higher processing speeds and the less design efforts required when compared to other technologies such as NMOS. CMOS has also proven to be a very reliable technology for purely analogue, purely digital and increasingly for mixed analogue/digital applications in the field of telecommunications, automotive, industrial and computer electronics.

The application range of CMOS for ASICs could be extended further with various additional sophisticated techniques and clever tricks. But, to keep in pace with today's needs and high standards of circuit integration and moreover to fulfill the requirements for the ever

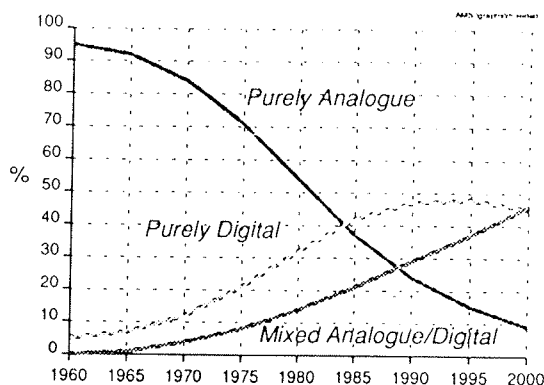
growing number of mixed analogue and digital circuits (see adjacent figure) the CMOS process as such had to undergo fundamental modifications.

The so-called BiCMOS process that offers performance characteristics which cannot be found in purely bipolar or CMOS circuits represents this major further development of the basic CMOS technology. BiCMOS circuits combine bipolar and MOS transistors on a single integrated circuit. Additional mask and process steps as well as in-depth process know-how make the BiCMOS process possible. For the realization of transistors with an increased bandwidth and speed BiCMOS circuits additionally contain high performance vertical NPN transistors and parasitic PNP transistors.

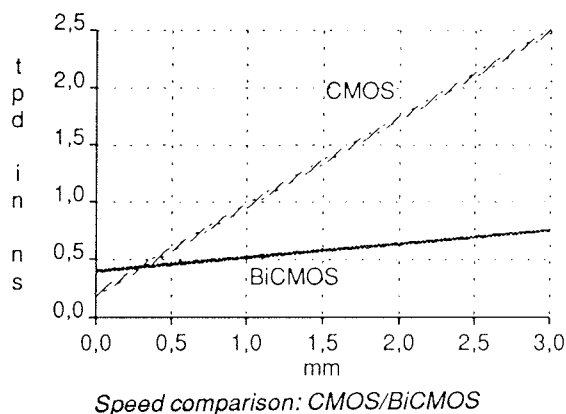
Thus, to further increase the circuit's speed and to improve its highly complex analogue characteristics, BiCMOS has advanced as the ideal technology in the arena of today's semiconductor technology.

The BiCMOS process furthermore provides systems designers with superior advantages. The ultimate goal of systems integration is to combine the majority of all discrete elements in one ASIC: This technology makes possible an optimal approximation towards these systems demands. Whether mainly digital or mainly analogue elements are to be integrated in a circuit, the new BiCMOS process provides for areawise smaller cells, for better performance and overall for more cost effective solutions.

The advantages of BiCMOS: the essential parameters that determine a circuit's characteristics are its process-



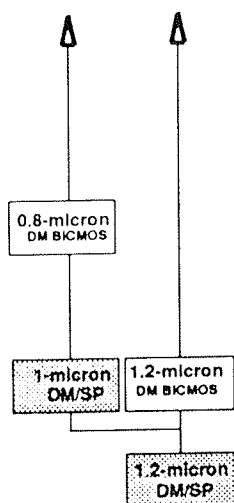
The dynamic growth of the mixed signal circuit market



ing speed as well as its switching capacity and driving capability. The speed of circuits with structures of $1.2\mu\text{m}$ and below are determined less by delay times of singular gates than by the time span for the reloading of connected cell blocks and their capacitances. A comparison between a BiCMOS gate and a CMOS gate clearly illustrates the above in the top figure. With interconnecting wire lengths of only 0.5 mm (surely no rarity within every ASIC product) the BiCMOS process is clearly faster.

A transistor in BiCMOS technology is far superior to a MOS transistor: When utilizing the same area it offers four times the power. Even though a greater number of components are required for a BiCMOS circuit as compared to a conventional circuit (because for bipolar transistors additional process and mask steps need to be implemented) this has hardly any effect on the circuit's size. Since the output current of the BiCMOS transistors is higher they can be laid out in a smaller fashion than comparable MOS transistors.

Furthermore, the characteristics of analogue ICs can be improved dramatically with the help of BiCMOS technology. Within the analogue sector advantages outweigh other factors such as costs and the more intense manufacturing efforts - side effects of the BiCMOS process.



BiCMOS process evolution at AMS

The application of BiCMOS technology is appropriate for VLSI circuits and complex logic at process structure levels of $1.2\mu\text{m}$ and less.

The following BiCMOS processes are currently under development at AMS:

A $0.8\mu\text{m}$ double-metal BiCMOS process - a derivative of the AMS $1.0\mu\text{m}$ double-metal single-poly process and

a $1.2\mu\text{m}$ double-metal BiCMOS process - a further advancement of the proven AMS $1.2\mu\text{m}$ double-metal single-poly process.

The special characteristics of the new AMS $1.2\mu\text{m}$ BiCMOS process, which is going to be manufactured as a so-called poly emitter and deep collector process are the high transit frequencies of up to 8 Gigahertz and the high amplification. This process is especially suited for mixed analogue/digital ASIC solutions: circuits with over 200,000 transistors can be realized. The new process was primarily developed for ASICs incorporating a complex digital part with high speed and high density analogue elements. Lowest power consumption, noise immunity and applicability to a wide range of telecommunication, automotive and industrial design requirements are further key benefits of this new AMS BiCMOS process.

AMS, with its in-house research and development department and state-of-the-art manufacturing equipment, now can provide 40 proven CMOS and NMOS processes. Because of AMS' parallel support of new, traditional and mature process technologies, AMS' process flexibility guarantees the duration of any one process as long as a specific product is required.

Among the attractions of BiCMOS - as mentioned before - is the capability it offers of putting high performance digital and analogue functions on the same chip, permitting high degrees of system integration. And, three trends are fueling the growth of mixed signal ASICs which will speed up the need for the availability for this new process technology. These include the gradual movement towards adding analogue input/output sections to digital microprocessors, the replacement of some traditional analogue functions by digitally intense architectures, and the advent of mixed signal ASICs. Specific applications for this innovative process will evolve in a wide range of various fields such in telecommunications, automotive and industrial electronics.

In the **telecommunications** market this will mean mixed-signal applications for both voice communication products such as diallers, ringers, line interfaces and codecs and for data communication products such as filters and modems, and for bipolar high frequency analogue ASICs such as in mobile communications. Because of the high processing speeds inherent with the BiCMOS process it will also be ideal for the **automotive** segment. Typical applications will include novel ICs for safety electronics and in the near future the overall electronics management of the automobile itself. In the

Industrial market BiCMOS will offer the ideal prerequisites for high performance mixed analogue and digital cells to make possible the implementation of enhanced robotics, sensors, remote control encoders/decoders and advanced instrumentation. And, in **computer** electronics BiCMOS will meet the growing demand for increased performance in data manipulation and data transfer in systems with reduced component counts, higher levels of integration and increased complexity of SRAMs and logic.

The present development of BiCMOS represents a dramatic technological upheaval in microelectronics - the tidal wave racing towards BiCMOS is closing in - and AMS is ready and prepared to meet this challenge.

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AUSTRIA

AMS first semiconductor manufacturer to install Synchromaster for RF-Testing

AMS, Austria Mikro Systeme International, is the first semiconductor manufacturer worldwide to install the new Synchromaster AC with RF (Radio Frequency) option for testing high performance application specific integrated circuits (ASICs).

AMS can now provide customers with ideal solutions for testing BiCMOS circuits for mobile telephones including synthesizers, mixers, VCOs and OpAmps operating in the Gigahertz range.

The company has thus set a new standard in coping with the accelerating need for the design, fabrication and test of high performance mixed signal circuits with high pin counts for the telecommunications market, allowing coverage for all of the commercial cellular and personal phone standards, including CT-2, DECT and GSM. The new test system which utilizes the enhanced architecture of LTX' established linear and digital testers gives AMS the added capability for testing up to 4.3 Gigahertz.

The new tester represents a major investment of 20 million Austrian Schillings making further highly qualified jobs available.

With the addition of this enhanced tester, AMS' IC testing capabilities are unparalleled in the industry; test systems include Sentry 21, LTX TS88 and DX90 and Advantest T3320. AMS offers its expanded test capabilities as a separate stand-alone service to any interested parties as well.

With its fully integrated factory which houses R & D, mask lithography, wafer fabrication, assembly and test, AMS specializes in ASIC development, design and production as well as silicon foundry services.

Note: In 1989 Austria Mikro Systeme International was the first semiconductor manufacturer in the world to install and operate the new generation digital and analogue LTX IC-tester "Synchromaster" which AMS engineers developed together with LTX - recognized as the world leader in mixed signal testing. The new tester is the fourth synchromaster implemented at AMS.

KOLEDAR PRIREDITEV 1992

OKTOBER

5. - 6. VITEL 92, International telecommunications symposium, Ljubljana (EZS Ljubljana)

5. - 10. SODOBNA ELEKTRONIKA, 39. mednarodna razstava elektronike, Ljubljana (Gospodarsko razstavišče)

7. - 9. 43. POSVETOVANJE O METALURGIJI IN KOVINSKIH GRADIVIH, Portorož, Slovenija (ZITS, 61-212139)

7. - 10. COMPONENTA 92, mednarodni strokovni sejem za dobavitelje komponent in elementov

14. - 16. COMETT workshop: Access to ASIC's for small and medium sized companies, Graz (Joanneum ges., Graz, Steyergasse 17)

20. - 21. TEST 92, Test: Design Through To Support Conference, Brighton (fax. 071-4177500)

27. - 30. BIET 92, mednarodni sejem za električni inženiring in industrijsko elektroniko, Budimpešta

NOVEMBER

10. - 14. ELECTRONICA 92, 15. international Trade Fair for Components and Assemblies in Electronics, München

IZOBRAŽEVALNI TEČAJI - jesen 1992

Vse uporabnike vakuumske tehnike obveščamo, da sta za letošnjo jesen planirana naslednja dva strokovno izobraževalna tečaja:

VZDRŽEVANJE VAKUUMSKIH NAPRAV

- 22. in 21. oktobra 1992

Na njem bo obravnavana predvsem tematika, ki jo srečujemo v tehniki grobega in srednjega vakuumu, to je: delovanje, vzdrževanje in popravila rotacijskih črpalk, pregled in uporaba različnih črpalk, ventilov in drugih elementov, meritve vakuumu, hermetičnost in odkrivanje netesnosti v vakuumskih sistemih, materialih za popravila, tehnike čiščenja in spajanja, skupno 16 ur, od tega tretjina praktičnih prikazov in vaj. Cena tečaja je 14.000 SIT (280 DEM). Vsak tečajnik prejme tudi brošuro: "Vzdrževanje vakuumskih naprav" in izkaz o opravljenem tečaju.

OSNOVE VAKUUMSKE TEHNIKE

- 3., 4. in 5. novembra 1992

Ta tečaj je popolnejši od prvega, obravnava podrobneje vsa prej omenjena področja, poleg tega pa še: pomen

in razvoj vakuumske tehnike, fizikalne osnove, črpalke za visoki vakuum, tankoplastne in druge vakuumske tehnologije, čiste postopke, analize površin ter doziranje, čiščenje in preiskave plinov - skupno z vajami in ogledom Inštituta 20 ur. Namenjen je tako vzdrževalcem in projektantom vakuumskih naprav kot tudi raziskovalcem, ki pri svojem razvojnem ali študijskem delu potrebujejo vakuumske pogoje. Cena tečaja je 12.500 SIT (250 DEM). Udeleženci prejmejo zbornik predavanj: "Osnove vakuumske tehnike" in dokument o opravljenem tečaju.

Oba tečaja se pričnejo v torek ob 8.00 uri v knjižnici Inštituta za elektroniko in vakuumsko tehniko, Teslova 30, Ljubljana. Prosimo zainteresirane, da se informativno javijo čimprej, za dokončno potrdilo pa velja kopija položnice o plačilu - najkasneje nekaj dni pred pričetkom tečaja na naslov: Društvo za vakuumsko tehniko Slovenije, Teslova 30, 61111 Ljubljana (štev. ŽR: 50101-678-52240). Prijave sprejema organizacijski odbor (Koller, Spruk, Drab, Nemanič), ki daje tudi vse dodatne informacije (tel. 061 263-461).

OBVESTILO ČLANOM DRUŠTVA MIDEM IN OSTALIM ZAJINTERESIRANIM

1. V uredništvu časopisa Informacije MIDEM imamo na voljo še nekaj izvodov časopisa iz prejšnjih letnikov in sicer:

- ☐ Informacije MIDEM, letnik 91: št. 1
- ☐ Informacije MIDEM, letnik 90: št. 1, 2, 3 in 4
- ☐ Informacije MIDEM, letnik 89: št. 2, 3 in 4

Vsi člani društva manjkajoče izvide dobijo brezplačno, ostali pa z 20% popustom glede na veljavne cene.

2. Na voljo so tudi publikacije društva MIDEM in sicer:

- ☐ MIKROELEKTRONIKA IN DRUŽBA Prispevki s posvetovanja ob Sodobni elektroniki, oktobra 1988, Brdo pri Kranju
cena 200 SIT

- ☐ Zbornik referatov, MIEL 91, Beograd
cena 200 SIT
- ☐ Zbornik referatov, MIEL 90, Ljubljana
cena 200 SIT
- ☐ Zbornik referatov, SD 90, Radenci
cena 200 SIT

V primeru, da želite naročiti katero od zgoraj omenjenih publikacij, prosimo, pošljite naročilo ali pa pokličite:

Rudi Ročak
MIKROIKS d.o.o.
Dunajska 5, 61000 Ljubljana
tel. 061-312898, 319170
fax. 061-319170

NADALJEVANJE OBJAVLJANJA TERMINOLOŠKIH STANDARDOV

V tej številki nadaljujemo z objavljanjem terminoloških standardov. Na vrsti so **POLPREVODNIŠKI ELEMENTI**.

Z aradi enostavnosti in točnosti bomo objavili kopije iz standardov v taki obliki, kot so napisani originalno. Opričujemo se zaradi morebitnih slabših odtisov.

Vsebina standarda:

1. Splošni izrazi
2. Diode
3. Bipolarni tranzistorji in poljski tranzistorji
4. Tiristorji

NAVODILA AVTORJEM

Informacije MIDE M je znanstveno-strokovno-društvena publikacija Strokovnega društva za mikroelektroniko, elektronske sestavne dele in materiale-MIDE M. Časopis objavlja prispevke domačih in tujih avtorjev, še posebej članov MIDE M, s področja mikroelektronike, elektronskih sestavnih delov in materialov, ki so lahko:

izvirni znanstveni članki, predhodna sporočila, pregledni članki, razprave z znanstvenih in strokovnih posvetovanj in strokovni članki.

Članki bodo recenzirani.

Časopis objavlja tudi novice iz stroke, vesti iz delovnih organizacij, inštitutov in fakultet, obvestila o akcijah društva MIDE M in njegovih članov ter druge relevantne prispevke.

Strokovni prispevki morajo biti pripravljeni na naslednji način

- 1. Naslov dela, imena in priimki avtorjev brez titula.
- 2. Ključne besede in povzetek (največ 250 besed).
- 3. Naslov dela v angleščini.
- 4. Ključne besede v angleščini (Keywords) in povzetek v angleščini (Abstract).
- 5. Uvod, glavni del, zaključek, zahvale, dodatki in literatura.
- 6. Imena in priimki avtorjev, titule in naslovi delovnih organizacij, v katerih so zaposleni.

Ostala splošna navodila

1. Članki morajo biti tipkani na listih A4 formata v vrsticah dolžine 16 cm. Rob na levi strani mora biti širok 3.5-4 cm.

2. V članku je potrebno uporabljati SI sistem enot oz. v oklepaju navesti alternativne enote.

3. Risbe je potrebno izdelati s tušem na pavs ali belem papirju. Širina risb naj bo do 7.5 oz. 15 cm. Vsaka risba, tabela ali fotografija naj ima številko in podnapis, ki označuje njeno vsebino. Risb, tabel in fotografij ni potrebno lepiti med tekst, ampak jih je potrebno ločeno priložiti članku. V tekstu je potrebno označiti mesto, kjer jih je potrebno vstaviti.

4. Delo je lahko napisano in bo objavljeno v kateremkoli jugoslovanskem jeziku v latinici in v angleščini.

Uredniški odbor ne bo sprejel strokovnih člankov, ki ne bodo poslani v treh izvodih.

Avtorji, ki pripravljajo besedilo v urejevalnikih besedil, lahko pošljejo zapis datoteke na disketi (360 ali 1,2) v formatih ASCII, wordstar (3.4, 4.0), wordperfect, word, ker bo besedilo oblikovano v programu Ventura 2.0. Grafične datoteke so lahko v formatu HPL, SLD (AutoCAD), PCX ali IMG/GEM.

Avtorji so v celoti odgovorni za vsebino objavljenega sestavka. Rokopisov ne vračamo.

Rokopise pošljite na naslov

Uredništvo Informacije MIDE M
Elektrotehniška zveza Slovenije
Dunajska 10, 61000 Ljubljana

UPUTE AUTORIMA

Informacije MIDE M je znanstveno-stručno-društvena publikacija Stručnog društva za mikroelektroniku, elektronske sestavne dijelove i materijale - MIDE M. Časopis objavljuje priloge domaćih i stranih autora, naročito članova MIDE M, s područja mikroelektronike, elektronskih sastavnih dijelova i materijala koji mogu biti:

izvirni znanstveni članci, predhodna priopćenja, pregledni članci, izlaganja sa znanstvenih i stručnih skupova i stručni članci.

Članci će biti recenzirani.

Časopis također objavljuje novosti iz struke, obavijesti iz radnih organizacija, instituta i fakulteta, obavijesti o akcijama društva MIDE M i njegovih članova i druge relevantne obavijesti.

Stručni članci moraju biti pripremljeni kako slijedi

- 1. Naslov članka, imena i prezimena autora bez titula.
- 2. Ključne riječi i sažetak (najviše 250 riječi).
- 3. Naslov članka na engleskom jeziku.
- 4. Ključne riječi na engleskom jeziku (3Key Words) i sažetak na engleskom jeziku (Abstract).
- 5. Uvod, glavni dio, zaključni dio, zahvale, dodaci i literatura.
- 6. Imena i prezimena autora, titule i naslovi institucija u kojima su zaposleni.

Ostale opšte upute

1. Prilozi moraju biti strojno pisani na listovima A4 formata u redovima dužine 16 cm. Na lijevoj strani teksta treba biti rub širok 3.5 do 4 cm.

2. U prilogu treba upotrebljavati SI sistem jedinica od. u zagradi navesti alternativne jedinice.

3. Crteže treba izraditi tušem na pausu ili bijelom papiru. Širina crteža neka bude do 7.5 odnosno 15 cm. Svaki crtež, tablica ili fotografija treba imati broj i naziv koji označuje njen sadržaj. Crteže, tabele i fotografije nije potrebno lijepiti u tekst, već ih priložiti odvojeno, a u tekstu samo naznačiti mjesto gdje dolaze.

4. Rad može biti pisan i biti će objavljen na bilo kojem od jugoslovenskih jezika u latinici i na engleskom jeziku.

Autori mogu poslati radove na disketama (360 ili 1,2) u formatima tekst procesora ASCII, wordstar (3.4. i 4.0), word, wordperfect pošto će biti tekst dalje obrađen u Venturi 2.0. Grafičke datoteke mogu biti u formatu HPL, SLD (AutoCAD), PCX ili IMG/GEM.

Urednički odbor će odbiti sve radove koji neće biti poslani u tri primjerka.

Za sadržaj članaka autori odgovaraju u potpunosti. Rukopisi se na vraćaju.

Rukopise šaljite na adresu:

Uredništvo Informacije MIDE M
Elektrotehnička zveza Slovenije
Dunajska 10, 61000 Ljubljana
Slovenija

INFORMATION FOR CONTRIBUTORS

Informacije MIDE M is professional-scientific-social publication of Professional Society for Microelectronics, Electronic Components and Materials. In the Journal contributions of domestic and foreign authors, especially members of MIDE M, are published covering field of microelectronics, electronic components and materials. These contributions may be:

original scientific papers, preliminary communications, reviews, conference papers and professional papers.

All manuscripts are subject to reviews.

Scientific news, news from the companies, institutes and universities, reports on actions of MIDE M Society and its members as well as other relevant contributions are also welcome.

Each contribution should include the following specific components:

- 1. Title of the paper and authors' names.
- 2. Key Words and Abstract (not more than 250 words).
- 3. Introduction, main text, conclusion, acknowledgements, appendix and references.
- 4. Authors' names, titles and complete company or institution address.

General information

1. Papers should be typed on page format A4 in lines up to 16 cm long. Space on left side of the text should be at least 3.5 to 4 cm long.

2. Authors should use SI units and provide alternative units in parentheses wherever necessary.

3. Illustrations should be in black on white or tracing paper. Their width should be up to 7.5 or 15 cm. Each illustration, table or photograph should be numbered and with legend added. Illustrations, tables and photographs are not to be placed into the text but added separately. However, their position in the text should be clearly marked.

4. Contributions may be written and will be published in any Yugoslav language and in english.

Authors may send their files on formatted diskettes (360 or 1,2) in ASCII, wordstar (3.4 or 4.0), word, wordperfect as text will be formatted in Ventura 2.0. Graphics may be in HPL, SLD (AutoCAD), PVX or IMG/GEM formats.

Papers will not be accepted unless three copies are received.

Authors are fully responsible for the content of the paper. Manuscripts are not returned.

Contributions are to be sent to the address:

Uredništvo Informacije MIDE M
Elektrotehniška zveza Slovenije
Dunajska 10, 61000 Ljubljana,
Slovenia

TERMINOLOŠKI STANDARDI

2 Splošni izrazi in definicije 2.1 Fizikalni izrazi

Zaporedna številka	Izrazi v jezikih jugoslovanskih narodov	Izrazi v tujih jezikih	D e f i n i c i j a
1	2	3	4
2.1.1	• Poluprovodnik • Poluvodič • Полупроводник • Polprevodnik	147-0/0-1.1 • Semiconductor • Semiconducteur	Material, katerega specifična upornost je v področju med kovinami in izolanti in v katerem raste koncentracija nosilcev elektrine z večanjem temperature v določenem temperaturnem območju.
2.1.2	• Primesni poluprovodnik • Primesni poluvodič • Примесен полупроводник • Nečistotni polprevodnik	147-0/0-1.2 • Extrinsic semiconductor • Semiconducteur extrinsèque	Polprevodnik, katerega koncentracija nosilcev elektrine je odvisna od nečistot ali drugih neopolnosti.
2.1.3	• Poluprovodnik N-tipa • Poluvodič tipa N • Полупроводник од N-тип • Polprevodnik tipa N	147-0/0-1.3 • N-type semiconductor • Semiconducteur type N	Polprevodnik s primesmi, pri katerem je gostota prevodnih elektronov večja od gostote premičnih vrzeli.
2.1.4	• Poluprovodnik P-tipa • Poluvodič tipa P • Полупроводник од P-тип • Polprevodnik tipa P	147-0/0-1.4 • P-type semiconductor • Semiconducteur type P	Polprevodnik s primesmi, pri katerem je gostota premičnih vrzeli večja od gostote prevodnih elektronov.

TERMINOLOŠKI STANDARDI

1	2	3	4
2.1.5	• Poluprovodnik I-tipa (soprstveni) • Poluvodič tipa I (intrinzični) • Безпримесен полупроводник, полупроводник од I-тип • Polprevodnik tipa I	147-0/0-1.5 • I-type (intrinsic) semiconductor • Semiconducteur type I (intrinsèque)	Skoraj čist in idealen polprevodnik, pri katerem je gostota elektronov in vrzeli ob termičnem ravnotežju skoraj enaka
2.1.6	• Spoj, prelaz • Spoj, prijelaz • Спoй, прeлaз • Spoj	147-0/0-1.6 • Junction • Jonction	Področje prehoda med polprevodniki različnih električnih lastnosti.
2.1.7	• PN-spoj • PN-spoj • PN-спoй • PN-spoj	147-0/0-1.7 • PN junction • Jonction PN	Spoj med polprevodniki tipa P in N.
2.1.8	• Legirani spoj • Legirani spoj • Легирaн cпoй • Legirani spoj	147-0/0-1.8 • Alloyed junction • Jonction par alliage	Spoj, nastal z legiranjem enega ali več materialov s polprevodniškim kristalom.
2.1.9	• Difundovani spoj • Difundirani spoj • Дифундиpан cпoй • Difuzijski spoj	147-0/0-1.9 • Diffused junction • Jonction par diffusion	Spoj, nastal z difuzijo primesi v polprevodniški kristal.
2.1.10	• Izvlačeni spoj • Izvlačeni spoj • Извлекyван cпoй • Vlečeni spoj	147-0/0-1.10 • Grown junction • Jonction par tirage	Spoj, ki se tvori pri rasti polprevodniškega kristala iz taline.

TERMINOLOŠKI STANDARDI

1	2	3	4
2.1.11	- Nosilac (naelektrisanja) - Nosilac naboja - Носитель (на электрический) - Nosilec elektrine	147-0/0-1.11 - Charge carrier, carrier - Porteur de charge, porteur	Premični (prosti) prevodni elektron ali premična vrzel v polprevodniku.
2.1.12	- Večinski nosilci (u nekoj oblasti poluprovodnika) - Večinski nosilci (u nekom području poluvodiča) - Основни носители (во некоја област на полупроводникот) - Večinski nosilec (v polprevodniškem področju)	147-0/0-1.12 - Majority carrier (in a semiconductor region) - Porteur majoritaire (dans un région semiconductor)	Tip nosilca, ki vsebuje več kot polovico skupne koncentracije nosilcev elektrine.
2.1.13	- Manjšinski nosilci (u nekoj oblasti poluprovodnika) - Manjšinski nosilci (u nekom području poluvodiča) - Споредни носители (во некоја област во полупроводникот) - Manjšinski nosilec (v polprevodniškem področju)	147-0/0-1.13 - Minority carrier (in a semiconductor region) - Porteur minoritaire (dans une région semiconductor)	Tip nosilca, ki vsebuje manj kot polovico skupne koncentracije nosilcev elektrine.
2.1.14	- Osiromašeni sloj - Osiromašeni sloj - Осиромашен слой - Osiromašeni sloj	147-0/0-1.14 - Depletion layer - Couche diélectrique	Področje, v katerem gostota premičnih nosilcev elektrine ni zadostna, da bi nevtralizirala nepremično gostoto naelektronosti donorja in akceptorja.

TERMINOLOŠKI STANDARDI

1	2	3	4
2.1.15	• Proboj (inverzno polarisanog PN-spoja) • Proboj (zarogno polariziranog PN-spoja) • Пробив (на инверзно поларизирани PN-спой) • Preboj (inverzno polariziranega PN-spoja)	147-0/0-1.15 • Breakdown (of a reversebiased PN junction) • Claquage (d'une jonction PN, polarisée en inverse)	Pojav prehoda iz stanja visoke dinamične upornosti v stanje znatno nižje dinamične upornosti zaradi povečanja inverznega toka.
2.1.16	• Lavinski proboj (poluprovodničkog PN-spoja) • Lavinski proboj (poluvodičkog PN-spoja) • Лавински пробив (на полупроводнички PN-спой) • Plazovni preboj	147-0/0-1.16 • Avalanche breakdown (of a semiconductor PN junction) • Claquage par avalanche (d'une jonction PN semiconductrice)	Preboj, ki ga povzroči kumulativno razmnoževanje prostih nosilcev elektrine (v polprevodniku) pri delovanju močnega električnega polja. Prosti nosilci dobijo dovolj energije, da s pomočjo ionizacije sprostijo nove pare elektronov.
2.1.17	• Lavinski napon • Lavinski napon • Лавински напон • Napetost plazovnega preboja	147-0/0-1.17 • Avalanche voltage • Tension d'avalanche	Napetost, pri kateri nastaja plazovni preboj.
2.1.18	• Termični proboj (poluprovodničkog PN-spoja) • Toplinski proboj (poluvodičkog PN-spoja) • Теплинский пробив (на полупроводнички PN-спой) • Termični preboj (polprevodniškega PN-spoja)	147-0/0-1.18 • Thermal breakdown (of a semiconductor PN junction) • Claquage par effet thermique (d'une jonction PN semiconductrice)	Preboj, ki ga povzroča nastajanje prostih nosilcev elektrine zaradi kumulativnega medsebojnega učinkovanja med povečano izgubo moči in povečano temperaturo spoja. Opomba: Ta pojav v nekaterih deželah imenujejo termično odpoval.

TERMINOLOŠKI STANDARDI

1	2	3	4
2.1.19	• Zenerov preboj (poluprovodničkog PN-spoja) • Zenerov preboj (poluvodičkog PN-spoja) • Зенеров пробив (на полупроводнички PN-спой) • Zenerski preboj (polprevodniškega PN-spoja)	147-0/0-1.19 • Zener breakdown (of a semiconductor PN junction) • Claquage par effet Zener (d'une jonction PN semiconductrice)	Preboj ki nastane s prehodom elektrine iz valenčnega pasu v prevodni pas zaradi tunelskega pojava pod vplivom močnega električnega polja.
2.1.20	• Zenerov napon • Zenerov napon • Зенеров напон • Zenerska napetost	147-0/0-1.20 • Zener voltage • Tension de Zener	Napetost, pri kateri pride do znerskega preboja.
2.1.21	• Tunelski efekt • Tunelski efekt • Эффект на тунелирање • Tunelski pojav	147-0/0-1.21 • Tunnel effect • Effet tunnel	Prehod nosilcev (razložen s kvantno mehaniko), če je širina praga dovolj majhna.
2.1.22	• Tunelovanje (kroz PN-spoj) • Tuneliranje (kroz PN-spoj) • Тунелирање (низ PN-спой) • Tunelski proces (v PN-spoju)	147-0/0-1.22 • Tunnel action (in a PN junction) • Action tunnel (dans une jonction PN)	Proces, pri katerem nastaja prevajanje čez potencialni prag. Zaradi tunelskega pojava in v katerem prehajajo elektroni v katerikoli smeri med prevodno zono v N področju in valenčno zono v P področju. Opomba: Tunelski proces, za razliko od difuzije nosilcev elektrine zajema samo elektrone in je v vseh praktičnih primerih čas prehoda zanemarljiv.