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? Regulator (tips sid 9)

INNEHÅLLSFÖRTECKNING Sid

Forts. Innehållsförteckning

STUDIEBESÖK I DELFT MÅNDAGEN DEN 29 MAJ 1972.

Inledning.

Vid tekniska högskolan i Delft, som har ca 10.000 studerande, är reglertekniken uppdelad inom 3 olika avdelningar:

Teknisk Fysik
Elektronik
Maskinteknik.

Vid flera av avdelningarna finns också flera professurer i reglerteknik. Vid mitt besök diskuterade jag med representanter från alla tre avdelningarna. Beträffande kurser så skiljer sig det holländska systemet från vårt därigenom att man har en femårig utbildning. De första tre åren är således av allmän karaktär och därefter specialiserar sig studenten inom ett fackområde där han också gör sitt examensarbete. Examensarbetet omfattar som regel 9 månaders heltidsarbete. Detta betyder som regel att man ägnar sig åt laboratoriearbete i mycket större utsträckning i Delft än vad vi gör i Sverige. Laboratorieprojekten är också mycket mer omfattande. Däremot så är antalet studenter som läser högre kurser mindre. Det förekommer reglerteknik i de inledande kurserna under de första tre åren, men huvudsaklig utbildning är förlagd till de sista två åren. Denna utbildning kallas i Holland för "graduate studies" och är närmast att jämföra med den amerikanska "masters degree". Däremot finns ej någon organiserad doktorsutbildning. Beträffande kursernas detaljutformning hänvisas till de rapporter, som varje år erhålles från "Heads of the North Western Control Laboratories". Jag kommer i denna rapport därför endast att ta upp ämnen som är av speciellt intresse för mig och mina medarbetare på institutionen.

REGLERTEKNISK VERKSAMHET VID SEKTIONEN FÖR TEKNISK FYSIK.

Vid sektionen för teknisk fysik finns två professurer med stark reglerteknisk anknytning, Professor Verhagen och Professor Veldtman, som har mät- och reglerteknik, resp. regler- och signalteori. Professor Verhagen var bortrest, men jag hade goda möjligheter att diskutera med professor Veldtman. Genom att man har ett stort antal studenter, ca 20 stycken, som genomför examensarbeten av 9 månaders omfattning, sker forskningsarbeten i stor utsträckning i anslutning till dessa projekt. Nedan ges en lista av pågående projekt.

<u>Biologische Natuurkunde (BN)</u>

BN1	Pitch perception of click pair stimuli.
BN2	Pitch of monaural and binaural tone complexes.
BN3	Binaural lateralization in relation to pitch perception.
BN4	Visual perception of periodic spatial patterns.
BN5	The aftereffect of moving visual patterns.
BN6	Firing pattern of auditory in response to sounds with their repetition.
BN7	Pitch phenomena and their common central origin.

<u>Bestuurde Prothesen (BP)</u>

BP1	Prothesis control by pattern recognition.
BP2	Movement studies of human extremities by means of a TV camera.
BP3	An experimental amplifier for surface electromyography.
BP4	Electrical skin stimulation as a sensory substitute.
BP5a	Interface for the digital magnetic tape recorder.

BP5b A shift register buffer for the digital tape recorder.

BP6 Zero voltage crossing switch.

Instrumentatie (IN)

IN1 Automatic reading of handwritten numbers.

IN2 A video digital converter for four levels.

IN3 The die-tester.

IN4 Automatic chromosome analysis.

IN5 Automatic interpretation of vectorcardiograms.

IN6 Hybrid differential analyser.

IN7 Thick-film hybrid microelectronics.

IN8 Insulating layers by sputtering.

Ontmoetingscentrum voor Meet- en Regeltechniek - Signaalverwerking (OC-SV)

OC-SV1 The measurement of thermal diffusivity of thermal isolators.

OC-SV2 Complex phase velocity through a collapsible tube.

OC-SV3 Climate control in incubators.

OC-SV4a Monte Carlo experiments with an Insing lattice.

OC-SV4b Monte Carlo experiments on a crystal growth model.

OC-SV5 A digital echo generator for the measurement of speech intelligibility.

OC-SV6 A universal data acquisition system.

OC-SV7 A digital controlled multi character XY phototable.

OC-SV8a Generation of random sequences with specified correlation and distribution.

OC-SV8b A noise generator.

OC-SV9a Estimation of parameters of linear systems using periodic test signals.

OC-SV9b On-line correlator and Fourier analyzer.

OC-SV10 Time compression correlation.

OC-SV11	A maximum sequence generator with preset time shifts.
OC-SV12	Position detection by measuring transit time of noise.
OC-SV13	A digital filter in hubrid implementation.
OC-SV14a	Computer aided design of printed circuit layouts.
OC-SV14b	An XY tablet for digital conversion of graphic data.
OC-SV14c	Interface for a storage display unit.
OC-SV15a	Electrical properties of a thick film interconnection pattern.
OC-SV15b	Computer aided design of interconnection patterns, phase II.
OC-SV16	Improved address organisation of the cycle-steal interface.

Några projekt, som har beröringspunkter med verksamheten vid vår egen institution, är

- o Mätning av värmeledningstal. (Intr. för Bo Leden.)
- o Reglering av inomhusklimat i inkubator för nyfödda barn. I inkubator-projektet hade man mycket hårda krav på reglersystemet. Temperaturtolerans och fukttolerans var således mycket snäva och dessutom hade man kraftiga störningar då dessa inkubatorer i allmänhet står i rum där solljus direkt kan skina på inkubatorerna. Man hade byggt upp en försöksanläggning och experimenterade direkt med att göra reglering av den. Här finns flera beröringspunkter med Lars Jensens projekt beträffande klimatreglering.
- o xy-tablett som inorgan till en dator.
  Den grafiska terminalen till datorn som utvecklats var förhållandevis billig. Apparatkostnaden för ett bord av storlek 50 x 70 cm var ca 2.000 kronor. Apparaten finns beskriven i en särskild rapport som bifogas reserapporten.

Identifieringsproblem.

Identifieringsproblem diskuterades med van den Bos. Bl.a. behandlades asymptotiska egenskaper hos autoregressiva spektralestimat, maximal entropiestimat och utnyttjande av periodiska signaler i processidentifiering.

VERKSAMHET INOM INSTITUTIONEN FÖR MASKINTEKNIK.

Den reglertekniska verksamheten har en professur inom ämnet maskinteknik, professor Boyten. Han har mycket stor grupp med mellan 40 och 45 fast anställda och 60 studenter. Verksamheten är uppdelad på 5 forskningsprojekt.

1. Man maskinsystem (Stassen).

Verksamheten är huvudsakligen inriktad på att karakterisera människans egenskaper i olika reglerfunktioner. Man hade bl.a. byggt ett intressant experimentsystem, nämligen en cykel, där man hade goda möjligheter att studera människan som en flervariabel regulator. Man hade till en början utgått från Graham McRuels resultat, men man hade nu också börjat undersöka Kleinmans resultat, som går ut på att beskriva människan som en optimal linjärkvadratisk regulator. Man hade också börjat studera protesproblem, speciellt med tonvikt på människa-maskin kommunikation.

2. Tekniska system (Streiff).

Detta omfattar bl.a. processidentifiering och modellbygge. Man har utvecklat modeller för elektriska kraftstationer (intressant för Sture Lindahl!), destillationskolonner (intressant för Gustaf Olsson!) och man studerade reglering av verkliga processer. Det fanns en ganska omfattande laboratorieutrustning, bl.a. en modell av en kraftstation, omfattande ånggenerator, turbin, generator med elektrisk uppvärmning och elektrisk överhettning. Elektriciteten användes som elektrisk överhettare till ånggeneratorn.

3. Hydraulik (Viersma).

Detta var ett av de mest aktiva programmen. Man utvecklade således komponenter, ventiler, tryckregulatorer och system. Bland de tillämpningar, som studerats, märks numeriskt styrda verktygsmaskiner och medicinska system. Man hade t.ex. utvecklat en säng med vibrerande rörelser för personer med hjärtinfarkt, som visade sig vara mycket användbar. Vidare hade en hydrauliksimulator för simulering av tankhydraulik byggts, liksom en tredimensionell press. Man föreföll vara synnerligen väl förtrogen med hydraulisk teknologi, och man utvecklade praktiskt taget alla delkomponenter som ventiler och kolvar.

4. Instrumentering.

Detta omfattar konstruktion av mätinstrument. En viktig del av verksamheten var koncentrerad till proteser. Man hade således utvecklat en mycket liten ventil med låg energiförbrukning. Principen för ventilen var att en kula trycktes mot ett hål med hjälp av en tråd. Genom att värma tråden elektriskt kunde man sedan reglera trycket på kulan och därmed också flödet. Hela ventilen vägde mindre än 1,3 gram. Den var 3 mm i diameter och 20-30 mm lång. Man hade också utvärderat en protes, som var byggd i Delft. Vid diskussionen refererades till ett möte, som nyligen hade hållits i Dubrovnik, där man avsåg att kartlägga de för dagen mest relevanta tesproblemen. Det fanns ingen svensk representant med i detta möte.

5. Tillämpning av systemteori på problem inom Industrial Management.

Detta var ett av professor Boytens egna huvudintressen. Man hade bl.a. undersökt distribution och lagerstyrning.

En studie av manuell reglering av stora tankbåtar hade initierats tillsammans med det skeppstekniska laboratoriet. Man avsåg bl.a. att beskriva rorsmannens egenskaper. Man hade också ägnat sig åt EEG-studier, bl.a. för att få en bättre uppfattning om hur den mänskliga operatören beter sig. I samband med styrexperimentet tog man således ut EEG-signaler. Arbetet bedrevs i samarbete med den medicinska fakulteten vid Universitetet i Ütrecht. I samband med protesstudier hade man också lagt ner mycken möda på att undersöka om proteser skulle vara hastighetsstyrda eller positionsstyrda.

VERKSAMHET VID INSTITUTIONEN FÖR ELEKTROTEKNIK (professor Honderer)

Inom institutionen för Elektroteknik finns det två professurer i Reglerteknik, professor Honderer och van Nanta Lemke. Man hade nyligen börjat med doktorsutbildning. Man har haft två kurser, en 10-dagars kurs om digitala system, där auditoriet hade varit ca 40 ingenjörer med praktisk erfarenhet. Vidare hade en 3-dagars kurs i optimal reglering givits.

Forskning.

Forskningen var uppdelad på sju projekt. I varje projekt ingick två fast anställda, en till två tekniker och tre till fyra studenter. Man hade följande projekt:

1. Kraftsystem.

Modeller för on-line datorstyrning av kraftsystem hade utvecklats. Man hade således behandlat frekvensreglering och man var verksam med att utforma ett reglersystem för en 120 MW anläggning i Amsterdam. Man hade också studerat diverse optimeringsproblem, t.ex. lastfördelning. I detta sammanhang hade man gjort intressanta experiment. Man hade således simulerat enstaka kraftstationer på små analogimaskiner i kombination med en mycket enkel statisk modell av nätet. Man styrde sedan kraftstationerna med optimala kommandon från en dator PDP 11.

2. Skeppsstyrning.

Adaptiva regulatorer för skeppsmanövrering studerades. På grund av variationer i vattendjup och vågornas karaktär kommer skeppsdynamiken att ändras avsevärt, och man undersökte härvid möjligheten att utnyttja adaptiva reglersystem. I samband med detta hade man också studerat processidentifiering.

3. Processreglering.

Detta omfattade modellbygge och on-line reglering. Man hade några enklare processer i laboratoriet, bl.a. värmeväxlare, tanksystem och en PI-reglerkrets såsom testexempel.

4. Motorstyrning.

Hastighetsreglering av elektriska motorer med effekter överstigande 10 kW studerades.

5. Servosystem.

6. Datorstödd konstruktion PDP 9.

Ett datorbaserat system för dimensionering av reglersystem hade utvecklats. Man hade ett oscilloskop av typ "refreshing" med ljuspenna på vilket man kunde rita blockschema och få ut systemsimulering.

7. On-line datorstyrning (PDP 11).

Institutionen förfogade över en PDP 11, som användes för experiment av on-line datorstyrning. Man studerade bl.a. hierarkisk styrning.

Intressanta tips (Leif Andersson, Bo Leden).

Man hade i laboratoriet flera fyndiga experimentuppställningar. Bl.a. fastnade jag för en systemsimulator, som bestod av ett antal plåtlådor, som lätt kunde kopplas ihop med standardkontakter. Man hade 4 kontakter, 2 för signal- och 2 för kraftförsörjning. I dessa lådor hade man sedan med hjälp av operationsförstärkare byggt in typiska operatorer. Lådorna hade blockschema symboler på framsidan. Man kunde kombinera lådorna på många olika sätt och enkelt bygga upp system för demonstration. Man hade även utvecklat samplade regulatorer som realiserade samplare och hållkretsar och z-transformer (borde vara intressant för Källe-Regulator).

BESÖK PÅ TEKNISKA HÖGSKOLAN I TWENTE TISDAGEN DEN 30 MAJ.

Tekniska Högskolan i Twente skiljer sig avsevärt från de övriga högskolorna. Den är ny, ca 10 år gammal, och har campuskaraktär. Det krävs således att studenterna bor på campus under de första åren. Många av studenterna bor sedan kvar där. Flera av fakultetens medlemmar bor också ständigt på campus. Man hade även här en Bachelors Degree som tar 3 1/2 år, man studerar i tre år och har en kort avhandling. Masters Degree tar sedan ytterligare två år. Vid universitetet i Twente finns reglertekniken representerad på tre professurer, professor Rijnsdorp, Process Dynamics, Professor Offereins, Electrical Engineering, och Professor Kwakernak, Tillämpad Matematik. Jag hade möjlighet att diskutera med alla tre och att se samtliga laboratorier.

REGLERTEKNIK VID INSTITUTIONEN FÖR KEMITEKNIK.
Professor Rijnsdorp.

Professor Rijnsdorp, som ursprungligen kommer från Shell, är ansvarig för undervisning i reglerteknik inom sektionen för kemiteknik. Ämnet kallas här processdynamik. Grundidén är att ge studenterna en känsla för processdynamik och processreglering. Flera kurser är av direkt intresse för oss vid LTH, bl.a. i samband med kemiutbildningen. Vi överenskom om ett utbyte av kompendier och undervisningserfarenhet (intressant för Gustaf Olsson). Kursen för kemister omfattar således tre enheter där varje enhet motsvarar en föreläsningstimme per vecka. Förutom den inledande kursen har man 4 fortsättningskurser, som behandlar komplexa system, optimering, flervariabla system och tillämpningar av on-line datastyrning. Datorstyrningskursen, som definitivt är av intresse, gavs på prov förra året med fyra studenter. En kopia av kursprogrammet finns som bilaga till denna rapport.

Forskningsprogram.

Forskningsprogrammet omfattade 4 projekt:

1. Reglering nära begränsningar.

Vid många industriella processer är det ett speciellt problem att reglera processer, som ligger nära begränsningar. Å ena sidan vill man ligga så nära begränsningen som möjligt, men det kan vara katastrofalt att överskrida begränsningen. På detta sätt får man asymmetriska kriterier.

2. Flervariabel reglering.

Rijnsdorp ansåg att de väsentliga problemen inom processreglering finns bland de flervariabla systemen. Man hade därför ett projekt inom detta område.

3. Icke tekniska system.

Man studerade bl.a. analys av reningsverk, och man hade även ett mindre projekt beträffande världsmodeller. Överhuvudtaget fanns ett mycket stort intresse för Forresters arbeten i Holland.

4. Ergonometrics.

Man hade ett stort projekt, som avsåg att studera människa-maskin funktioner i samband med processreglersystem. Man hade för detta ändamål byggt modulära operatörspaneler, med vilka man lätt skulle kunna experimentera. Man hade också en psykolog anställd på institutionen för projektet.

Laboratorier.

I laboratoriet fanns en destillationskolonn-liknande apparat, där man använde sig av varmluft och varmt vatten. Man hade dessutom ett ph-reglersystem och ett enklare tanksystem för undervisning. I laboratoriet fanns dessutom en analogimaskin, modell AD-4. Vidare hade man några mindre analogimaskiner av samma fabrikat, och dessutom hade man en PDP 11.

BESÖK PÅ AVDELNINGEN FÖR ELEKTROTEKNIK.
Professor Offereins.

Även inom avdelningen för elektroteknik hade man komplett reglerteknisk undervisning inklusive laboratorier. Denna verksamhet leddes av professor Offereins, som kommer från Philips.

Kurser.

Man hade följande kurser:

1. Inledande kurs i reglerteknik.
2. Samplade system.
3. Optimalreglering.
4. Servosystem.
   - Fjädrande last.
   - Glapp.
   - Störningar.
   - Minimaltidsinställning.
5. Simulering.

Kursen om servosystem var speciell och den byggde på professor Offereins särskilda erfarenheter under hans verksamhet vid Philips. Han hade också nära kontakt med en av Philips lokala industrier, som tillverkade eldledningsutrustningar.

Laboratoriet.

Som vanligt var laboratoriet väl utrustat. Det fanns dels ett vanligt undervisningslaboratorium med en tankprocess. Förutom nivåreglering gjordes även försök med temperaturreglering. Man hade prövat att göra optimal nivåinställning och funnit att detta var svårt. Vidare fanns logiksimulatorer och pneumatiska system. Man hade dessutom en rolig apparat, en kula som rullade på tvådimensionellt plan. Planet lutades pneumatiskt och kulans läge avkändes med hjälp av en TV-monitor. Dessutom hade man gjort försök med skeppsstabilisatorer varvid kompletta gyroplattformar utnyttjats. På institutet hade man dessutom tillverkat en liten dator, men man höll nu på att övergå till PDP 11. Storskärmsoscilloskop utnyttjades ofta vid undervisningen.

AVDELNING FÖR TILLÄMPAD MATEMATIK.

Inom avdelning för tillämpad matematik hade man också reglerteknik. Den representerades i form av professor Kwakernak, vars professur hette stokastiska system och tillämpad fysik. Professor Kwakernak ägnar sig huvudsakligen åt stokastisk reglerteori. Han har nyligen skrivit en bok. Bland de problem, vi diskuterade, märktes bl.a. en stokastisk process, som är sådan att den är periodisk, $x(t) = x(t+T)$. Med Mr. P. Alper diskuterades även reglering av icke-tekniska system.

BESÖK PÅ SHELLS FORSKNINGSLABORATORIUM.

Inledning.

Shell har sin forskning koncentrerad till ett stort centralt laboratorium i Amsterdam. Dessutom har man ett antal perifera laboratorier, t.ex. i Delft och i England. Man genomgår för närvarande en kris då bl.a. engelska laboratorierna och dessutom laboratoriet i Delft också skall läggas ner. Detta har bl.a. medfört att marknaden för kemiingenjörer i Holland nu är synnerligen besvärlig. Nyutexaminerade ingenjörer kan således svårligen vänta sig att få arbeten.

Organisation.

Forskningslaboratoriet, som totalt omfattar 1.930 personer, är uppdelat på fyra avdelningar:

Oil product and processes
Chemical products and processes
Engineering
Fundamental Sciences

Varje laboratorium ledes av en direktör. Reglertekniken finns representerad inom Engineering och inom Fundamental Sciences. Den stora aktiviteten finns inom Engineering som är uppdelad på följande avdelningar:

Equipment Engineering
Materials
Operations Control
Physical Separation

Den reglertekniska avdelningen är den som kallas Operations Control. Den består för närvarande av ca 40 personer, varav 24 är på doktorsnivå.

Filosofi.

Jag hade tillfälle att diskutera den allmänna uppläggningen av verksamheten inom Operations Control med Dr. de Jong, och han gav följande bild av verksamheten. Inom avdelningen sysslar man med samtliga reglertekniska aspekter inom hela företaget. Man behandlar således en rad skilda problem, såsom

Refining
Chemical Manufacturing
Marine
Pipelines
Warehousing (operations research)
Basic Research

Det var i viss utsträckning förvånande att höra att man även ägnade sig åt problem rörande skeppsautomation, men då Shell är den största ägaren av tankbåtar i världen, är detta inte onaturligt.

Industriell processreglering.

Den grundläggande synen på industriell processreglering kan illustreras med bilden i Fig. 1.

En industriell process betraktas således som sammansatt av tre komponenter: processen, reglerutrustningen och operatören. Den väsentliga funktionen av reglersystemet är att eliminera störningar, som kan uppkomma inuti processen, i reglerutrustningen, eller genereras av operatören. Störningarna kan också komma från utomstående källor. Problemet är att arrangera det totala systemet så att det blir okänsligt för alla former av störningen. Man hade utfört ganska omfattande forskning vad beträffar utformningen av reglerutrustningen. Man hade baserat erfarenheterna på 8 datorer, som för närvarande fanns on-line. Man hade också konstruerat speciell interface utrustning, där ett intressant särdrag var att man lagt in en hel del av back-up funktioner i interfacet. En annan intressant synpunkt var att man gärna ville ha en flytande gräns mellan människa och maskin. Man kunde alltså tänka sig att vid olika typer av fel så kunde systemet struktureras om så att en del funktioner flyttades över till operatören, respektive till datorn. Man lade för närvarande mycket stor vikt på människa-maskin-problem. Man hade här ett etablerat samarbete med universitetet i Utrecht, där man har tillgång till psykologer.

Forskningsprogrammet inom avdelningen för refining kan uppdelas på fyra delar:

Ergonometri
Control Theory
Computer Hardware
Electronics

Det var också intressant att notera att man för närvarande hade relativt begränsade erfarenheter av sofistikerade regleralgoritmer (se vidare under diskussion).

Hybriddator (Mr. Anzenhofer).

Shell har en mycket stor hybridanläggning (troligen en av de största i världen). Den består av två Comcor analogimaskiner med 24 resp. 35 integratorer. Vidare har man 2 datorer, Sigma 5 och Sigma 7, och man har ett specialbyggt interface, levererat från England. Hela anläggningen kan sammanfogas till en enhet, men man kan också köra de olika delarna var för sig eller i olika konfigurationer. Man hade för närvarande stora simuleringsproblem, framför allt vad beträffar processer, som beskrivs av partiella differentialekvationer. Man hade haft en hel del problem med utrustningen. Framför allt så hade interfacet mellan analog- och digital-delarna ej fungerat tillfredsställande. Man tänkte sig att i en framtid ersätta hela anläggningen med en digital simulator. Dock ansåg man att det i dagens läge ej var möjligt att göra, då människa-maskin-problemen ej var lösta för digitala simulatorer. För begränsade problem hade man haft god erfarenhet av digitala simulatorer. Man använde ett språk RXDS, som påminner om CSSMP för IBM resp. CSSL för UNIVAC.

Föredrag.

Jag gav i ett föredrag en översikt av institutionens forskningsverksamhet.

Industriell processreglering - diskussion.

Jag hade möjlighet att tillsammans med en mindre grupp diskutera reglerproblem inom kemiindustrin. Följande personer deltog:

Snoek

Bos
van Holtz
Turner
van de Vet
van Aarle
Dwaal

Dessa personer representerar ett brett spektrum av erfarenheter. Mr. Bos hade t.ex. sysslat med tillämpning av processdatorer i raffinaderier och i högvacuumdestillationsanläggningar. Han var speciellt intresserad av DDC. Mr. Snoek hade undersökt möjligheter att förenkla analoga simuleringar genom att först transformera problemet till jordanform. Mr. van Holtz var intresserad av automation av skeppsmaskineri och bryggstyrning. Han hade bl.a. studerat kollisionsvarning, styrning, dimensionering av reglersystem för skeppsmaskinerier. Han var speciellt intresserad av hög pålitlighet och diagnostik. I samband med styrprojektet hade man studerat den s.k. deck-modellen, där parametrarna i en andra ordningens olinjär modell bestäms ur inversa spiraltest. Man hade undersökt kollisionsvarning för tvåskeppsförhållanden, men inte för flerskeppsförhållanden. Mr. Turner hade sin erfarenhet från det kemiska fältet, reglering av polyprotylen, etylen, övervakande reglering av en etylenugn, stationär optimering, dynamisktmodellbygge, snabba avstängningar och uppstarter. Han hade arbetat med reglering av en besvärlig destillationskolonn. Han nämnde t. ex. att man utan svårigheter simulerade system med flera hundra differentialekvationer. Mr. van Aarle hade undersökt dynamiken hos destillationskolonner. Han hade misstänkt att det skulle finnas stora variationer i parametrar, som skulle motivera adaptiva regulatorer. Han var för närvarande engagerad i reglering av pipelines och simulering. Mr. Dwaal var sektionschef.

Bland de synpunkter, som bringades upp i diskussionen, kan nämnas störningar och regleralgoritmer.

Störningar.

Man har trots ett stort antal loggningar ingen klar bild av störningarnas egenskaper, men man indikerade dock att många störningar rimligen ej var gaussiska och stationära. Man kunde tänka sig modeller där man har flera typer av processer och man skiftar mellan dessa olika typer. (Detta är en fråga, som vi borde titta närmare på på institutionen, då det är centralt för processregleringar att ha en god beskrivning av störningarna.)

Regleralgoritmer.

Man ansåg (van Aarle) att PID-regulatorer var tillräckligt för 80% av alla reglerkretsar. Man trodde att nivåreglerkretsar skulle vara olinjära. Praktist taget inga regleringrepp så länge nivån ligger inom rimliga gränser men kraftiga regleringrepp, när man närmar sig tomma tankar resp. fulla tankar. Problem då man styr nära begränsningar förefaller vara intressant. Man ville gärna ha asymmetriska regleralgoritmer som gör mycket större regleringrepp när man tenderar att överskrida gränserna än när gränsen underskrides. Man tänkte sig att mer elaborerade regleralgoritmer behövs när det gäller system med tidsfördröjningar. Det viktigaste problemet inom reglering av industriella processer ansåg man dock vara reglering av flervariabla system. Man nämnde även en intressant metod för dekomposition av komplexa system som skulle presenteras på en NATO-konferens i Cambridge i september.

BESÖK I EINDHOVEN, TORSDAG - FREDAG 720601-02.

Inledning.

Universitetet i Eindhoven är ca 10 år gammalt. Även här finns reglertekniken representerad inom två avdelningar, avdelningen för Teknisk Fysik och avdelningen för Elektroteknik. Inom avdelningen för Elektroteknik finns 4 professurer, inom Teknisk Fysik en professur. Jag hade möjlighet att diskutera med båda grupperna samt dessutom att besöka laboratorierna.

SEKTIONEN FÖR TEKNISK FYSIK.

Reglertekniken inom sektionen för Teknisk Fysik förestås av professor Rademaker. Han har tidigare varit reglertekniker vid Shell-laboratorierna och har därigenom en stark kemisk inriktning. Jag gick i korthet igenom kurserna och koncentrerade mig på att studera deras laboratorier. En detaljerad presentation sker nedan. Professor Rademaker var numera kraftigt engagerad i systemdynamik, baserad på Forresters arbeten. Ett speciellt referat av detta ges även.

Studentlaboratoriet.

Laboratorierna var mycket välutvecklade och synnerligen välutrustade. Man hade också en stor omfattning av den experimentella verksamheten. I studentlaboratoriet hade man bl.a. följande processer:

1. Pots and Pans.

Denna process påminner mycket om vår plas- och pys-process men var mycket större i geometrisk utsträckning. Det var också intressant att notera att man hade två identiska parallella processer bl.a. för att få icke minimum-faseffekter.

2. Pneumatiska system.

Man hade också ett synnerligen komplett laboratorium för pneumatiska komponenter. Det mest kompletta laboratorium i detta avseende som jag sett! Det fanns många stationer och hela programmet var upplagt för att ge studenterna en mycket god detaljkunskap om pneumatiska regulatorer och pneumatiska reglerkretsar. Man började således med en uppställning där man studerade de fundamentala komponenterna, flapperventil, reläförstärkare och ventil. Därefter övergick man i flera stationer till att studera DP-celler, regulatorer, ventilmodeller. Slutligen hade man en enkel tankprocess med ett antal tankar, och man kunde studera såväl kontinuerliga regulatorer som regulatorer av on-off-typ. Totalt hade man ca 250 studenter i laboratoriet. En komplett laborationskurs omfattar 12-13 halvdagar. Det var intressant att notera, att man offererade detta som en separat kurs till studenterna.

Forskningslaboratoriet.

I forskningslaboratoriet hade man för närvarande fyra processer:

1. Destillationskolonn

2. Värmeväxlare
3. Ånggenerator, kondensor
4. Ph-reglering

Destillationskolonnen var samma typ som glaskolonnen på Kemicentrum vid LTH. Den har använts mycket under första året men hade sedan inte använts. Skälet till detta var, att den var alltför komplicerad att hanteras av studenter. Man hade däremot haft stor glädje av värmeväxlarprocesserna. De var mycket lätta att köra, och man hade utfört många experiment med dem, och studenterna kunde utan svårighet sätta sig in i dessa laboratorieutrustningar. Beträffande ph-reglering använde man metron kalomelelektroder, som var tillverkade i Schweiz. Man refererade även till en artikel av Kochenburger, som hade utfört en analys av problemet.

Processimulator.

För undervisningsändamål hade man utvecklat en speciell processimulator. Den var uppbyggd av traditionella analogimaskinkomponenter, och man kunde simulera olika processmodeller i snabb tidsskala. Simulatorn var dessutom försedd med olika faciliteter. Man kunde således visa stegsvar för öppna och slutna system. Man kunde direkt registrera Bode-diagram och Nyquist-kurvor. Man kunde simulera störningar av olika slag, och man kunde presentera kurvor, som visar hur störningarna dämpas av reglersystemet inom olika frekvensområden. Man sade sig ha mycket goda erfarenheter av denna processimulator både i undervisning på civilingenjörsnivå och på lägre nivå.

Datorlaboratorium.

Man hade ett datorlaboratorium bestående av två PDP 8:or och en Telefunken analogimaskin. Det var också möjligt att koppla processerna i forskningslaboratoriet samt i studentlaboratoriet till dessa PDP 8:or. Man hade skivminne, och man utvecklade för närvarande programvara själv.

Hybridlaboratorium.

Man hade ett hybridlaboratorium bestående av en analogimaskin Pace 231 R, tämligen väl utbyggd med ca 100 förstärkare varav 30 integratorer. Dessutom hade man en EAI 680 med 70 förstärkare, varav 30 integratorer.

Systemdynamik.

Professor Rademaker var mycket intresserad i systemdynamik. Som tidigare nämnts fanns ett mycket stort intresse för detta i Holland. Professor Rademaker hade utgått från Forresters modeller och simulerat dem. Den speciella modell, man studerat, var den, som av Forrester kallas för "world two", vilken består av fem olinjära differentialekvationer. Rademaker hade påvisat, att den tillståndsvariabel, som svarar mot "pollution", svänger in sig mycket snabbt i förhållande till de övriga och att Forrester valt mycket olyckliga begynnelsevärden av denna variabel. Vidare hade man påvisat, att ekvationerna kunde separeras i två grupper. Man hade vidare gjort en känslighetsanalys och som klart indikerar att resultaten kunde påverkas mycket drastiskt genom små ändringar i vissa parametrar. Vidare hade man funnit att Forresters resultat var känsliga för mindre ändringar i integrationsalgoritmerna. Den filosofi, man hade, var att ta existerande modeller och sedan applicera sund systemteknik på dessa. Man avsåg inte aktivt medverka i modellbyggandet i någon större omfattning. Man hade följande planer för det fortsatta arbetet.

1. <u>Förståelse av modellen</u>.

Man ville undersöka dekomposition och storleksordningar för att få insyn hur modellen fungerar.

2. <u>Känslighetsanalys</u>.

Genom traditionell känslighetsanalys ville man undersöka hur känslig modellen var för parametervariationer. Detta arbete hade som angivits ovan redan startat.

3. <u>Dynamiska förbättringar</u>.

Man diskuterade olika möjligheter att förbättra modellen. För närvarande tänkte man sig att införa en åldersfördelning och att införa naturtillgångar.

4. <u>Val av styrvariabler</u>.

I modellen World 1 styrde man endast på koefficienterna. Man kunde säkert tänka sig andra former av styrvariabler.

5. <u>Stabiliserande reglerstrategier</u>.

På basis av modellen ville man undersöka hur man skulle styra den för att få bästa möjliga resultat, t.ex. om man stoppar alla investeringar, sätter dem till en konstant nivå, visar det sig att modellen svänger in sig mycket fint.

6. Dynamisk optimering.

Man vill undersöka olika former av optimala strategier.

7. Simuleringsteknik.

Man vill undersöka olika modeller att simulera den givna modellen.

I det fortsatta programmet tänkte man sig bl.a. följande. Professor Tinbergen ("Nobelpristagare" i ekonomi) hade börjat intressera sig för modellen och speciellt ville han undersöka samspelet mellan rika länder och fattiga länder. I projektet hade man för närvarande 6 personer heltid, 4 studenter och 2 assistenter. Dessutom använde Rademaker ca 25% av sin tid på projektet. Ca 25 personer var också engagerade på deltid.

Undervisning i reglerteknik för kemister.

Genom sin bakgrund från Shell hade professor Rademaker flera synpunkter på undervisning i reglerteknik för kemister. Han ansåg att den uppläggning, som Rijnsdorp hade, var mycket bra, och han lovade att skicka över några av sina kompendier. Dessutom nämnde han att han själv brukade ta ett avslutande exempel som visar hur svårt det var att göra reglersystem. Exemplet utgick från ett uppmätt stegsvar. Han visade sedan hur man kan anpassa tre olika överföringsfunktioner till stegsvaret, men att de genom att passera reglerstrategi, som dimensioneras på basis av de olika överföringsfunktionerna, är helt olika. Genom att sedan förklara vad som händer avsåg han att visa att reglerteknik icke är så lätt som det kanske framgått i kursen. Avsikten var att uppmana kemitekniker

Är detta korrekt? (kemi. sid 17)

att ta kontakt med professionella reglertekniker istället för att ägna sig åt "hemslöjd", när de stöter på reglerproblem.

AVDELNINGEN FÖR ELEKTROTEKNIK.

Inledning.

Inom avdelningen för Elektroteknik finns för närvarande fyra professorer, varav tre på heltid, Eykhoff, Mulders, Kijlstra och Bekkering. Dessutom fanns 14 fast anställda akademiska medarbetare. Jag gick igenom forskningsprogrammen och diskuterade speciellt den verksamhet, som utförs av professor Mulders och professor Eykhoff.

Tröghetsnavigering.

Professor Mulders har ett program i tröghetsnavigering. Det är i viss utsträckning förvånande, därför att det ej finns någon holländsk industri, som arbetar inom området. Å andra sidan har professor Mulders stor erfarenhet från utveckling av mätutrustningar. Han tror också att det finns billiga tillämpningar av tröghetsteknik. Professor Mulders filosofi var att arbeta med relativt enkla och billiga komponenter med låg noggrannhet. Jag tittade bl.a. på följande tillämpningar:

Schuleravstämning
Foucaultpendel
Illustration av stabilisering av enkel flygplansmodell

Man hade byggt en 1-axlig Schuler-avstämning, baserad på min och öing. Hectors idé med ett enkelt gyroskop.

Jordgravitationen simulerad med en spänd fjäder. Jordradien i experimentet var ca 20 meter. Man hade lyckats få tag på flera billiga gyroskop, bl.a. ett från Timex, och man hade också gjort gyroskop själv av freeflextyp, där man använder Bendix fjädrande upphängningar.

Flygplansmodellen var mycket intressant. Man visade ett odämpat fjädrat system, och sedan hade man en fläkt, som blåste och visade hur man på ett enkelt sätt kunde införa stabilisering med ett reglersystem. Man hade byggt all elektronik själv och man hade de vanliga svårigheterna med elektronik, som hade byggts av studenter.

VERKSAMHET INOM AVDELNING FÖR REGLERTEKNIK (Prof. Eykhoff).

Jag presenterade två föreläsningar, en om tröghetsnavigering och en om erfarenheter av processidentifiering. Dessutom besökte jag professor Eykhoffs laboratorium, och jag diskuterade med hans studenter.

Pågående projekt.

Professor Eykhoff hade ett stort antal studenter, som var engagerade med processidentifiering. Bl.a. diskuterades följande.

1. Ivahnenkos metod.

En av Eykhoffs studenter hade studerat professor Ivahnenkos metod för att hitta strukturer i flervariabla system. Han hade haft svårigheter att få rätt struktur, och metoderna är också beroende på hur man startar.

2. Utveckling av estimationsteknik.

Man tittade bl.a. på ordningstest och användning av Instrumental Variables.

3. Dispersionsfunktioner.

En student hade undersökt Rajbmans teori om dispersionsfunktioner.

4. Blodcirkulation.

Man hade ett ganska omfattande program för att studera blodcirkulation. Man koncentrerade sig på diagnos av hjärtfel i aortatrakten. Man hade gjort mätningar på såväl patienter som på en laboratorieutrustning. Man gjorde en modell i form av en transmissionsledning, eventuellt med vissa olinjäriteter. Kvantiseringsfenomen hade undersökts, och man hade börjat diskutera parameterskaffning. Det fanns en omfattande experimentell utrustning, bestående av en plastmodell av aorta med pumpar och en analogimaskin, där man efterbildade de dynamiska egenskaperna. Strömningshastigheter mättes med dopplerteknik.

5. Hjärtmodeller.

Man hade försökt identifiera en dipolmodell av ett hjärta. Man hade spaltat upp hjärtat i fem sektioner, där man karakteriserade varje dipol med en intensitet och en responskurva, som hade ungefär gaussform med en intensitets-parameter, en tidsfördröjningsparameter och en spridningsparameter. Totalt får man således 15 parametrar. Dessutom tillkom de parametrar, som beskriver hur det elektriska fältet breder ut sig från hjärtat till receptorerna. Man hade använt parameterskattningsteknik för att bestämma de okända parametrarna. Man hade dessutom gjort en analogisimulering, och denna visade, att man kunde få mycket god anpassning till vanliga EEG, åtminstone för normala patienter.

6. Q-värdesmätning.

Man hade betraktat problemet med Q-värdesmätning som ett processidentifieringsproblem. Det gäller att bestämma R, L och C för en ekvivalent krets, och man hade utvecklat en speciell hårdvara för att göra detta. Man tänkte sig många tillämpningar när det gäller produktionskontroll av elektronikkomponenter.

7. Aktiv motorstyrning.

På basis av en doktorsavhandling av Wynfried Spet i Braunschweig "Selbstanpassende Regelsysteme in der Antriebstechnik" Dissertation Technischer Universität Karolo Wilhelmina zu Braunschweig 1971. Mr. Spet finns för närvarande på Siemens AG, Postfach 1, 8520 Erlangen, Deutschland. Ett referat av avhandlingen finns även i Siemens Zeitschrift 42 (1968) 765-768. Man hade byggt ett liknande system i laboratoriet med en ganska stor elektrisk motor av länddimensionen 1/2 meter och till detta hade man ett elektronikskåp, och man hade mycket fina resultat på de självinställande regulatorerna.

8. Den mänskliga operatorn.

Man hade även försökt att identifiera den mänskliga operatorn med processidentifieringsteknik.

Laboratorier.

Laboratorierna var synnerligen välförsedda. Man hade således en hybriddator, baserad på Hitachi plus IBM 360 modell 30. Man hade ett stort antal analogidatorer, och man hade många uppställningar för studentexperiment och dessutom fanns laboratorier, där studenterna kunde göra sina examensarbeten. Dessutom hade man nyligen fått en processdator, PDP 11.

ALLMÄNNA INTRYCK.

Den stora skillnaden på civilingenjörsutbildningen i Holland och i Sverige är, att man i Holland som regel har ett 3-årigt program, som är lika för alla, och efter detta två år av specialisering. Dessa två specialiserade år tillbringar studenten i allmänhet på ett fåtal institut, t.ex. reglerteknik. I den specialiserade utbildningen ingår också ett examensarbete, som skall genomföras på 9 månader. Dessa examensarbeten är ofta av experimentell karaktär. Detta har som omedelbar konsekvens, att den experimentella verksamheten har en mycket större omfattning i Holland, än den har i Sverige. Många studenter ägnar sitt examensarbete åt praktiska problem, t.ex. att bygga elektronik och experimentutrustningar, att göra datorprogram etc. Denna form av utbildning är förträfflig, men den kräver mycket handledning. Det belyses t.ex. av det relativt stora antalet fast anställd personal. Man har inte korttidstjänster, motsvarande våra assistenter, utan istället fast anställd personal. I samband med den experimentella verksamheten har man stött på samma problem som vi har sett i liten skala i Lund, nämligen att det är mycket svårt att få studenter att under ett examensarbete göra förstklassig elektronik och förstklassig programvara.

En annan skillnad är att reglertekniken är utspridd på olika avdelningar. De totala resurserna i Holland vad beträffar reglertekniken är således avsevärt mycket större än vad de är i Sverige. Enbart i Delft har man således 6 professurer, som direkt sysslar med reglerteknik, och man har ca 100 fast anställda akademiker på civilingenjörsnivå, som fungerar som biträden vid undervisningen. Det holländska undervisningsministeriet har emellertid i dagarna framlagt en ny plan för civilingenjörsutbildningen, som kommer att ta 4 år, och det är ännu inte klart på vilket sätt den ska förverkligas, och hur utbildningen kommer att påverkas.

Visit Prof.K.J. Åström, May 30, 1972

10.23 Arrival

11.00 J.E. Rijnsdorp, Prof. of Process Dynamics and Control, Chemical Engineering Department

12,00 R.W. Offereins, Prof. of Automatic Control, Electrical Engineering Department

13.00 Lunch

14.00 - 15.30 Seminar, EF 8130

16.00 Informal discussion, A 103

Evening: dinner, departure for Amsterdam.

Gudmar
Här finns mera korrekt
Vill Du skriva försättssida
och innehållsförteckning

Studiebesök i Delft (versaler!) MÅNDAGEN DEN 29 MAJ 1972

INLEDNING

Vid tekniska högskolan i Delft som har ca 10.000 studerande, är reglertekniken uppdelad inom 3 olika avdelningar

Teknisk Fysik
Elektroteknik
Maskinteknik

Vid flera av avdelningarna finns också flera professurer i reglerteknik. Vid mitt besök diskuterade jag med representanter från alla tre avdelningarna. Beträffande kurser så skiljer sig det holländska systemet från vårt därigenom att man har en femårig utbildning. De första 3 åren är således av allmän karaktär och därefter specialiserar sig studenten inom ett fackområde där han också gör sitt examensarbete. Examensarbetet omfattar som regel 9 månaders heltidsarbete. Detta betyder som regel att man ägnar sig åt laboratoriearbete i mycket större utsträckning i Delft än vad vi gör i Sverige. Laboratorieprojekten är också mycket mer~~a~~ omfattande. Däremot så är antalet studenter som läser som läser högre kurser mindre. Det förekommer reglerteknik i de inledande kurserna under de första tre åren, men huvudsaklig utbildning är förlagd till de sista två åren. Denna utbildning kallas i Holland för "graduate studies" och är närmast att jämföra med den amerikanska "masters degree". Däremot finns ej ~~ännu så~~ någon ~~länge ingen~~ organiserad doktorsutbildning. Beträffande kursernas detaljutformning hänvisas till de rapporter som varje år erhålles från "Heads of the North Western Control Laboratories". Jag kommer i denna rapport därför endast att ta upp ämnen ~~saker~~ som är av speciellt intresse för mig och mina medarbetare på institutionen.

REGLERTEKNIKS VERKSAMHET VID SEKTIONEN FÖR TEKNISK FYSIK

Vid sektionen för teknisk fysik finns två professurer med stark reglerteknisk anknytning, Professor Verhagen och professor Veldtman som har mät- och reglerteknik, respektive regler- och signalteori. Professor Verhagen var bortrest, men jag hade goda möjligheter att diskutera med professor Veldtman. Genom att man har ett stort antal studenter, ca 20 stycken, som genomför examensarbeten av 9 månaders omfattning ~~karaktär~~, Demonstraties op vrijdag 10 maart 1972 in het Laboratorium voor Technische Natuurkunde.

Biologische Natuurkunde (BN)

BN1	Pitch perception of click pair stimuli.
BN2	Pitch of monaural and binaural tone complexes.
BN3	Binaural lateralization in relation to pitch perception.
BN4	Visual perception of periodic spatial patterns.
BN5	The aftereffect of moving visual patterns.
BN6	Firing pattern of auditory in response to sounds with their repetition.
BN7	Pitch phenomena and their common central origin.

Bestuurde Prothesen (BP)

BP1	Prothesis control by pattern recognition.
BP2	Movement studies of human extremities by means of a TV camera.
BP3	An experimental amplifier for surface electromyography.
BP4	Electrical skin stimulation as a sensory substitute.
BP5a	Interface for the digital magnetic tape recorder
BP5b	A shift register buffer for the digital tape recorder.
BP6	Zero voltage crossing switch.

Instrumentatie (IN)

IN1	Automatic reading of handwritten numbers.
IN2	A video digital converter for four levels.
IN3	The die-tester.
IN4	Automatic chromosome analysis.
IN5	Automatic interpretation of vectorcardiograms.
IN6	Hybrid differential analyser.
IN7	Thick-film hybrid microelectronics.
IN8	Insulating layers by sputtering.

Ontmoetingscentrum voor Meet- en Regeltechniek - Signaalverwerking (OC-SV)

OC-SV1	The measurement of thermal diffusivity of thermal isolators.
OC-SV2	Complex phase velocity through a collapsible tube.
OC-SV3	Climate control in incubators.
OC-SV4a	Monte Carlo experiments with an Ising lattice.
OC-SV4b	Monte Carlo experiments on a crystal growth model.
OC-SV5	A digital echo generator for the measurement of speech intelligibility.
OC-SV6	A universal data acquisition system.
OC-SV7	A digital controlled multi character XY photo-table.
OC-SV8a	Generation of random sequences with specified correlation and distribution.
OC-SV8b	A noise generator.
OC-SV9a	Estimation of parameters of linear systems using periodic test signals.
OC-SV9b	On-line correlator and Fourier analyzer.
OC-SV10	Time compression correlation.
OC-SV11	A maximum sequence generator with preset time shifts.
OC-SV12	Position detection by measuring transit time of noise.
OC-SV13	A digital filter in hubrid implementation.
OC-SV14a	Computer aided design of printed circuit layouts.
OC-SV14b	An XY tablet for digital conversion of graphic data.
OC-SV14c	Interface for a storage display unit.
OC-SV15a	Electrical properties of a thick film interconnection pattern.
OC-SV15b	Computer aided design of interconnection patterns, phase II.
OC-SV16	Improved address organisation of the cycle-steal interface.

Plattegrond Laboratorium voor Technische Natuurkunde, zie achterzijde.

Programma:

14.00-14.30	Inleiding zaal B aula.
14.30-.....	Demonstraties. De werkgroepen staan vermeld op de plattegrond op de achterzijde en de nummers van de nummers van de demonstraties op de borden in de gang.
15.30-16.00	Koffie in de leeszaal (zie plattegrond).
16.00-.....	TeePeeKaaFee (kelder onder D vleugel).

så sker forskningsarbeten i stor utsträckning i anslutning till dessa projekt. Nedan ges en lista av pågående projekt.

Ge lista på separat blad!

?

Några projekt som har beröringspunkter med verksamheten vid vår egen institution är

- x) Mätning av värmeledningstal (Intressant för Bo Leden!)

- Reglering av inomhusklimat i inkubator för nyfödda barn. Här finns flera beröringspunkter med Lars Jensens projekt beträffande klimatreglering.

  x) ~~Här finns goda anknytningspunkter till Bo Ledens projekt på vår värmestav.~~

- xy-tablett som inorgan till en dator.
  ~~In~~ I inkubator projektet hade man mycket hårda krav på reglersystemet. Temperaturtolerans och fukttolerans var således mycket snäva och dessutom hade man kraftiga störningar då dessa inkubatorer i allmänhet står i rum där solljus direkt kan skina på inkubatorerna. Man hade byggt upp en försöksanläggning och experimenterade direkt med att göra reglering av den. Den grafiska terminalen till datorn som ~~man~~ utvecklats var att förhållandevis billig. Apparatkostnaden för ett bord av storlek 50 x 70 cm var ca 2.000 kronor. Apparaten finns beskriven i en särskild rapport som bifogas reserapporten.

Identifieringsproblem

~~Jag diskuterade också~~ Identifieringsproblem ~~i något mer detalj~~ diskuterades med van den Bos. ~~Vi diskuterade~~ Bl a behandlades assymptotiska egenskaper hos autoregressiva spektralestimat, maximal entropiestimat och utnyttjande av periodiska signaler i processidentifiering.

Verksamhet inom institutionen för Maskinteknik

Den reglertekniska verksamheten har en professur inom ämnet maskinteknik, professor Boyten. Han har mycket stor grupp med mellan 40 och 45 fast anställda och 60 studenter. Verksamheten är uppdelad på 5 forskningsprojekt

1. Man maskinsystem (Stassen)

Verksamheten är huvudsakligen inriktad på att karakterisera ~~en mänsklig operatör~~ människans egenskaper i olika reglerfunktioner. Man hade bl a ~~upp~~byggt ett intressant experimentsystem, nämligen en cykel där man hade goda möjligheter att studera människan som en flervariabel regulator. Man hade till en början utgått från Graham McRuels resultat, men man hade nu också börjat att undersöka ~~de~~ resultat ~~av~~ Kleinman som ~~utvecklats beträffande~~ går ut på att beskriva ~~den mänsklige operatören~~ människan som en optimal linjärkvadratisk regulator. Man hade också börjat ~~att titta på~~ studera protesproblem, speciellt med tonvikt på människa-maskinkommunikation.

2. Tekniska system (Streiff)

Detta omfattar bl a processidentifiering och modellbygge. Man har utvecklat modeller för elektriska kraftstationer (intressant för Sture Lindahl!), destillationskolonner (intressant för Gustaf Olsson) och man studerade reglering av verkliga processer. ~~Man hade~~ Det fanns en ganska omfattande laboratorieutrustning, ~~så hade man t ex~~ bl.a. en modell av en kraftstation omfattande ånggenerator, turbin, generator med elektrisk uppvärmning och elektrisk överhettning. Elektriciteten användes ~~sedan~~ som elektrisk överhettare till ånggeneratorn.

3. Hydraulik (Viersma)

Detta var ett av de mest aktiva programmen. Man utvecklade således komponenter, ventiler, tryckregulatorer och system. Bland de tillämpningarna som ~~man~~ studerats ~~kan~~ märks numeriskt styrda verktygsmaskiner, medicinska system. Man hade t ex utvecklat en säng med vibrerande rörelser för personer med hjärtinfrakt som visade sig vara mycket ~~lämplig~~. ~~Man hade~~ Vidare ~~gjort~~ en hydrauliksimulator ~~där~~ man kan simulera tankhydraulik. ~~Vidare hade man utvecklat~~ en tredimensionell press. Man föreföll vara synnerligen väl förtrogen med hydraulisk teknologi och man utvecklade ~~även komponenter av typen.........~~

4. Instrumentering

Detta omfattar konstruktion av mätinstrument. En viktig del av verksamheten var ~~för närvarande~~ koncentrerad ~~på~~ proteser. Man hade således utvecklat en mycket liten ventil ~~som hade mycket~~ låg energi-~~konsumtion~~. Principen för ventilen var att en kula trycktes ~~upp~~ mot ett hål med hjälp av en tråd ~~och xxxxxx~~ genom att värma tråden elektriskt kunde man sedan reglera trycket på kulan och därmed också flödet. Hela anordningen vägde ~~inte mer~~ än 1,3 ~~gr och~~ var 3 mm i diameter och 20-30 mm lång. Man hade också ~~evaluerat~~ en protes som var byggd i Delft. ~~I detta~~ sammanhang refererades ~~också~~ till ett möte som nyligen hade ~~av~~hållits i Dubrovnik, där man avsåg att kartlägga de för dagen mest relevanta tesproblemen. Det fanns ingen svensk representant med i detta möte.

5. Tillämpning av systemteori på problem inom Industrial Management

Detta var ett av professor Boytens egna huvudintressen. Man hade bl a undersökt distribution och lagerstyrning.

~~I studiet~~ man-maskin system ~~hade man även börjat titta på~~ reglering av stora tankbåtar. ~~Man hade~~ tillsammans med det skeppstekniska laboratoriet ~~försökt sig på~~ att beskriva rorsmannens egenskaper ~~i detta sammanhang~~. Man hade också ägnat sig åt EEG-studier, bl a för att få ~~lite mer~~ uppfattning om hur den mänskliga operatorn ~~skulle~~ bete sig. I samband med styrexperimentet tog man således ut EEG-signaler och ~~man samarbetade här~~ med medicinska fakulteten vid Universitetet i Utrecht. I samband med protesstudier hade man också lagt ner mycket ~~energi~~ på att undersöka ~~huruvida~~ proteser skulle vara hastighetsstyrda eller positionsstyrda.

VERKSAMHET VID INSTITUTIONEN FÖR ELEKTROTEKNIK

Professor Honderer

Inom institutionen för Elektroteknik finns det två professurer i Reglerteknik, professor Honderer och van .... Man hade här börjat med doktorsutbildning. Man hade för närvarande haft två kurser, en 10-dagars kurs om digitala system, där auditoriet hade varit ingenjörer med erfarenheter i praktiken. Man hade haft 40-42 deltagare. Vidare hade man haft en 3-dagars kurs i optimal reglering.

Forskning

Forskningen var uppdelad på sju projekt. I varje projekt ingick två fast anställda medlemmar, en till två tekniker och tre till fyra studenter. Man hade följande projekt

1. Kraftsystem

Modeller för on-line datorstyrning av kraftsystem hade utvecklats. Man hade således behandlat frekvensreglering och man var verksam med att utforma reglersystem för en 120 megawatt anläggning i Amsterdam. Man hade också studerat diverse optimeringsproblem, t ex lastfördelning. I detta sammanhang hade man gjort intressanta experiment. Man hade således på små analogimaskiner uppbyggt modeller av enstaka kraftstationer. Dessa styrdes sedan och man hade mycket enkel statisk modell av nätet. Man styrde sedan kraftstationerna med optimala kommandon från en dator PDP 11.

2. Skeppsstyrning

Man var sysselsatt med att utforma adaptiva regulatorer för skeppsmanövrering. På grund av variationer i vattendjup och vågornas karaktär kommer skeppsdynamiken att ändras avsevärt och man undersökte härvid möjligheten att utnyttja adaptiva reglersystem. I samband med detta hade man också studerat processidentifiering.

3. Processreglering

Detta omfattade modellbygge och on-line reglering. Man hade några enklare processer i laboratoriet, bl a värmeväxlare, tanksystem och en PD-reglerkrets såsom testexempel.

4. Motorstyrning

Man studerade hastighetsreglering på elektriska motorer med effekter å överstigande 10 kW. studerades

5. Servosystem

6. ~~Computeraided Design~~ Datorstödd konstruktion PDP 9

~~Man hade en dator PDP 9 för vilken man utvecklat~~ Ett datorbaserat system för dimensionering av reglersystem. Man hade ett ocsilloskåp av typ "refreshing" med ljuspenna på vilket man kunde rita blockschema och få ut systemsimulering.

7. On-line datorstyrning (PDP 11)

Institutionen förfogade över en PDP 11 som användes för experiment av on-line datorstyrning. Man studerade bl a hierarkisk styrning.

<u>Intressanta tips</u> (Leif Andersson, Bo Leden)

Man hade i laboratoriet flera fyndiga experimentuppställningar. Bl a fastnade jag för en systemsimulator som bestod av ett antal plåt~~burkar~~ lådor som lätt kunde kopplas ihop med standardkontakter. Man hade 4 kontakter, 2 för signal- och 2 för kraftförsörjning. I dessa ~~burkar~~ lådor hade man sedan ~~byggt in~~ med hjälp av operationsförstärkare ~~och~~ byggt in typiska operatorer. ~~som hade skrivits med tydlig text på utsidan.~~ Lådorna hade blockschema symboler på framsidan. Man kunde ~~sedan~~ kombinera ~~ihop dessa~~ lådorna på många olika sätt och ~~så~~ enkelt bygga upp system för demonstration. Man hade även ~~i detta sammanhang~~ utvecklat samplade regulatorer som realiserade ~~samplokolkretsar~~ samplare och hållkretsar och ~~säte~~ Z-transformer, (borde vara intressant för Källe-Regulator).

BESÖK PÅ TEKNISKA HÖGSKOLAN I TWENTE TISDAGEN DEN 30 MAJ

Tekniska Högskolan i Twente skiljer sig avsevärt från de övriga högskolorna. Den är ~~ganska~~ ny~~bildad~~, ca 10 år gammal, och har campuskaraktär. Det krävs således att studenterna bor på campus under de första åren. Många av studenterna bor sedan kvar där~~, vidare också~~. Flera av fakultetens medlemmar bor också ständigt på campus. Man hade även här en Bachelors degree som tar 3 1/2 år, man studerar i tre år och har en kort avhandling. Masters degree tar sedan ytterligare två år. Vid universitetet i Twente finns reglertekniken representerad på tre professurer, professor Rinstorp, Process Dynamics, Professor

Offer~~ings~~, Electric Engeneering och Professor Kwakernak, Tillämpad Matematik. Jag hade möjlighet att diskutera med ~~samtliga~~ tre ~~representanter~~ och ~~även~~ att se samtliga laboratorier.

REGLERTEKNIK VID INSTITUTIONEN FÖR KEMITEKNIK

Professor ~~Rxnxxxxp~~ Rijnsdorp

Professor Rijnsdorp som ursprungligen kommer från Shell är ansvarig för undervisning i reglerteknik inom sektionen för kemiteknik. Ämnet kallas här processdynamik. Grundidén är att ge studenterna en känsla för processdynamik och processreglering. ~~Några~~ flera kurser ~~som~~ är av direkt intresse för oss vid LTH, bl a i samband med kemiutbildningen Vi överenskom om ett utbyte av kompendier och undervisningserfarenhet. (intressant för Gustaf Olsson). Kursen för kemister omfattar således 3 enheter där varje enhet motsvarar en föreläsningstimma per vecka. Förutom den inledande kursen har man ~~även~~ 4 ~~vidaregående~~ kurser som handlar ~~om~~ komplexa system, optimering, flervariabla system och tillämpningar av on-line datastyrning. Datastryningskursen som definitivt är av intresse gavs på prov förra året med 4 studenter. En kopia på kursprogrammet finns ~~medlagt~~ som bilaga till denna rapport.

<u>Forskningsprogram</u>

Forskningsprogrammet omfattade 4 projekt.

1. Reglering nära begränsningar

Vid många industriella processer är det ett speciellt problem att reglera processer som ligger nära begränsningar. Å ena sidan vill man ligga så nära begränsningen som möjligt, men det kan vara katastrofalt att överskrida begränsningen. På detta sätt får man asymetriska kriterier

2. Flervariabel reglering

Rijnsdorp ansåg att de ~~mer~~ väsentliga problemen inom processreglering låg bland de flervariabla system, man hade därför ett projekt inom detta område.

3. Icke tekniska system ~~problems~~

Man studerade bl a. analys av reningsverk och man hade även ett mindre projekt beträffande världsmodeller. Överhuvudtaget fanns ett mycket stort intresse för Forresters arbeten ~~inom~~ i Holland.

4. Ergonometrics

Man hade ett ~~rätt~~ stort projekt som avsåg att studera människa-maskin funktioner i samband med processreglersystem. Man hade för detta ändamål ~~tänkt sig begrepp~~ byggt modulära operatörspaneler med vilka man lätt skulle kunna experimentera. Man hade också en psykolog anställd på institutionen för ~~ändamålet.~~ projektet.

Laboratorier

I laboratoriet ~~så hade man~~ fanns en destillationskolonn liknande apparat där man använde sig av varmluft och varmt vatten. Man hade dessutom ett ph-reglersystem och ett enklare tanksystem för undervisning. I laboratoriet fanns dessutom en analogimaskin, ~~play dynamics~~, modell AD-4, vidare hade man några mindre analogimaskiner av samma fabrikat och dessutom hade man en PDP 11.

BESÖK PÅ AVDELNINGEN FÖR ELEKTROTEKNIK
Professor ~~Offerings~~ Offereins

Även inom avdelningen för elektroteknik hade man komplett reglerteknisk undervisning inklusive laboratorier. Denna verksamhet leddes av professor Offereins som kommer från Philips.

Kurser

Man hade följande kurser

1. Inledande kurs i reglerteknik
2. Samplade system
3. Optimalreglering
4. Servosystem

Fjädrande last

Glapp

Störningar

Minimaltidsinställning

5. Simulering

Kursen om servosystem var speciell och den byggde på professor Offereyns särskilda erfarenheter under hans verksamhet vid Philips. Han hade också nära kontakt med en av Philips lokala industrier som tillverkade eldledningsutrustningar.

Laboratoriet

Som vanligt var laboratoriet väl utrustat. Man hade dels ett vanligt undervisningslaboratorium där man bl a kunde lägga märke till en tankprocess. Förutom nivåerna gjordes man även försök med temperaturreglering. Man hade gjort några försök till att göra optimal nivåinställning på den och funnit att det var inte helt lätt att utföra detta. Vidare fanns logiksimulatorer och pneumatiska system. Man hade dessutom en rolig apparat, en kula som man rullade på tvådimensionellt plan, som inställdes pneumatiskt där man kände av kulans läge med hjälp av en TV-monitor. Dessutom hade man gjort försök med skeppsstabilisatorer och man hade därvid kompletta jyroplattformar. På institutet hade man dessutom tillverkat en liten dator, men man höll nu på att övergå till PDP 11. Storskärmsoscilloskop utnyttjades xxkxå ofta vid undervisningen.

AVDELNING FÖR TILLÄMPAD MATEMATIK

Inom avdelning för tillämpad matematik hade man också reglerteknik. Den representerades i form av professor Kwakernak, vars professur hette stokastiska system och tillämpad fysik. Professor Kwakernak ägnar sig huvudsakligen åt stokastisk reglerteori, han har nyligen slutfört en bok. Bland de problem vi diskuterade märktes bl a en stokastisk process som är sådan att den är periodisk. $x(t) = x(t+T)$ Med Mr. Alper diskuterades även reglering av icke-tekniska system.

BESÖK PÅ SHELLS FORSKNINGSLABORATORIUM 720531

Inledning

Shell har sin forskning koncentrerad till ett stort centralt laboratorium i Amsterdam. Dessutom har man ett antal perifiera laboratorier, t ex i Delft och i England. Man genomgår för närvarande en kris då bl a engelska laboratorierna ~~ska läggas ner~~ och dessutom laboratoriet i Delft också skall läggas ner. Detta har bl a ~~haft till effekt~~ medfört att marknaden för kemiingenjörer i Holland nu är synnerligen besvärligt. Nyutexaminerade ingenjörer kan således svårligen vänta sig att få arbeten.

Organisation

Forskningslaboratoriet som totalt omfattar1.930 personer är uppdelat på 4 avdelningar

- Oilproduct and processes
- Chemical products and processes
- Engineering
- Fundamental Sciences

Varje laboratorium ledes av en direktör. Reglertekniken finns representerad inom Engineering och inom Fundamental Sciences. Den stora aktiviteten ~~försigår~~ finns inom Engineering som är uppdelad på följande avdelningar

- Equipment Engineering
- Materials
- Operations Control
- Physical Separation

Den reglertekniska avdelningen är den som kallas Operations Control. Den består för närvarande av ca 40 personer, varav 24 är på doktorsnivå.

Filosofi

Jag hade tillfälle att diskutera den allmänna uppläggningen av verksamheten inom Operations Control med Dr. de Jong, och han gav följande bild av verksamheten. Inom avdelningen sysslar man med samtliga reglertekniska aspekter inom hela företaget. Man behandlar således en rad skilda problem, ~~t ex~~ såsom

Refining
Chemical Manufacturing
Marine
Pipelines
Warehousing (operations research)
Basic Research

Det var i viss utsträckning förvånande att höra att man även ägnade sig åt problem rörande skeppsautomation, men då Shell är den största ägaren av tankbåtar i världen, är detta inte ~~längre så~~ onaturligt.

INDUSTRIELL PROCESSREGLERING

Den grundläggande synen på industriell processreglering kan illustreras med bilden i Fig. 1.

En industriell process betraktas således som sammansatt av tre komponenter: processen, reglerutrustningen och operatören. Den väsentliga funktionen av reglersystemet är att eliminera störningar som kan uppkomma inuti processen, i reglerutrustningen, eller genereras av operatören. Störningarna kan också ~~vara genererade~~ komma från utomstående källor. Problemet är att arrangera det totala systemet så att det blir okänsligt för alla former av störningen. Man hade utfört ganska omfattande forskning vad beträffar utform~~andet~~ningen av reglerutrustningen. Man hade baserat erfarenheterna på 8 datorer som för närvarande fanns on-line. Man hade också konstruerat speciell interface utrustning, där ett intressant särdrag var att man lagt in en hel del av back-up funktioner i interfacet. Ett annan intressant ~~särdrag~~ synpunkt var att man gärna ville ha en flytande gräns mellan människa och maskin. Man kunde alltså tänka sig att vid olika typer av fel så kunde systemet struktureras om så att en del funktioner flyttades över till operatören, respektive till datorn. Man lade för närvarande mycket stor vikt på människa-maskin problem. Man hade här ett etablerat samarbete med universitetet i Utrecht, där man har tillgång till psykologer.

Forskningsprogrammet inom avdelningen för refining kan uppdelas på fyra delar

- Ergonometri
- Control Theory
- Computer Hardware
- Electronics

Det var också intressant att notera att man för närvarande hade relativt begränsade erfarenheter av sofistikerade regleralgoritmer, se vidare under diskussion.

Hybriddator, Mr. Anzenhofer

Shell har en mycket stor hybridanläggning (Troligen en av de största i världen). Den består av två ~~stycken~~ Comcor analogimaskiner med 24 respektive 35 integratorer. Vidare har man 2 datorer, Sigma 5 och Sigma 7, och man har ett specialbyggt interface, levererat från England. Hela anläggningen kan sammanfogas till en enhet, men man kan också köra de olika delarna var för sig ~~och~~ eller i olika konfigurationer. Man hade för närvarande ~~ganska~~ stora simuleringsproblem framförallt vad beträffar processer som beskrivs av partiella differentialekvationer. Man hade haft en hel del problem med utrustningen. Framförallt så hade interfacet mellan analog och ~~de~~ digitala delarna ej fungerat tillfredsställande. Man tänkte sig att i en framtid ersätta hela anläggningen med en digital simulator, dock ansåg man att det i dagens läge ej var möjligt att göra, då människa-maskin problemen ej var lösta för digitala simulatorer. För begränsade problem hade man ~~skaffat sig ganska~~ haft god erfarenhet av digitala simulatorer, man använde ett språk RXDS som påminner om CSSMP för IBM respektive CSSL för UNIVAC.

Föredrag

Jag gav i ett föredrag en översikt av institutionens forskningsverksamhet. ~~vilket väckte stort intresse.~~

INDUSTRIELL PROCESSREGLERING, DISKUSSION

Jag hade möjlighet att tillsammans med en mindre grupp diskutera reglerproblem inom kemiindustrin. Följande personer deltog

Snoek
Bos
van Holtz
Turner
van de Vet
van Aarle
Dwaal

Dessa personer representerar ett brett spektrum av erfarenheter. Mr. Bos hade t ex sysslat med tillämpning av processdatorer i raffinaderier och i högvacumdestillationsanläggningar. Han var speciellt intresserad av DDC.

Mr. Snoek hade undersökt möjligheter att förenkla analoga simuleringar genom att först transformera problemet till jordanform. Mr. van Holtz var intresserad av automation av skeppsmaskineri och bryggstyrning. Han hade bl a ~~tittat på~~ studerat kollisionsvarning, styrning, dimensionering av reglersystem för skeppsmaskinerier. Han var speciellt intresserad av hög pålitlighet och diagnostik. I samband med stryprojektet hade man ~~börjat titta på~~ studerat den s k deck-modellen, där parametrarna i en andra ordningens olinjär modell bestäms ur inversa spiraltest. Man hade undersökt kollisionsvarning för tvåskeppsförhållanden, men inte för flerskeppsförhållanden. Mr. Turner hade sin erfarenhet från det kemiska fältet, reglering av polyprotylen, etylen, övervakande reglering av en etylenugn, stationär optimering, dynamisk modellbygge, snabba avstängningar och uppstarter. Han hade ~~tittat på~~ arbetat med reglering av en besvärlig destillationskolon. Han nämnde t ex att man utan svårigheter simulerade system med flera hundra differentialekvationer. Mr van Aarle hade undersökt dynamiken hos destillationskolonner, han hade misstänkt att det skulle finnas stora variationer i parametrar som skulle motivera adaptiva regulatorer. Han var för närvarande ~~sysselsatt med~~ engagerad i reglering av pipelines och simulering. Mr. Dwaal var sektionschef. Bland de synpunkter som bringades upp i diskussionen kan nämnas störningar och regleralgoritmer.

Störningar

Man har trots ett stort antal loggningar ingen klar bild av störningarnas egenskaper, men man indikerade dock att många störningar rimligen var ej gaussiska och ej stationära. Man kunde ~~förmodligen~~ tänka sig modeller där man har flera typer av processer och man skiftar mellan dessa olika typer. Detta är ~~onekligen~~ en fråga som vi borde titta närmare på på institutionen då det är centralt för processregleringar att ha en god beskrivning av störningarna.

Regleralgoritmer

Man ansåg (van Aarle) att ~~de~~ ~~idé~~regulatorer var ~~till fylles till~~ 80% av alla reglerkretsar. Man trodde att nivåreglerkretsar skulle vara olinjära. Praktiskt taget inga regleringrepp så länge nivån ligger inom rimliga gränser men kraftiga regleringrepp när man närmar sig tomma tankar respektive fulla tankar. Problem då man styr nära begränsningar förefaller vara intressant. Man ville ~~här på Shell~~ gärna ha asymetriska regleralgoritmer som gör mycket större regleringrepp när man tenderar att överskrida gränserna än ~~annars~~. Man tänkte sig att mer elaborerade regleralgoritmer behövs när det gäller system med tidsfördröjningar. Det viktigaste problemet inom reglering av industriella processer ansåg man dock vara reglering av flervariabla system. Man nämnde även en intressant metod för dekomposition av komplexa system som skulle presenteras på ~~NASA-mötet~~ i Cambridge.

BESÖK I EINDHOVEN, TORSDAG - FREDAG 720601-02

Inledning

Universitetet i Eindhoven är ca 10 år gammalt. Även här finns reglertekniken representerad inom två avdelningar, avdelningen för Teknisk Fysik och avdelningen för Elektroteknik. Inom avdelningen för Elektroteknik finns ~~dessutom~~ 4 professurer. Jag hade möjlighet att diskutera med båda grupper, samt dessutom att besöka laboratorierna.

SEKTIONEN FÖR TEKNISK FYSIK

Reglertekniken inom sektionen för Teknisk Fysik förestås av professor Rademaker. Han har tidigare varit reglertekniker vid Shell-laboratorierna och har därigenom en stark kemisk inriktning. Jag gick i korthet igenom kurserna och koncentrerade mig på att studera deras laboratorier. En detaljerad presentation sker nedan. Professor Rademaker var numera kraftigt engagerad i systemdynamik baserad på Forresters arbeten, ett speciellt referat av detta ges även.

Studentlaboratoriet

Laboratorierna var ~~överhuvudtaget~~ mycket välutvecklade och synnerligen välutrustade. Man hade också en stor omfattning av den experimentella verksamheten. I studentlaboratoriet hade man bl a följande processer:

1. Pots and Pans

Denna process påminner mycket om vår plask och pysprocess men var mycket större i geometrisk utsträckning. Det var också intressant att notera att man hade två identiska parallella processer ~~som satt parallellt bredvid varandra,~~ bl a för att få ~~fram~~ icke minimum-faseffekter.

2. Pneumatiska system

Man hade också ett synnerligen komplett laboratorium för pneumatiska komponenter. Det mest kompletta laboratorium i detta avseende som jag har sett! Det fanns många ~~Man hade ett stort antal~~ stationer och hela programmet var upplagt för att ge studenterna en mycket god detaljkunskap om pneumatiska regulatorer och pneumatiska reglerkretsar. Man började således med en uppställning där man studerade de fundamentala komponenterna, flapperventil, reläförstärkare och ventil. Därefter övergick man i flera stationer till att studera DP-celler, regulatorer, ventilmodeller. Slutligen hade man en enkel processsimulator där man simulerade hela reglerkretsen. Denna bestod av en enkel tankprocess med ett antal tankar och man kunde studera såväl kontinuerliga regulatorer som regulatorer av on-off typ. Totalt hade man ca 250 studenter i laboratoriet, en komplett laborationskurs omfattar 12 - 13 halvdagar. Det var intressant att notera att man offererade detta som en separat kurs till studenterna.

Forskningslaboratoriet

I forskningslaboratoriet hade man för närvarande 4 processer

1. Destillationskolonn
2. Värmeväxlare
3. Ånggenerator, kondensor
4. Ph-reglering

Destillationskolonnen var samma typ som glaskolonnen på Kemicentrum vid LTH. Den har använts mycket under första året men hade sedan ~~sedemera~~ inte använts. Skälet till detta var att den var alltöfr komplicerad att hanteras av studenter. Man hade däremot haft stor glädje av värmeväxlarprocesserna. De var mycket lätta att köra och man hade utfört många experiment med dem och studenterna kunde utan svårighet sätta sig in i dessa laboratorieutrustningar. Beträffande ph-reglering använde man metron kalomelelektroder som var tillverkade i Schweiz. Man refererade även till en artikel av Kochenburger som hade utfört en analys av problemet.

Processimulator

För undervisningsändamål hade man utvecklat en speciell processimulator. Den var uppbyggd av traditionella analogimaskinkomponenter och man kunde simulera olika processmodeller i snabb tidsskala. Simulatorn var dessutom försedd med olika ~~passiviteter~~ faciliteter. Man kunde således ~~ta upp~~ visa stegsvar för öppna och slutna system. Man kunde direkt ~~få~~ Bodediagram registrera, ~~man kunde direkt registrera~~ och Nyquistkurvor. Man kunde simulera störningar av olika slag och man kunde presentera kurvor som visar hur störningarna dämpas av reglersystemet inom olika frekvensområden. Man sade sig ha mycket goda erfarenheter av denna processsimulator, både i undervisning på civilingenjörsnivå och på lägre nivå.

Datorlaboratorium

Man hade ett datorlaboratorium bestående av två ~~stycken~~ PDP 8:or och en Telefunken analogimaskin. Det var också möjligt att koppla processerna i forskningslaboratoriet samt i studentlaboratoriet till dessa PDP 8:or. Man hade skivminne och man utvecklade för närvarande programvara själv.

Hybridlaboratorium

Man hade ett hybridlaboratorium bestående av en analogimaskin Pace 231 R, tämligen väl utbyggd med ca 100 förstärkare varav 30 integratorer. Dessutom hade man en EAI 680 med 70 förstärkare, varav 30 ~~var~~ integratorer.

Systemdynamik

Professor Rademaker var ~~för närvarande~~ mycket intresserad i systemdynamik. Som tidigare nämnts fanns ett mycket stort intresse för detta i Holland. Professor Rademaker hade utgått från Forresters modeller och simulerat dem. Den speciella modell man ~~hade utgått~~ studerat

Detta skall skjutas in på sid 17

1.

~~Rademaker~~

~~Beträffande världsmodellerna hade man följande planer~~

1. Förståelse av modellen

Man ville undersöka dekomposition och storleksordningar för att få insyn hur modellen fungerar.

2. Känslighetsanalys

Genom traditionell känslighetsanalys ville man undersöka hur känslig modellen var för parametervariationer. Detta arbete hade som angivits ovan redan startat

3. Dynamiska förbättringar

Man diskuterade olika möjligheter att förbättra modellen, för närvarande tänkte man sig att införa en åldersfördelning och att införa naturtillgångar.

4. Val av styrvariabler

I modellen World 1 styrde man endast på koefficienterna. Man kunde säkert tänka sig andra former av styrvariabler.

5. Stabiliserande reglerstrategier

På basis av modellen ville man undersöka hur man skulle styra den för att få bästa möjliga resultat, t ex om man stoppar alla investeringar, sätter dem till en konstant nivå, visar det sig att modellen svänger in sig mycket fint.

6. Dynamisk optimering

Man vill undersöka olika former av optimala strategier.

7. Simuleringsteknik

Man vill undersöka olika modeller att simulera den givna modellen.

~~ifrån~~ var den som av Forrester kallas för "world ~~true~~ two", vilken består av 5 olinjära differentialekvationer. Rademaker hade påvisat, att den tillståndsvariabel som svarar mot "pollution"..... svänger in sig mycket snabbt i förhållande till de övriga och att Forrester valt mycket olyckliga begynnelsevärden av denna variabel. Vidare hade man påvisat att ekvationerna kunde separeras i två grupper. Man hade vidare gjort en känslighetsanalys och som klart indikerar ~~att några parametrar~~ att resultaten kunde påverkas mycket drastiskt påverka ~~resultaten~~ genom små ändringar i vissa parametrar. Vidare hade man ~~för dessa parametrar~~ funnit ~~stor känslighet i motsvarande olinjära funktioner som införts av Forrester, om man ändrade xxxxxpå interpolationen från linjär till t ex kvadratisk interpolation, kunde resultaten förändra sig högst avsevärt.~~ att Forresters resultat var känsliga för mindre ändringar i integrationsalgoritmerna. Den filosofi man hade var att ta existerande modeller och sen applicera sund systemteknik på dessa. Man avsåg inte aktivt medverka i modellbyggandet i någon större omfattning. Man hade följande planer för det fortsatta arbetet

Undervisning i reglerteknik för kemister

Genom sin bakgrund från Shell hade professor Rademaker flera synpunkter på undervisning i reglerteknik för kemister. Han ansåg att den uppläggning som Rijnsdorp hade var mycket bra och han lovade ~~själv~~ att skicka över några av sina kompendier ~~som han begagnade sig av.~~ Dessutom nämnde han att han brukade själv ta ett avslutande exempel som ~~avslutning när han~~ visar hur svårt det var att göra reglersystem~~teknik. Det exempel han hade var att utgå från ett stegsvar,~~ Exemplet utgick från ett uppmätt stegsvar. ~~och~~ Han visade sedan hur man kan ~~till detta~~ anpassa tre olika överföringsfunktioner till stegsvaret men att de ~~samt att visa, genom att passera~~ reglerstrategi som dimensioneras på basis av de ~~på dessa tre~~ olika överföringsfunktioner ~~kommer man till helt olika resultat.~~ är helt olika. Genom att sedan ~~göra en~~ förklara ~~ing av fenomenen~~ vad som händer avsåg han att visa att reglerteknik icke är så lätt som det kanske framgått i kursen. Avsikten var ~~för~~ att ~~därvid~~ uppmana kemitekniker att när de stöter på reglerproblem ta kontakt med professionella reglertekniker, istället för att ~~kvacka själva.~~ ägna sig åt "hemslöjd".

AVDELNINGEN FÖR ELEKTROTEKNIK

Inledning

Inom avdelningen för Elektroteknik finns för närvarande fyra professorer varav tre på heltid, Eykhoff, Mulders, Kijlstra och Bekkering. Dessutom fanns 14 fast anställda akademiska medarbetare. Jag gick igenom forskningsprogrammen och diskuterade speciellt den verksamhet som utförs av professor Mulders och professor Eykhoff.

Tröghetsnavigering

Professor Mulders har ett program i tröghetsnavigering. Det är i viss utsträckning förvånande därför att det finns ~~ingen~~ holländsk industri som ~~tar upp detta.~~ Å andra sidan har professor Mulders stor erfarenhet från utveckling av mätutrustningar. Han tror också att det finns billiga tillämpningar av tröghetsteknik. Professor Mulders filosofi var att arbeta med relativt enkla och billiga komponenter med ~~relativt~~ låg noggrannhet. Jag tittade bl a på följande tillämpningar:

Schuleravstämning
Foucaultpendel
Illustration av stabilisering av enkel flygplanmodell

Man hade byggt en 1-axlig Schuleravstämning baserad på min och Hectors idé med ett enkelt gyroskåp ~~och~~ Jordgravitationen simulerad med en spänd fjäder. Jordradien i experimentet var ca 20 meter. Man hade lyckats få tag på flera billiga gyroskåp, bl a ett från Timex och man hade också gjort gyroskåp själv av freeflextyp där man använder Bendix fjädrande upphängningar. Flygplanmodellen var mycket intressant. Man visade ett odämpat fjädrat system och sedan hade man en fläkt som blåste och visade hur man kunde på ett enkelt sätt med ett reglersystem införa stabilisering. Man hade byggt all elektronik själv och man hade de vanliga svårigheterna med elektronik som hade byggts av studenter.

börjat diskutera parameterestimering. Försöket hade en ganska stor experimentell sida där man byggt en plastmodell av aortan med pumpar och en analogimaskin där man efterbildade de dynamiska egenskaperna. Man sysslade även med att mäta strömningshastigheter med dopplerteknik.

Hjärtmodeller

Man hade försökt identifiera en ..dypolmodell av ett hjärta. Man hade spaltat upp hjärtat i 5 sektioner där man karakteriserade varje dypol med en intensitet och en responskurva som hade ungefär gausform med en intensitet, en tidsfördröjningsparameter och en spridningsparameter. Totalt får man således 15 parametrar. Dessutom tillkom de parametrar som beskriver hur det elektriska fältet breder ut sig från hjärtat till receptorerna. Man hade använt parameterestimeringsteknik för att bestämma de okända parametrarna. Man hade dessutom gjort en analogisimulering och denna visade att man kunde få mycket god anpassning till vanliga EEG, åtminstone för normala patienter.

..........mätning

Man hade betraktat problemet med ....mätning som ett processidentifieringsproblem. Det gäller att bestämma R, L och C för en ekvivalent krets och man hade utvecklat en speciell hårdvara för att göra detta. Man tänkte sig många tillämpningar när det gäller produktionskontroll av elektronikkomponenter.

Aktiv motorstyrning

På basis av en doktorsavhandling av Wynfried Spet i Braunschweig "Selbstanpassende Regelsysteme in der Antriebstechnik" Dissertation Technischer Universität Karolo Wilhelmina zu Braunschweig 1971. Mr. Spet finns för närvarande på Siemens AG, ... 1,8520 Erlangen, Deutschland. Ett referat av avhandlingen finns även i Siemens Zeitschrift 42 (1968) 765-768. Man hade byggt ett liknande system i laboratoriet med en ganska stor elektrisk motor av länddimensionen 1/2 meter och till detta hade man ett elektronikskåp och man hade mycket fina resultat på de självinställande regulatorerna.

Den mänskliga operatorn

Man hade även försökt att identifiera den mänskliga operatorn med dagarna framlagt en ny plan för civilingenjörsutbildningen som kommer att ta 4 år och det är ännu inte klart på vilket sätt den ska förverkligas. Och hur utbildningen kommer att påverkas

I det fortsatta programmet tänkte man sig bl a följande. Professor Tinbergen ("Nobelpristagare" i ekonomi) hade börjat intressera sig för modellen och speciellt ville han undersöka samspelet mellan rika länder och fattiga länder. I projektet hade man för närvarande 6 ~~människor~~ personer heltid, 4 studenter och 2 assistenter, dessutom ~~spenderade~~ använde Rademaker ca 25% av sin tid på projektet. Ca 25 personer var också engagerade på deltid.

Verksamhet inom avdelning för reglerteknik (Prof. Eykhoff)

Jag presenterade 2 föreläsningar, en om tröghetsnavigering och en om erfarenheter av processidentifiering. Dessutom besökte jag professor Eykhoff's laboratorium och jag diskuterade med hans studenter.

Pågående projekt

Professor Eykhoff hade ett stort antal studenter som var engagerade med processidentifiering. Bl a diskuterades följande. Ivahnenko's metod för att hitta strukturer i flervariabla system.

En av Eykhoffs studenter ~~hade tittat på detta~~ studerat prof Ivahnenkos metod. ~~Det är stora~~ Man hade haft svårigheter att få rätt struktur och metoderna är också beroende på hur man startar.

Utveckling av estimationsteknik

Man tittade bl a på ordningstest och användning av Instrumental Variables.

Dispersionsfunktioner

En student hade undersökt Rajbmans ~~resultat beträffande~~ teori om dispertionsfunktioner.

Blodcirkulation

Man hade ett ganska omfattande ~~studium av~~ program för att studera blodcirkulation. Man koncentrerade sig på diagnos av hjärtfel i aortatrakten. Man hade gjort mätningar på såväl patienter som på en laboratorieutrustning. Man gjorde en modell i form av en transmissionsledning, eventuellt med vissa olinjäriteter. ~~Man~~ hade undersökt kvantiseringsfenomen och man hade

AFDELING DER TECHNISCHE NATUURKUNDE

A REPETITIVE ANALOGUE COMPUTER FOR SIMULATING CONTROL SYSTEMS

Prof.ir. O. Rademaker
ir. G. Dekker / J.W. van Drie

- juni 1967 -

A REPETITIVE ANALOGUE COMPUTER
FOR SIMULATING CONTROL SYSTEMS

O. Rademaker, G. Dekker, J.W. van Drie

PART I

General introduction. Description of the simulation units

General purpose analogue computers have proved to be extremely powerful tools in many different types of studies, including those of automatic control problems. The very universality of these machines, however, implies that they may not be particularly suitable for one particular type of job, such as the study of control systems dynamics. To supplement our accurate general purpose computer (an E.A.I. PACE 231R), we therefore developed an analogue computer for the special purpose of simulating control systems. This computer, which is called the "RECTOR" (for Repetitive Electronic Computer for Testing and Optimizing Responses) has now been in almost continuous use for over three years. We have found that its special purpose features not only make it faster and much more convenient than a conventional computer, but also that they induce the operator to exploit some important possibilities of analogue simulation in a far more penetrating way. Thus, the breadth, depth and duration of control system studies were found to profit from this special purpose approach*.

The RECTOR is a fast, repetitive analogue computer of limited accuracy** containing about forty operational amplifiers. It enables the user to subject linear, non-linear and sampling control systems to the customary types of input signal (impulse, step, ramp, sine, noise)

----

* With a view to the ever-growing stream of problems, we are, in fact, building another simulator, the "STUDENT" (a Dutch acronym for Simulation Techniques Applied in an Extremely Efficient and Useful Way) which, although of younger age, is a very similar simulator.

** The maximum error in linear equations being 1 % of range.

and to examine control system performance by means of:

- o transient responses
- o Bode-diagrams (not for sampled-data systems)
- o Nyquist-diagrams
- o deviation-ratio diagrams
- o computation of the criteria: $\hat{\varepsilon}$, $\overline{|\varepsilon|}$, $\overline{\varepsilon^2}$,

$$\int_0^\infty \varepsilon \, dt, \quad \int_0^\infty \varepsilon^2 dt, \quad \int_0^\infty |\varepsilon| dt, \quad \int_0^\infty |\varepsilon| t \, dt, \quad \int_0^\infty \varepsilon^2 t \, dt.$$

if desired as a function of any measurable parameter.

These techniques can be applied simply by setting a single switch. The display unit (usually one of the various oscillographs or voltmeters) is selected by means of another switch which also automatically connects the appropriate time base signals, signal attenuators, etc., so that few, if any, adjustments are necessary. As the computation is normally repeated many times per second, the whole response can be made visible on an oscillograph and the consequences of varying a parameter manifest immediately. Thus one can, for example, rapidly find the optimum setting of a parameter according to one of the criteria mentioned before. This explains why we found the simulator to be more effective in studying the optimum performance of sampled-data systems than a digital computer* although such systems are eminently suitable for digital treatment.

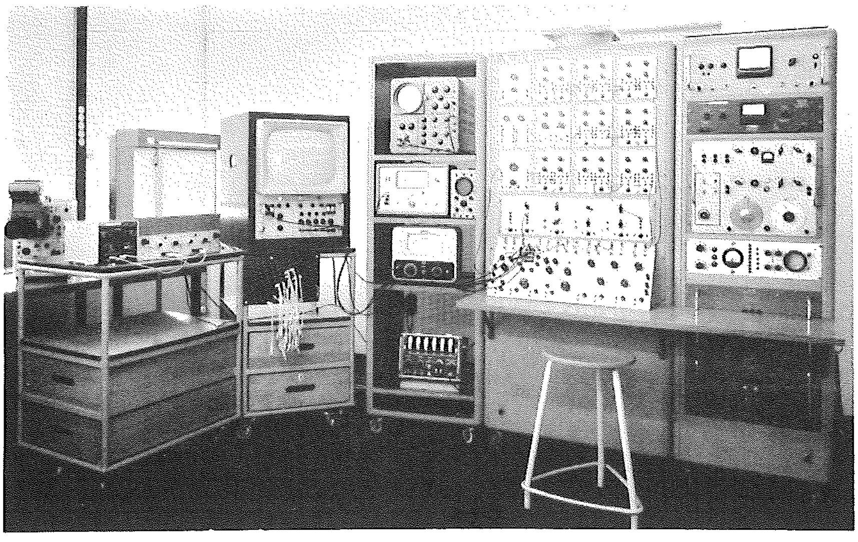

Figure 1

General view of the installation

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* See: Optimization of sampled-data control systems using dynamic criteria (in Dutch), by A.L. Nagel, Thesis Technological University of Eindhoven,1967.

A general view of the installation is shown in Figure 1. It consists mainly of: (1) a set of simulation units, (2) a central command unit, and (3) a collection of generators and display units with associated equipment. Commercially available instruments are employed where possible.

The actual simulation part (1) contains a PID-controller and a number of proportional amplifiers, integrators, units with first-order differential equation, delay-time units, sampling units including a sampled-data controller, certain non-linear units and, of course, a number of free potentiometers. Most units also act as summers. All units are interchangeable, except the PID-controller. Patch cords are used to interconnect the simulation units.

The most important signals, such as the controlled variable and the error signal, are brought to the central command unit (2) for further processing. This unit contains all sorts of circuits for timing the simulation cycle, generating oscillograph time-base and intensity-modulation signals and for realizing the desired interrelation between signal generators, simulation circuit and display units.

Apart from the display units mentioned before, the auxiliary equipment (3) also comprises a noise generator, a sine/cosine generator, a phase meter and a logarithmic amplifier.

We shall now describe the installation in more detail, emphasizing the functional aspects rather than the electronic circuitry. Thus the set of simulation units is described in the following paragraph, whereas the central command unit and the peripheric equipment is dealt with in Part II of this series. A few illustrative applications will be described in Part III, whereas Part IV will be devoted to the sampled-data units and Part V to some methods for plotting Nyquist diagrams of sampled-data systems.

Simulation units

The simulator comprises the following plug-in simulation units:

a) PID-controller	1x
b) Universal linear units	8x
c) Delay time unit	1x
d) Non-linear unit	1x
e) Quantization unit	1x
f) Sampled-data units (e.g. PID-controller)	2x

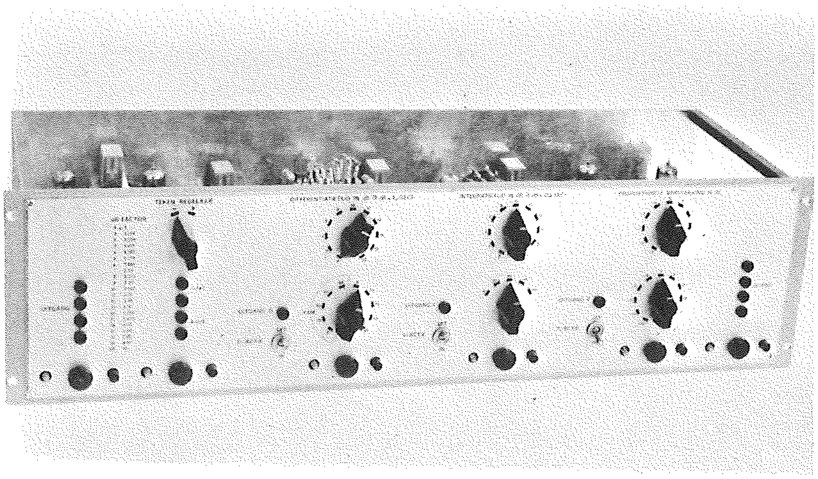
Units a, b and c are used in the simulation of continuous linear systems while units d, e and f have proved to be very useful in the study of non-linear and sampled-data systems. A standard plug-in chassis with 6 ten-turn potentiometers is available as well. Other units, such as function generators and time-division multipliers are available as self--contained accessories intended mainly for on-line treatment of measurement signals. Let us now briefly review some of the standard simulation units.

a) PID-controller (Figure 2)

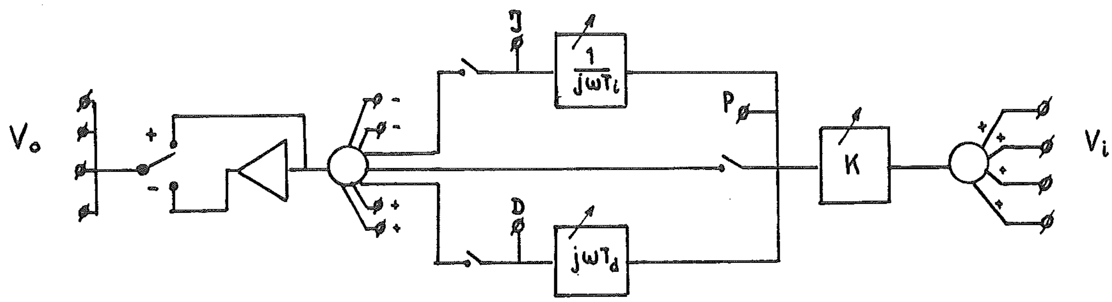
This is actually a controller with an adder at the input and an adder/subtractor at the output. Its output signal is described by:

$$V_{out} = \pm \; V_5 + V_6 - V_7 - V_8 + K\left(1 + \frac{1}{j\omega T_i} + \frac{j\omega T_d}{1 + j\omega\alpha T_d}\right)(V_1 + V_2 + V_3 + V_4)$$

where V_1 through V_8 are independent input voltages, K is the proportional gain, T_i the integration time and T_d the derivative time, while α determines the customary high-frequency gain limit of the derivative term. The value of K can be adjusted in 1 dB steps from -35 to +35 dB, whereas T_i and T_d can be adjusted in steps of 26 % (2 dB) from 10 μsec to 1 sec. Two values of α can be used: $\alpha = 0.2$ for "tame" derivative action and $\alpha = 0.05$ for "pure" derivative action.



a. Front view



b. Block diagram

Figure 2 PID controller

The three control actions can be switched on and off independently, so that any of the combinations P, PI, PD, PID, I, ID or D can be realized. As shown in Figure 2b, the signals produced by the individual control actions are always available on special output plugs. This feature can be very useful in lecture-room demonstrations. The summing facilities at input and output have also proved to be very convenient.

b) Universal linear unit (Figure 3 middle)

The word unit is somewhat misleading because actually each unit consists of two identical parts that are completely independent. For each part, a choice from the following transfer functions can be made by means of a switch:

$\frac{V_{out}}{V_{in}} = - \frac{1}{1+j\omega\tau}$ first order lag with adjustable τ

$\frac{V_{out}}{V_{in}} = - K;\ K < 1$ adjustable attenuation

$\frac{V_{out}}{V_{in}} = -1$ inversion

$\frac{V_{out}}{V_{in}} = - K;\ K > 1$ adjustable amplification

$\frac{V_{out}}{V_{in}} = \frac{10}{j\omega}$ integration starting from given initial value

$\frac{V_{out}}{V_{in}} = - \frac{1}{j\omega\tau}$ integration with adjustable gain

$\frac{V_{out}}{V_{in}} = - 10^8$ operational amplifier, to be supplemented with external networks

In the latter case, all potential applications of the operational amplifier amplifier can be realized by inserting a small plug with the appropriate input and feedback networks. In all other cases mentioned above, V_{in} is actually the sum of four input signals. The gain K is adjustable in 1 dB steps from -10 to +10 dB; the parameter τ can be adjusted in steps of 26 % between 10 μsec and 10 msec.

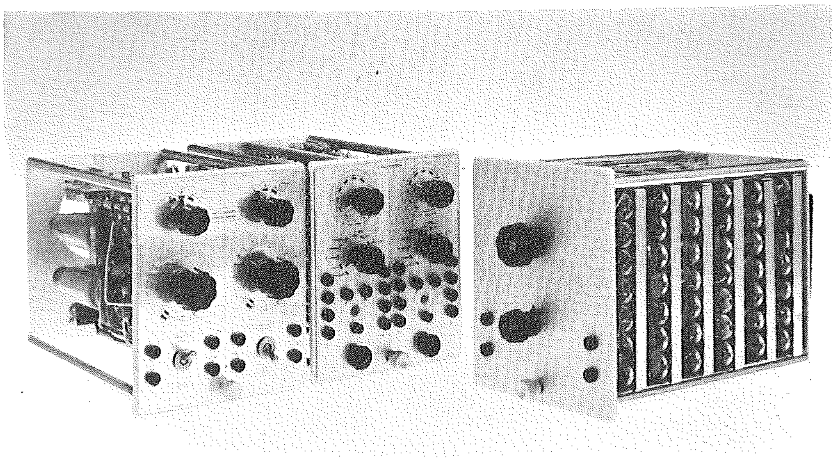


Figure 3 Front view of three simulation units
(left: non-linear unit; middle: universal linear unit;
right: delay time unit)

c) <u>Delay time unit (Figure 3 right)</u>

The transfer function of this unit is approximately:

$$\frac{V_{out}}{V_{in}} = e^{-j\omega\delta} ,$$

where the delay time δ can be adjusted in steps of 26 % from 10 μsec to 1 msec. The unit contains 250 individually-trimmed LC sections, of which the time constants are chosen so as to obtain the best average approximation over the whole range of δ . The accuracy of this unit is quite satisfactory in the frequency range from 30 to 15000 c/s. For example, for δ = 1 msec, the attenuation is only 9 dB at the upper frequency limit (15 kc/s), i.e. after the polar plot has described fifteen complete revolutions around the origin! At a frequency of 500 c/s, where the phase shift is -180°, the attenuation is about 0.05 dB, which means the signal is reduced by about $\frac{1}{2}$ %.

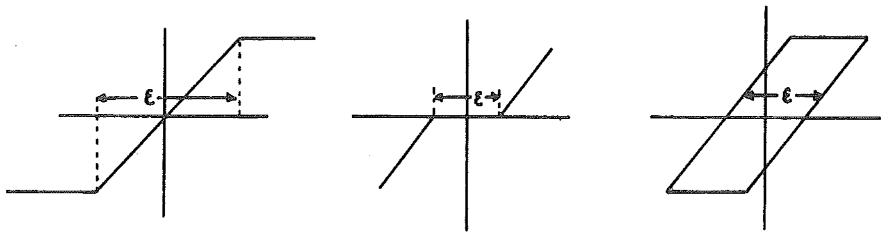
d) Non-linear unit (Figure 3 left)

This unit contains two independent but identical parts. Three types of non-linearity can be realized by each (see also Figure 4):

a) saturation;

b) dead zone ;

c) mechanical hysteresis (backlash and friction).



a. saturation b. dead zone c. mechanical hysteresis

Figure 4 Non-linear functions

Parameter ε can be adjusted continuously between fairly large limits. By means of a switch the non-linearity can be replaced by a proportionality with unity gain. This was found to be very effective in demonstrating the effect of the non-linearity in question.

e) Quantization unit

In this unit the input signal of magnitude A, is quantised in a linear fashion, so that the output signal v_q becomes:

$$v_q = nK$$

where n follows from:

$$\frac{2n-1}{2} q < A < \frac{2n+1}{2} q ,$$

The quantization level q is 1 volt and the number of levels is 21; hence the range of the input and output signals is $\pm$ 10 volt. The accuracy of the input and output switching levels is in the order of 2 %. Switching occurs with a hysteresis of less than 10 mv and the maximum switching time is less than 1 μsec; the dynamics of the quantization can be attributed mainly to parasitic time constants of the amplifiers employed.

f) Sampled-data units

In view of their special character, one of the subsequent parts of this series will be devoted entirely to these units.

PART II

Description of the units for disturbance generation, response analysis and visual display.

Input and output units

Commercially available instruments have been employed where possible, but certain units had to be specially developed to meet our requirements.

The principal input units are the signal generators. A commercial noise generator is employed, but transient signals are derived from specially designed circuits in the central command unit, which also generate all required oscilloscope time base and marking signals. The specification that Nyquist and Bode diagrams be drawn in a single stroke led to the requirement of a sine-cosine generator capable of covering the frequency range from 30 to 15000 c/s in a single sweep. Since no commercial instrument was available, the required generator was created by combining two conventional beat frequency oscillators as will be described further on in this article.

The output units can be classified in two groups: calculating units and display units. The former category comprises a logarithmic amplifier and a phase meter (for Bode diagrams), a multiplier (for Nyquist diagrams) and specially developed circuits for calculating criterion values such as integral of squared error. Also, a wave-form translator for copying high-speed oscillograph curves on an XY-plotter is available.

All display units are commercially available instruments: ac and dc tube voltmeters, a frequency and time-interval counter, a memoscope with polaroid camera, a large screen scope for demonstration purposes, and an XY plotter.

It is interesting to note that a very intensive and flexible use is made of nearly all display units, because the central command unit makes it so easy to switch back and forth between different instruments. If the operator were bothered by plugging-in various connections and by adjusting all sorts of gains, zero-shifts, synchronizations and time-base frequencies, he would sooner or later restrict himself to what he considers the most convenient unit, even while being well aware of the fact that another type of display might at times be very much more informative. Experience with the present installation has justified the design thesis that effortless creation of the desired displays fosters the efficient use of all available possibilities, thus enhancing the effectiveness of simulation studies.

Central command unit

The central command unit enables the operator to put a simulation circuit to work in the most effective way by subjecting it to chosen signals and by analyzing the responses in various ways. Its principal function is to achieve a variety of often complicated interconnections between the different parts of the installation. In view of this, it is not surprising that simplicity of operation has had to be paid for by the complexity of its circuitry. The central command unit contains the following three kinds of parts:

a) a generator of periodic impulse, step and ramp signals with associated time base, intensity modulation and time marking circuits;
b) switching circuits;
c) units for calculating various integral criteria, polar plots, the deviation ratio and other quantities.

A front view of the unit is shown in Figure 5.

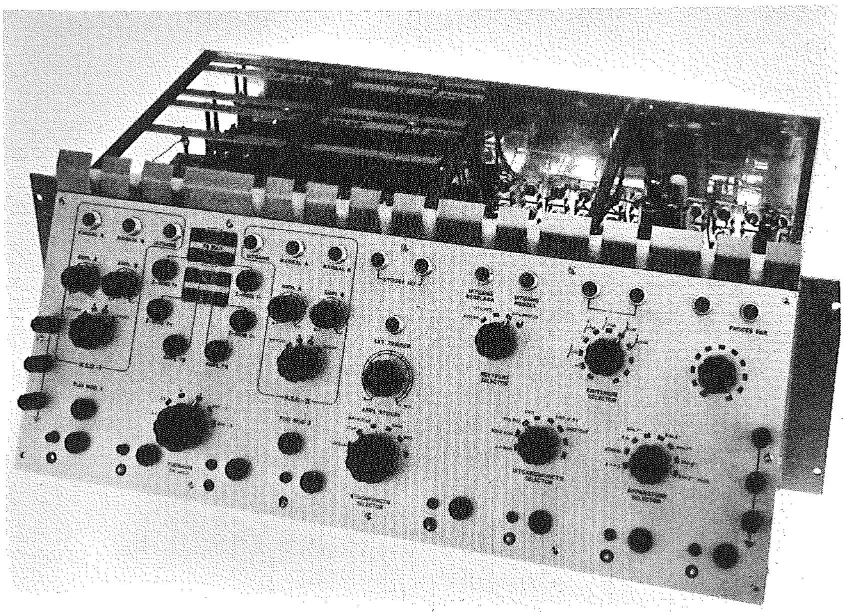


Figure 5 Front view of the central command unit

a) Generators

Basic waveforms.

Figure 6 shows a simplified block diagram of the generator circuits. A fixed-frequency signal of 10 kc/s is generated by a quartz crystal oscillator and changed into an impulse signal of the same frequency by a shaper. By means of three frequency dividers, the frequency can then be reduced, first by a factor of 10, subsequently by a factor of 8 and finally by two. Note that the first frequency divider can be bypassed. The interval between the impulses at the input of the second frequency divider is referred to as the unit of time, which is either 1 msec or 0.1 msec.

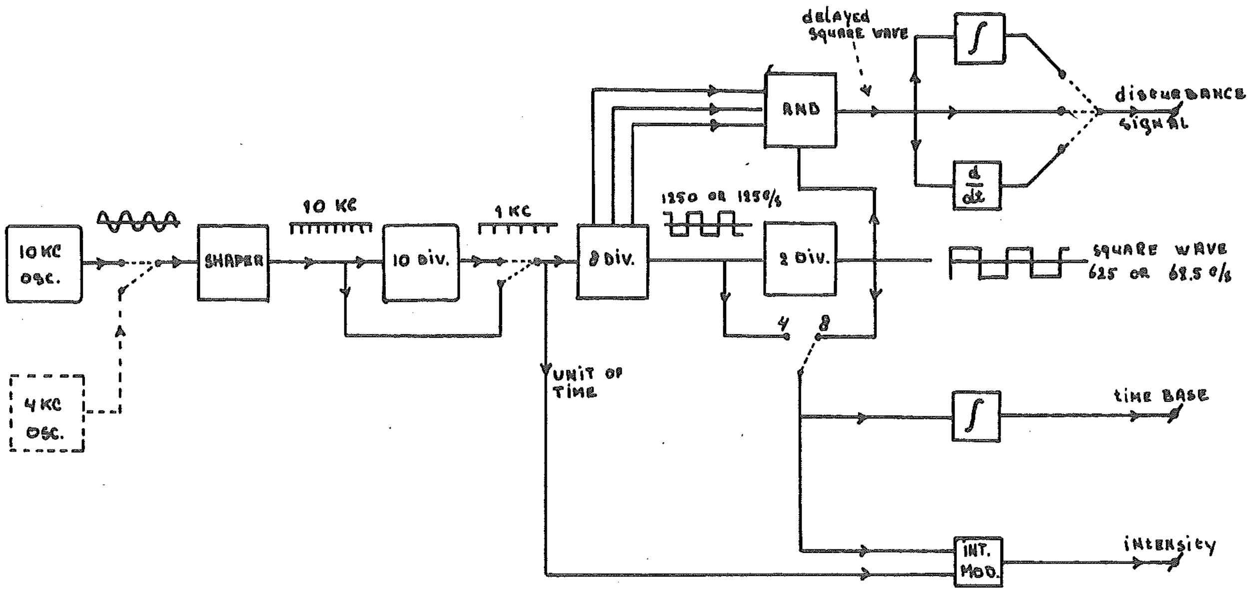


Figure 6 Block diagram of the generator circuits in the central command unit

All time base, intensity modulation and time marking signals are derived directly from the signals in the divider chain, whereas all disturbance signals are derived via a circuit introducing a delay of one unit of time.

Disturbance signals.

The output signal of the last frequency divider is positive for 8 units of time and negative for another 8 units of time. From this, the repetitive impulse, step and ramp disturbance signals are derived, It is important to note that the disturbance frequency is never the same as the power supply frequency. Consequently, if any hum is picked-up by the simulation circuit the oscilloscope traces start to wriggle. This would not happen and the unwanted signal might easily remain unnoticed, if the disturbance signal were synchronized with the mains frequency. It should be added that hum pick-up is of course often a great problem in normal cases, but when external circuits are added to the simulation circuit, or when measuring signals from an experimental installation are introduced, or when the simulator is made part of a larger system, then it is decidedly an advantage that unwanted hum signals are detected at once.

By means of a suitable "and"-circuit, a square wave (the step disturbance signal) is derived which is delayed by one unit of time (see Figure 7). As a result, the time base of the oscilloscopes starts before the disturbance occurs, so that one can easily verify whether the system is initially at rest and conveniently analyze the whole response, in particular the very first microseconds.

Impulse and ramp disturbance signals are derived from the square wave signal by differentiation and integration, respectively.

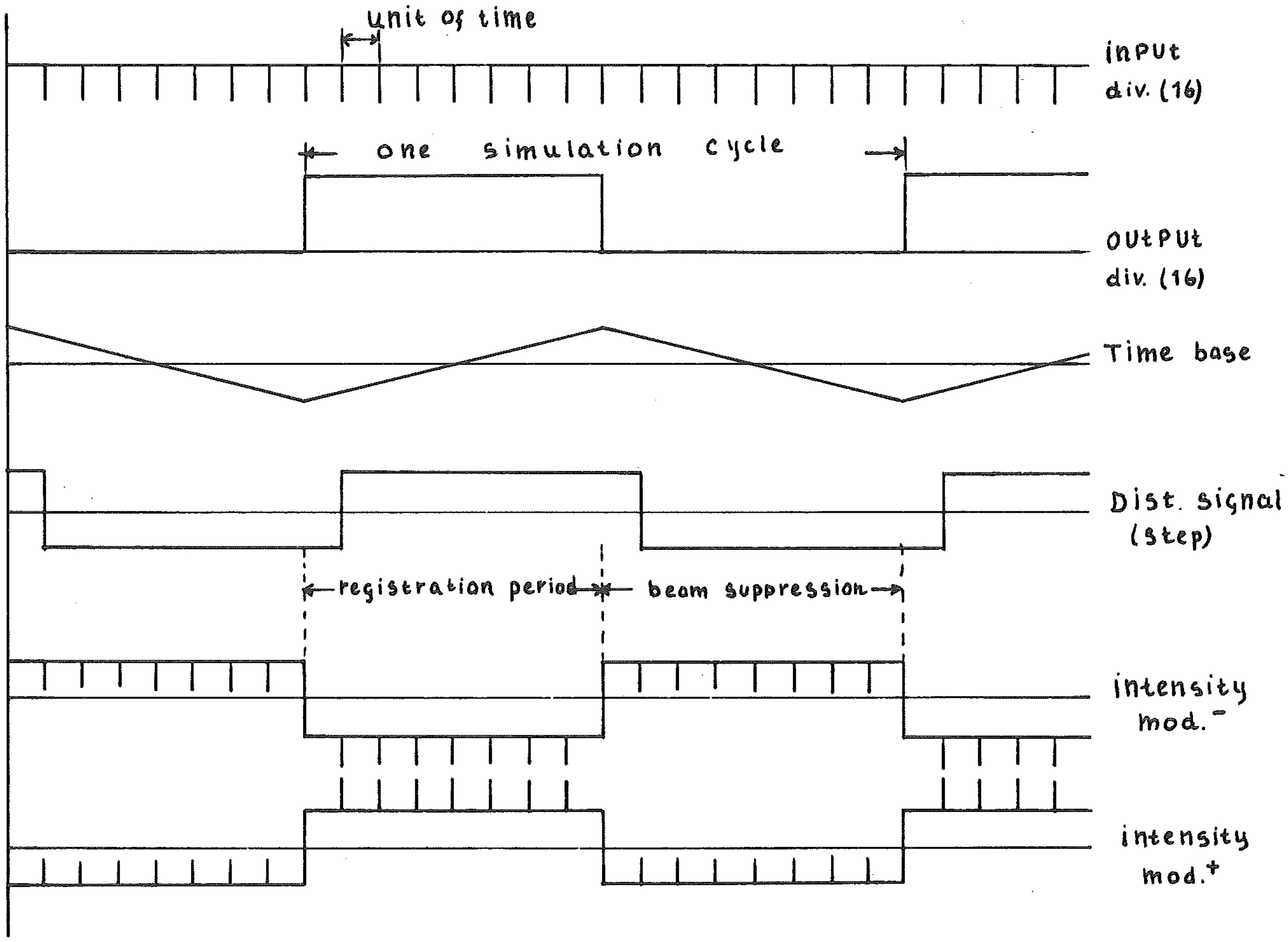


Figure 7 Generator signals in the central command unit

Time base signal.

The time-base signal is obtained by integration of the input or output signal of the last frequency divider (see Figures 6 and 7). When using the output signal, the time base is eight units of time, so that nearly the whole response to the positive disturbance can be displayed. During the next eight units of time the cathode ray is suppressed (see below). In case the input signal is used the integrator gain is doubled, so that the trace crosses the oscilloscope screen twice as fast, i.e. in four units of time. During the next twelve units of time the cathode ray remains suppressed. As a result, the first half of the response is stretched-out across the full width of the screen.

Intensity modulation.

The intensity modulation consists of two components, one governing the existence of a cathode ray during the first four or eight time units of every simulation cycle (dependent on the position of the switch) and another, marking each unit of time by means of a brightened spot on the trace. Several outputs are available for both positive and negative intensity modulation, with adjustable levels for both components of the modulation signal, so that different scopes can easily be accomodated.

External synchronization.

The useful part of a simulation cycle normally lasts for eight time units, i.e. for 0.8 or 8 msec. As explained before, the time base speed can be doubled, so that only the first half of the response appears on the screen. The normal computation intervals are usually quite satisfactory, but now and then the need for different intervals arises. Then, an external synchronization signal can be substituted for the crystal oscillator signal, and hence the whole generating system is forced to work on the time-scale defined by the external signal. Most contingencies were found to be satisfied by building-in an additional 4 kc/s master oscillator that can be used instead of the 10 kc/s oscillator, in which case the unit of time is either 0.25 or 2.5 msec.

b) Switching possibilities

Selection of disturbance signals:

The possibilities are: impulse, step, ramp, sine wave, noise, external signals. The amplitude can be adjusted continuously.

Selection of signal(s) to be analyzed:

By means of a switch one of four prepatched signals can be selected. The customary signals are the disturbance, process output, controller output and the error signal.

Selection of method of analysis:

The possibilities are: deviation ratio versus frequency diagram, Bode diagram, Nyquist diagram, criteria, criteria as a function of a certain process parameter, measuring point read-out, external signal read-out.
We shall now briefly review these possibilities.
The deviation ratio is defined for sinusoidal disturbances as the amplitude of a certain signal with control divided by the amplitude without control[1]. For linear single-loop systems, the deviation ratio is independent of the place where the disturbance enters and the place where the amplitude is measured. It is determined by adding a sine wave of constant amplitude to a signal somewhere in the loop and recording the amplitude directly after the summing point as a function of the slowly increasing frequency. A complete sweep from 30 to 15000 c/s usually takes several seconds; during the reverse sweep, the zero line is recorded.
In the Bode diagram, the phase-shift and the logarithm of the amplitude ratio are plotted versus the logarithm of the frequency. One of the curves

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1 Handbook of Automation, Computation and Control, Vol. 3, p. 10-04; edited by E.M. Grabbe et al, Wiley, 1961.

is drawn during the forward frequency sweep, the other during the reverse sweep. By means of a switch one can choose to plot the transfer of the process, the open loop or the closed loop, but other possibilities are easily realized by changing the prepatched connections normally made with error signal, process output and controller output.

In the Nyquist diagram, amplitude ratio and phase shift of a transfer function are plotted on polar coordinates. The method of obtaining this diagram will be discussed in Paragraph c.

To characterize the performance of a control system, a certain criterion is often applied to one of its variables. The following criteria* can be applied by means of a separate selection switch:

$$\hat{\varepsilon}\,,\ \overline{|\varepsilon|}\,,\ \overline{\varepsilon^2},\ \int_0^\infty \varepsilon\,dt,\ \int_0^\infty \varepsilon^2 dt,\ \int_0^\infty |\varepsilon| dt,\ \int_0^\infty |\varepsilon| t\,dt,\ \int_0^\infty \varepsilon^2 t\,dt,$$

where ε may be any signal in a control system (including for reference measurements, the disturbance signal). Since integration from zero to infinity might turn out to be somewhat time-consuming, integration is limited to the time interval from 0 to 7 units of time, that is at most from 0 to $17\frac{1}{2}$ msec. The principle of the calculations is further discussed in Paragraph c.

To study the parameter sensitivity of a system, the criterion value can be plotted against the parameter value (e.g. controller gain setting). In principle, this is only a minor extension of the previous possibility provided the parameter value can be read-out as a voltage or a resistance. Measuring point and external signal read-out stand for rather trivial interconnections between preselected points and display instruments. Yet, it has turned out to be very convenient if these possibilities can be effected simply by turning a knob, for example, in accurate Bode-diagram measurements.

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* $\hat{\varepsilon}$ denotes the maximum value of ε , $\overline{|\varepsilon|}$ the average of its absolute value.

In addition to the selection of disturbance signals, of the signal(s) to be analyzed and of the method of analysis, we have the possibility of choosing between the various display units mentioned before. The selector switch makes all the necessary interconnections, and preset switches and potentiometers are used wherever possible to avoid time-consuming adjustments. For example, the oscillographs automatically receive the appropriate time base and intensity modulation signals, while the vertical deflection can be connected to various prepatched signals, each with its own amplitude adjustment. Thus one can switch back and forth between different variables when adjusting the parameters of a control system without being distracted by the readjustment of the oscilloscope(s). It is even possible to check how a certain integral criterion is built-up during a simulation cycle, while keeping an eye on other variables in the control system, which has proved to be very instructive, particularly in studies of sampled-data systems.

c) Units for calculating criteria, etc.

Criteria.

The criteria mentioned in the preceding paragraph can be calculated for the transient response of any variable (ε). The disturbance most commonly employed are periodic step changes (a square wave signal). Usually, the variable ε is defined so that its initial value is zero. However, if a simulation circuit is subjected to a square-wave input, most signals will be more or less symmetric with respect to earth potential, and the values at the initiation of a simulation cycle will often differ from zero (see curve b of Figure 8). Therefore, the signal to be processed first enters a special unit which automatically adds the correct voltage to obtain a signal ε_m starting at zero potential (see curve c). To this end, a sample/hold-circuit stores the value of the input signal (curve b) at the end of each half of a simulation cycle, and during the next half of a simulation cycle this value is subtracted from i to obtain ε_m. Since the disturbance cycle lags one unit of time behind the basic simulator cycle, the signal ε_m is zero during each eighth and sixteenth unit of time. An important condition is, of course, that the time scale has been chosen so that the simulation circuit attains equilibrium within 7 units of time. Signal ε_m is called the modified response. Rectification of this signal gives $/\bar{\varepsilon}/$, peak rectification gives the criterion value $\hat{\varepsilon}$, and squaring followed by averaging gives $\bar{\varepsilon^2}$. It is further possible to integrate the modified signal, or its squared or absolute value, or expressions like $\varepsilon_m^2 t$ or $/\varepsilon_m/t$, with respect to time to obtain integral criterion values.

Integration takes place over the first 7 units of time after the occurrence of a positive disturbance. At the end of this period the integrator signal (see curve d) is transferred to a sample/hold-circuit that delivers the output voltage (see curve e) to the selector switches. During the negative part of the cycle, the integrator is reset.

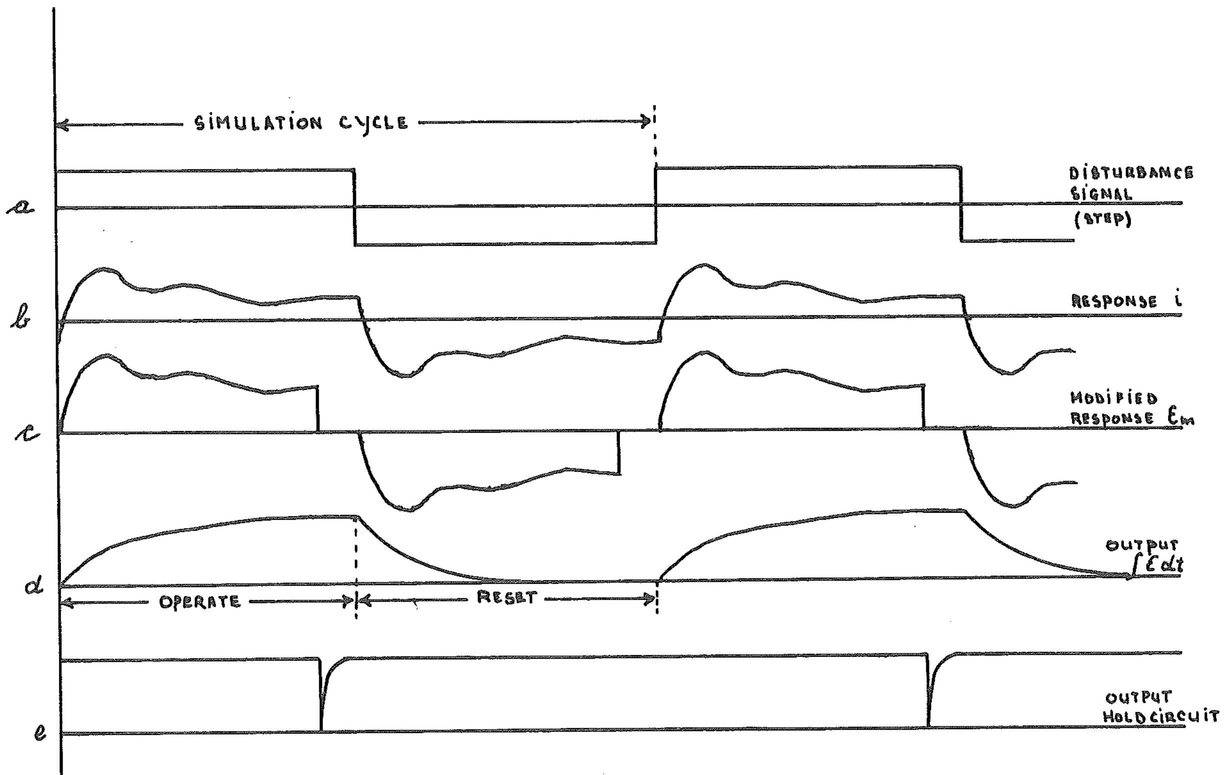

Figure 8   Characteristic curves for criterion calculation

In the computation of criteria, the amplitude scaling is somewhat more critical than in many simulation circuits. On the one hand, the diode circuits employed for most computations introduce errors in the order of 100 mV, unless special precautions are taken. Obviously, the consequences can be serious if the signal ε is of the same magnitude, but as long as it exceeds some 5 Volts, the error is smaller than 2 % of range. On the other hand, the output sample/hold-circuit becomes less accurate when the output voltage exceeds the design limits and also when, using external synchronization, the simulation cycle is unusually long. Both possibilities are detected by observing signal d on one of the oscillographs.

Polar plots.

Figure 9 shows the scheme used for plotting polar diagrams of transfer functions. By multiplying the output signal of the system under investigation by sin ωt and cos ωt, respectively, and smoothing the resulting signals, the X and Y coordinates of the diagram are obtained. By varying ω slowly over the frequency range of interest, a polar diagram can be drawn on an XY-plotter or a Memoscope.

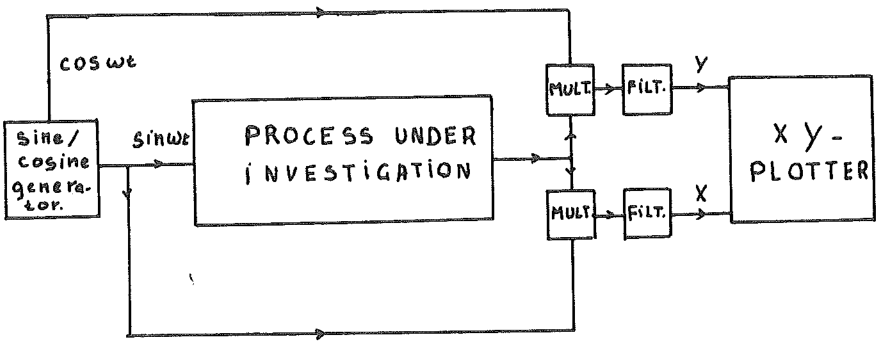

Figure 9 Scheme of plotting polar diagrams of transfer functions

A commercially available time-division multiplier is used to make the two products, but no sine/cosine generator covering the frequency range of 30-15000 c/s in a single sweep was available. Therefore, we composed such a generator from the parts of two common inference generators (beat-frequency oscillators) having the desired frequency range.

The principle of these interference generators is as follows. Two sine waves, one with a fixed frequency of 100 kc/s and another with an adjustable frequency in the range of 100-85 kc/s are mixed:

$$\sin \omega_1 t \cdot \sin \omega_2 t = \tfrac{1}{2} \left[\cos (\omega_1 - \omega_2)t - \cos (\omega_1 + \omega_2)t \right] .$$

The resulting low frequency component: $\frac{1}{2} \cos (\omega_1 - \omega_2)t$ is extracted by a filter to provide a cosine wave in the frequency range of about 30 - 15000 c/s. Also, we found it possible to obtain the corresponding sine wave by duplicating this process, starting from the same sine wave but introducing a 90° phase shift in the fixed signal (see Figure 10). The resulting low-frequency signal is a sine wave as follows from:

$$\sin(\omega_1 - \pi/2)t \cdot \sin \omega_2 t =$$

$$= \tfrac{1}{2} \left[\cos(\omega_1 - \pi/2 - \omega_2)t - \cos(\omega_1 - \pi/2 + \omega_2)t \right] ,$$

which yields the low-frequency signal:

$$\tfrac{1}{2} \cos(\omega_1 - \pi/2 - \omega_2)t = \tfrac{1}{2} \sin(\omega_1 - \omega_2)t.$$

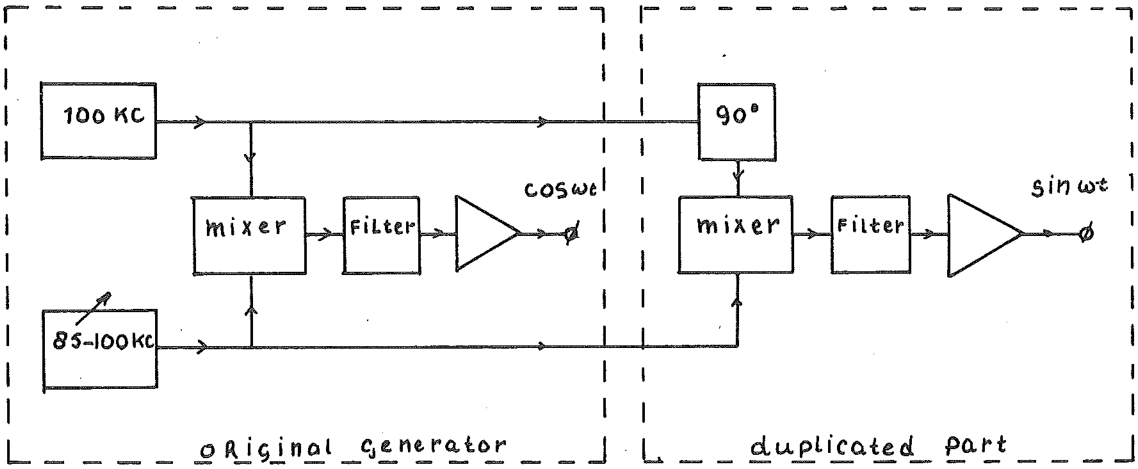

Figure 10 Block diagram of the sine/cosine generator

The accuracy of the generator is almost completely determined by the equality of the filters and amplifiers over the frequency range of 30-15000 c/s. An amplitude difference of less than 1 % and a phase mismatch of less than $1\frac{1}{4}^{\circ}$ can easily be achieved over the whole frequency range.

On the tuning capacitor, a potentiometer is mounted to obtain a voltage proportional to log ω for use in plotting Bode and deviation-ratio diagrams. The frequency sweep is effected by means of a reversible motor, speed and length of the sweep being adjustable. Figure 11 shows the front panel of the sine/cosine generator.

The automatic switch that determines the direction of the sweep is also used for other switching purposes, e.g. for lifting the pen of an XY-plotter or for drawing the amplitude curve of a Bode diagram during the forward sweep and the phase curve during the reverse sweep of the sine/cosine generator.

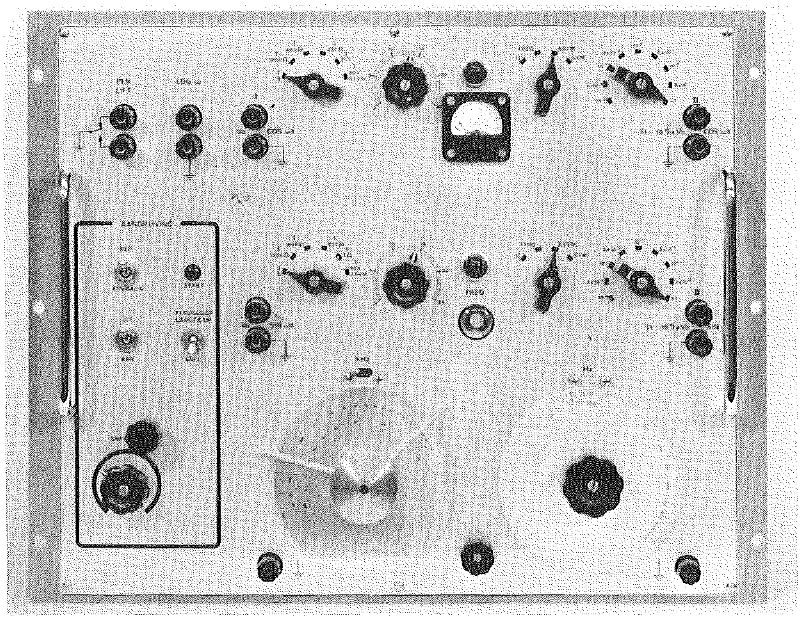

Figure 11   Front view of the sine/cosine generator

Deviation ratio.

Figure 12 shows the scheme used for plotting the deviation ratio versus frequency.

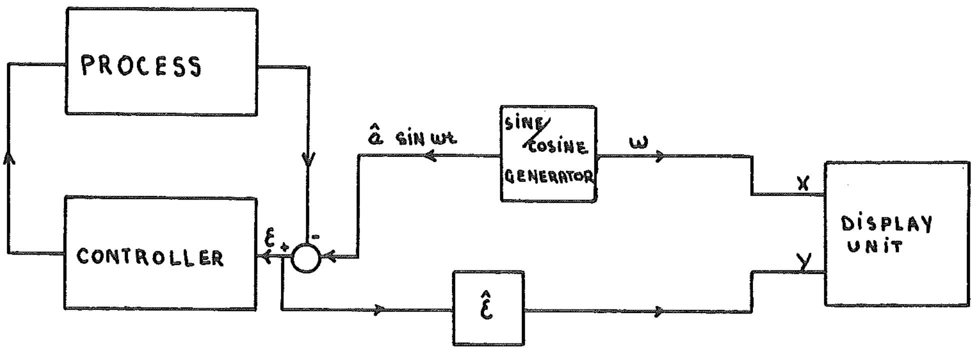

Figure 12   Block diagram of deviation ratio plotting

At a convenient point, a sine wave is injected into the control loop. Its amplitude is constant and its frequency is continuously variable over the range of interest. Without control, the error amplitude would be equal to â. With control $\hat{\varepsilon}$ is, by definition, equal to the deviation ratio times the amplitude â without control.

Hence, we only have to rectify $\mathcal{E}$ to obtain a signal proportional to the deviation ratio. Its value is plotted versus frequency during the forward sweep of the generator, while the zero line is drawn during the reverse sweep. By opening the control loop, the deviation ratio becomes equal to one, which serves to indicate the scale value of the deviation ratio axis on the display unit.

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Pitch perception of click pair stimuli.

When a sound stimulus is repeated after a short time interval, the so-called repetition pitch (RP) is perceived. The pitch of this stimulus corresponds to that of a sine wave having a frequency equal to the reciprocal value of the repetition time. A rather simple stimulus for investigating RP, is a pair of clicks seperated by a time interval τ. In our project a sequence of click pairs is used.

When one of the clicks of the pair is attenuated, the perceptibility of RP falls down; the threshold of perceptibility of RP is determined as a function of τ. When the first click of the pair is attenuated a lower threshold is found than when the second click is attenuated.
We are investigating in what manner this effect depends on the difference in mutual masking of both clicks; when the attenuated click follows the unattennuated one, it is more masked than when the small click proceeds the big one. When the first click is attenuated the time-interval is clearly present in the mechanical response of the basilar membrane (and thus detectable by the hair cells), but due to the lack of interaction between both clicks the power spectrum is rather flat. However, when the second click is attenuated, the mechanical response of the second click disappears in the response of the first one; this interaction between both clicks results in a spectral power density distribution along the basilar membrane with clear maxima at intervals $1/\tau$. The previous mentioned results suggest that pitch perception is based on time interval determination (autocorrelation) rather than on frequency spectrum processing.

Pitch of monaural and binaural tone complexes.

In order to get insight into some aspects of the (overall) pitch of complex tones (residue pitch, periodicity pitch, musical pitch) we determined the masked threshold for perception of pitch.
This threshold was defined as the relative power lewel of white noise needed to mask a 6 %-pitch change in two-interval forced choice tests; it was assumed to be an adequate quantity indicating pitch perceptibility.
The following conclusions could be drawn:
(a) For multi-component signals, pitch perceptibility is independent of phase. The signals investigated were a periodic pulse and periodic noise, both having the same power spectra, but different phase spectra.
(b) For 3-component signals, pitch perceptibility depends on phase if the harmonic number $n \gtrsim 8$.
(c) For 2- or 3-component signals with $n \sim 4$, pitch perceptibility is optimal and equal to pitch perceptibility for multi-component signals. This result underlines and, to a certain degree, explains the existence of the so-called dominant region.
(d) The results b and c together are able to account for the result a.
(e) For 2-component signals, pitch perceptibility does not change essentially when the components, instead of being presented to the same ear (monotically), are presented dichotically (one component to one ear and the other component to the other ear).

Binaural lateralization in relation to pitch perception.

Time differences as well as intensity differences at both ears are important cues for directional hearing or lateralization (when using headphones) of sound images.
Thus, apart from intensity mechanisms there has to be a timing mechanism that detects the interaural time differences. Some analogies exist between this timing mechanism and the time analyzing process for pitch perception.
The results of experiments up till now with filtered and unfiltered pulses of different polarities suggest the same sort of time fine structure and spectral dominance behaviour as found for pitch perception.
Particularly, since recent experiments have shown the same behaviour for monaural and binaural pitch perception, the analogy between pitch perception and lateralization seems even stronger.

Visual perception of periodic spatial patterns.

Basically, our spatial pattern project deals with questions of information processing by the visual system when stimulated by periodic spatial patterns (gratings). Recently, a series of experiments described in literature suggests that the visual system operates like a spatial frequency analyzer. Three specific experiments are in progress that deal with this concept.

(a) The contrast sensitivity transfer function measured with sinusoidal gratings as a function of the spatial frequency and the number of sine periods presented. Preliminary results have shown that about eight or more periods are needed for the contrast sensitivity to be optimal. This result is in accordance with the idea that spectral energy of a small number of periods (sine train) is spread over a set of hypothetical bandpass filters that are selectively sensitive for a rather small range of spatial frequencies.

(b) The perception of complex periodic spatial patterns (square wave grating, triangular grating etc...). In particular, the influence of the phase of each of the fourier components of the grating will be investigated. Whereas the eye seems to be phase insensitive at threshold level (in accordance with the fourier concept), it definitely is not at higher luminance levels. This apparent discrepancy leads to a number of crucial experiments.

(c) Sinusoidal gratings and also discontinuous spatial luminance distributions (compare Mach bands) show a rather strong afterimage under afterstimulation of the eye with a field of constant luminance. Using system theoretical concepts, the relation between the shape of the afterimage for discontinuous patterns and that of sinusoidal gratings (the afterimage contrast transfer function) will be studied.

The aftereffect of moving visual patterns.

If a moving spatial pattern is presented to the eye, one can perceive a moving aftereffect (the waterfall effect) in a direction opposite to that of the stimulus after termination of the stimulus.
It is studied whether the aftereffect is the result of adaptation to the movement or to eye-movements induced by the moving spatial pattern or to both.
We have attempted to quantify the aftereffect by matching the velocity with the velocity of a moving light spot (test stimulus).
It turned out that the velocity of the test stimulus can be measured with sufficient reliability as a function of the velocity of the moving pattern (adaptation stimulus without a fixation light spot).
Measurements of the aftereffect in the presence of a fixation spot, however, appear to be impossible.
Eye recordings taken from literature during and after moving patterns do show a strong relationship to the determined values for the velocity of the aftereffect.
On basis of prelimenary confirmation of eye displacements (by successive afterimages of light spots) a recording device for eye movement is being developed. Eye recordings will reveal the effect of the oculomotor system on the appearance of the movement aftereffect.

Firing pattern of auditory neurons in response to sounds with their repetition.

In order to obtain neuroelectric data on neuronal coding of musical pitch information, microelectrode experiments are designed to provide an estimate of the spike activities in several nuclei of the cats brain during excitation with paired clicks and repetitive noise.
As the organ of Corti (inner ear) gives a rather high Q oscillatory response to a short click, the net magnitude of the sum response to click pairs will depend upon both the phase relations between the first and the second click and on the magnitude of the response to the first click at the time the second click is applied.
Consequently the discharge rate of single auditory neurons (connected to hair cells in the organ of Corti) will show fluctuations as a function of the time separation between the two clicks.
For excitation with noise and its repetition or paired clicks with either the first click attenuated with respect to the second click or the second click attenuated with respect to the first one, this discharge distribution will possibly reflect the short time spectrum from which pitch is extracted and will provide data on the nonlinear properties of the auditory pathways.
Furthermore the possibility of cross-correlation in binaural interneurons will be studied with extra- and intracellular recording methods during dichotic excitation with paired clicks or noise with its repetition.
If a neuron is selectively sensitive for a certain time separation, this time separation can be retrieved from socalled spike interval histograms.

Pitch phenomena and their common central origin.

In literature several dichotic signals have been described which give rise to a central pitch sensation, viz. Huggins' pitch, Fourcin pitch and the pitch of dichotically presented two-tone complexes (Houtsma & Goldstein).
The present results of experiments with dichotically delayed noise, i.e. continuous wide-band noise in one ear and the same noise delayed by a time τ in the other ear, clearly indicate the existence of a (new) pitch phenomenon ("dichotic repetition pitch") that behaves like (monotic) repetition pitch, residue pitch or periodicity pitch.
The pitch corresponds to $1/\tau$ when the noise and delayed noise have equal polarity; it shows the first effect of pitch shift for the noises having opposite polarity.
The pitch phenomena mentioned can be described with the concept of a "central spectrum", the existence of which seems to be closely related to the existence of BMLD's.
Pitch may be extracted from the central spectrum, for example, by means of "spatio temporal crosscorrelation" or "spectral fine structure detection".

Possibilities for prothesis control by pattern recognition of shoulder muscle action potentials - J.H.Schimmel
J. van Gent

The aim is an investigation of the possibility of armprosthesis control by electromyographical (EMG) signals from the shoulder muscles.
Pattern recognition from a multi-electrode muscle complex has been a research subject for several years, our results were hardly satisfactory while using the unloaded hand or shoulder. Static load on the fore-arm of a healthy subject induces however reaction-forces in his shoulder.[1)] The activities of 10 selected shoulder-muscles caused by these forces form a coordinated pattern, which is related in a natural way to direction and size of the load on the fore-arm (or:the force exerted by the hand). This activity-pattern is detected as a pattern of 10 EMG-signals. By means of 10 bipolar skin-electrodes of suction-cup type, followed by 10 differential amplifiers, rectifiers, low-pass filters, sample hold circuits, a multiplexer and analog to digital converter the smoothed EMG-patterns are introduced to an IBM 1130 computer, together with information about magnitude and direction of exerted forces.
The subject grips a handlebar, which he has to maintain in the same position against the varying loads which are applied externally.
Pattern recognition programs from the Instrumentation Group are used succesfully to classify between 16 directions of exerted force in one plane from the EMG-pattern input. The massive computation of the classification coëfficients (the coëfficients of the separation planes) based on the learning samples of EMG plus force data is then performed off-line at the Computing Center. This includes a first test of the classifier on the remaining data as test samples.
The last part of the classifier program has been rewritten for the IBM 1130, with tape input of the computed coëfficients. This computer then functions as on-line classifier on real-time EMG input. The output is a real-time force vector display on the oscilloscope, and can thus be presented to the subject.

[1)] R.Wirta and D.Taylor, Moss Rehabilitation Hospital, Temple University, Philadelphia.

In this closed-loop situation we will study the control performance of the subject, the variability of patterns in relation to non-recent classification coëfficients and his adaptation to such phenomena for maintaining accuracy. Gradually more dynamic situations may be introduced in tracking experiments.
In the case of good results the elaborate test equipment can be replaced by pattern classifying networks with adjustable coëfficients.
The method described above uses normally occurring signal patterns of shoulder musculature which leads to expect that such a control method should not be too hard to adopt for the handicapped.

Movement studies of human extremities by means of a T.V.-camera interfaced to a digital computer - J.J.T.Hendriks
G.J. van Ingen Schenau

To investigate the characteristics of "normal" movement of the healthy arm our group developed in 1967 a video-to-digital converter for coupling a TV-camera system to the digital computer interface. (the development of a general purpose digital electronic interface to the computer IBM 1130 is a continuing project of the Signal Processing Group, Cooperation Centre and our group).
The television system is used as follows:
Small electric lamps are attached to the human body at a number of landmark points, they should be brighter than any other point seen by the camera in order to keep programming simple. The video signal is first quantized in two levels. The video-to-digital converter output then consists of an 8+8 bit binary code for the X and Y coördinates of each bright point in the camera picture plus an output flag pulse for each new codeword. The picture is scanned at the standard TV rate of 50 frames per second, 312 lines per frame of which 256 are used. On each line 256 intervals are defined by a 4 Mc clock. The TV camera is synchronized by pulses derived from interval and line counters. These counters are the source for digitizing the X and Y coördinates of each bright point. The presence of a bright point in the video signal causes instantaneous read out of the counter contents into a 16-bit register, which constitutes the VDC output code. The VDC has facilities for converting only contours of bright dots and for suppressing all but the first point of a contour, in order to reduce data flow into the computer.

The VDC can be connected to the digital computer interface for on-line movement analysis. For some experiments an off-line situation is more practical, the VDC is then connected to the Kennedy digital tape recorder which is described elsewhere in this report.

Much programming effort has been expended to numerical filtering methods, appropriate for the VDC coördinate signals which are relatively roughly quantized in amplitude apart from being quantized in time. The signals first pass screening programs where the serial positions are assigned to the individual lamps, and missing positions are detected. Some extrapolation filters (predictors) are used in searching and interpolation filters are used for replacing missing dots. After zero-order filtering differentiating filters can be used to determine velocities and accelerations.

Adaptive bandwidth filters are used here to suppress spikes with slowly changing signals which cross the quantising range only once in many sample periods.

Programming is now directed toward analysis and display of relevant features such as trajectories, angles, velocities, accelerations, etc. Momentany frames can also be selected for display to approximate the stick diagram representation.

In cooperation with the Biomechanical Lab.(Free University, Amsterdam) research with human subjects has started. Their first concern is gait analysis and they are interested to evaluate the precision obtainable, against the greater ease of the TV/computer method, as compared to stroboscopic photography or single-frame analysis of motion picture.
The aim of our group in the study of arm movement is to describe characteristics of patterns of so-called normal movement. Translated into kinematic concepts these could be valuable for semi-automating the movement of artificial arms under "supervisory" control. In some arm movements we have already observed patterns much like the programmed bang-off-bang control of acceleration from the domain of optimal control theory.

The VDC in a modified form is also used in the Pattern Recognition Group for computer input of stationary pictures with much detail such as chromosome microphotographs.

An Experimental amplifier for surface electromyography - J.Molenaar

On muscle contraction electric muscle action potentials are generated in the muscle fibres. A number of fibres, organised as a motor unit, contract together. In muscle contraction a varying number of motor units is active, distributed through the muscle body, so that on the skin above the muscle a summation signal can be detected which is called the surface electromyogram. Peak to peak values are of the order of 100 μV. The skin presents a high impedance, resistive and capacitive, to the amplifier electrodes, this impedance is not constant as it depends on skin moistness conditions. The contact is not stable, so that low frequency variations of the galvanic potential contribute to the signal. The most serious distance in the emg signal occurs by capacitive coupling of the body surface to the electric power mains. Voltages of 100 mV at 50 hz can occur between electrodes situated 5 cm apart. The emg signal is detected by a differential amplifier with two suction-cup electrodes over the muscle and a common reference electrode.

To determine the requirements for a miniature amplifier with integrated circuit active elements which is to be placed in a package with the electrodes directly over the skin, an experimental small IC instrumentation amplifier was built. This has a Common-Mode Rejection Ratio at 5.10^5, which means that a 50 hz signal of 5 V in common between the signal electrodes and the reference electrode produces the same output voltage (1 mV) as a 10 μV voltage between the two signal electrodes. The input impedances of the amplifier are of order $10^9 \Omega$ at 50 hz, the amplifier has a dc coupled input. The amplification factor, in difference mode, is 100.

With this amplifier the influence on the 50 hz output is studied of externally reducing the CMRR, the input impedances and introducing impedance unbalances. Some notions on the mechanisms of 50 hz interference are experimentally verified, a different design for the reference electrode has been proposed.

In a later stage a simplified amplifier using less IC's and with reduced supply current will be designed for use with the multi-emg pattern recognition project.

Electrical skin stimulation as a sensory substitute in handprostheses - H. van Stokrom

To provide externally powered handprostheses with sensory feedback without use of eye and ear, painless electrical stimulation of the skin is considered. With the use of short, negative, rectangular current pulses (pulse width below 0,5 ms; no dc component) and a small active electrode (0,9 cm^2 with the neutral one about 10 cm^2, both with salinated felt pad) the stimulus appears comfortable below three to five times the perception threshold. Perception threshold occurs about a few mA at 0,5 ms pulse width.
We are now looking for ways to stabilize the perception threshold (for long term experiments) with constant current density electrodes. We have started with a divided electrode (provisional with three parts), from which the current of each element is adjustable. With this divided electrode we shall try to analyse the interaction between the parts, to stabilize the current density.
Short term experiments with a multi-electrode configuration give an idea of the usefulness. A glove with seven surface contact zones delivers signals on touching metal objects. The contact area and therefore the contact force at each zone corresponds with pulse frequency at one related stimulus electrode. The electrodes are located on the upperarm in the same configuration as the contact zones in the glove. The perception of dynamic touching and grasping in these experiments appear to be very clear to the subjects.

Interface for the digital magnetic tape recorder - G.Klunder

The Kennedy recorder is mainly used to store measurement data which later on is processed by the computer. The input data for writing on tape is offered in 16-bit words to the recorder interface and after reading from tape the output to the computer is also in 16-bit word format.
On tape two bytes are needed for each 16-bit word. On the nine-track tape each byte is a character of 8 bit plus 1 parity bit.
The byte density is 800 bytes/inch (IBM format) and the speed is 25 inch per second so the time for each byte is 50 μs. The internal write clock rate is 20 kC. Tape length is 2400 feet per reel, continuous recording time is thus 19 minutes. One tape reel stores max. $23 \cdot 10^6$ bytes or the equivalent of 22 IBM 1130 storage disks.
At present the interface tape control section offers manual control of tape speed, direction, read or write and return to loadpoint. An external signal can also start and stop the recorder.
The interface has special sections which adapt to the characteristics of two data sources in our group, the video-to-digital converter and the electromyogram pattern acquisition. These sections perform some formatting of the specific data sequences of 16-bit or 10-bit words into pairs of 8-bit bytes. Moreover, for the video-digital signals which can occur at very high burst rates, this interface contains a 16 word buffer storage. Video coordinate data are stored here during the TV frame scan and if less than 16 words are presented, the sequence is completed with zeros. During the TV frame fly-back, on the frame synchronisation pulse, the buffer contents are sequentially written on tape, preceded by two recognition bytes of "ones". During the TV frame scan, the recorder also runs but no data is written.
The adapter for EMG is slightly different. There is continuous writing on tape, but if there is no data word presented, zero bytes are written. Data is presented in 10 bit words from the A/D converter, so in the two bytes for a data word a special bit is reserved which is "one" if it is a data-byte.
On reading the tape, special circuitry handles these recognition marks and reformats the data accordingly into 16 bit words, for transfer into the digital computer "Read" channel.
We are now designing more facilities for on-line computer control of the tape recorder.

A shift register buffer for the digital tape recorder - H.K.Nagtegaal
P.Beerends

The Kennedy tape recorder is a high-speed synchronous machine with write and read rates of 20.000 bytes per second. Start plus stop time is about 25 ms, which is equivalent to 500 bytes.
If the input data rate to be written on tape is appreciably slower than 20 kbytes/s it is advantageous to use the recorder in start-stop mode. It will then write blocks of data at 20 kbytes/s from an intermediate buffer storage. This will reduce unused tape length and so increase recording time in a 2400 feet reel. Note that a digital recorder of the incremental type is at present limited to about 1500 bytes/s. With the buffer system the maximum input rate depends on the buffer size. We have chosen a block size of 1280 bytes, this gives a maximum of 16 kbytes/s. On the IBM 1130 disk storage 1280 bytes fill 2 sectors. A block of 1280 8-bit bytes requires 80 128-bit shift registers, of a type which has been ordered.
The buffer is byte-oriented, 8 bit per byte.
A symmetric duplex buffer will be used, one 1280 byte buffer is reading data and when full will start the recorder, write on tape and stop the recorder, while the second buffer takes over the task of reading input data. This procedure iterates as long as input is presented.
After writing each block on tape, the recorder may write check bytes in the IBM 1130 format for Inter Record Gap.
Part of the control unit for this tape buffer is now being tested.

Zero Voltage Crossing Switch - H.K.Nagtegaal

This circuit has two functions.
The line filter removes as much as possible the spike disturbances from the mains line.
The triac zero crossing switch prevents the generation of spikes on the line when switching loads on or off.
The principle of the triac circuit is to switch a series load at or near the zero crossing of the line sine wave, so that there is no power for a current surge to generate a voltage spike.

The 9 volt sine wave is rectified and smoothed for the transistors dc supply. The 24 volt sine wave is rectified only and serves as inputsignal to the switching transistor BC 107. The BC 107 collector delivers positive-going pulses at the sine wave zero crossings.
Through an emitter follower BFY 50 these pulses may be applied to the triac gate via the on-off switch S.
After each gate pulse the triac will conduct through the next half of the voltage sine wave. When switching loads with an inductive component the gate pulse must be wide enough for the out of phase current to reach its holding value,otherwise the triac will turn off.
The gate pulse width may be adjusted by changing the 24 volt or the 5K5 series resistor.
The circuit draws about 8mA line current not including the switched load. For universal use a triac of minimal 400 V, 6A is recommended.
For loads above 1A the triac should have a cooling disk.

The triac is sensitive to line spikes and may be triggered by them. Spikes higher than the triac voltage rating may damage it. The line filter serves to minimize the line spikes reaching the triac and the load.
The results of this circuit is, that line spikes which penetrate on the output of a low-voltage stabilized power supply are reduced from 2V to 40mV when switching the same equipment on and off the line.

The size of the circuit allows it to be built into existing equipment.
The switch S then replaces the mains switch. If a separate mains switch is retained, this should be "on" before using the zero crossing switch.

Automatic reading of handwritten numbers

To automatic bank- and transfer business it is desirable to recognize numbers (account number, amount) without human intervention. For that purpose a device has been developed, which makes it possible to read handwritten numbers in an automatic way. In writing the numbers, the use of a special template is required. The numbers so written will have a more or less stylized nature. This system has the advantage that the numbers may be read easily by machines as well as human beings.

The reading of a number is done by determining, on seven essential parts of the number, if there is a line or not. The detection of the lines is done by means of seven photo transistors, each scanning a part of a number. The signals coming from the photo transistors are fed into an electronic system. They are digitalized and stored in binary memory elements.

Finally the information can be made visible by means of indication tubes. It also is possible to assemble the digital information in f.i. punching-machines.

A video digital convertor for four levels

With this video digital convertor (VDC) it is possible to store pictures from a t.v. camera into a computer. This device is used with e.g. the automatic recognition of chromosomes. The t.v. pictures are digitalised with the VDC and supplied to a IBM1130 computer. Before punching the data on papertape one can get the picture in four brightness levels on a display to check it.

The analog video signal of each picture point has to be converted in a two bits binary signal. This binary signal has to be sampled and supplied to the computer. So we get the brightness of each point in one of the four possible levels. The threshold values of the four levels can be adjusted manually and independent of each other. For some purposes it seems to be desirable to adjust the thresholds dynamicly.

Two t.v. frames are necessary for the picture consisting of 224 times 192 points, because of the transmission rate of the read channel of the IBM 1130.

With a light pen consisting of a phototransistor and an amplifier one may point at an arbitrary picture point on the monitor screen. The co-ordinates of that point can also be stored in the computer.

The die-tester

The die-tester is a gadget, built solely to demonstrate the application of contour followers.

The dice are placed in a perspex box, provided with a glass underside. The throwing is achieved by turning this box 360°.

At the thrown die, now at rest at the glass underside, a t.v. camera is aimed.

As we are only interested in the eyes of the die, a black die is used with a dark background. The first operation, performed on the t.v.-image, is one in which a differentiation is made between black and white. Everything above a certain level of brightness is called white; the opposite black. The black-white or white-black transitions (contours) in the image are obtained by differentiating the binary image signal. The separate contours in the image are followed by contour filters. These are based upon the fact that the t.v. camera traces an image in lines of 64 µs each. After 64 µs, the same spot of the image, but for the difference of one line, is traced.

If a puls has occurred in the differentiated signal, then 64 µs later the signal is checked for another pulse. If this happens to be the case this pulse is taken as one belonging to the same contour as the first one. After another 64 µs have elapsed, the signal is checked for a pulse etc. A contour is considered to be finished if after the termination of the 64 µs after the occurrance of a pulse no other pulse appears. The number of thrown eyes now is determined by counting the number of contours longer than a certain minimum number of lines. The total number of throws and each time a 1, 2, 6 comes up is counted by mechanical counters.

At first wooden dice were used. These however were not capable of standing a 10.000 number of throws in the box. So two black plastic dice were made. To obtain eyes, holes were drilled, which were filled with white plastic. In one of the dice, brass was used to fill one of the holes partly.

These dice have been tested in the apparatus. A chi^2 test, applied to the obtained results over 1100 throws, did give a probability of obtaining a uniform distribution of 65% for one of the dice, for the other die, this probability turned out to be zero.

Automatic chromosome analysis

This research is done in cooperation with the departments of histology of the Medical Faculty of Rotterdam (Prof. Galjaard) and of the University of Leiden (Prof. v. Duyn).

The chromosome analysis used clinically up till now, consists of cutting chromosomes from a photograph and ordering the chromosomes into seven distinct groups. The main features used for this classification are the length of the chromosomes and the place of a constriction, the so-called centromere.

These features might be computed automatically with a contour-analysis. This contour-analysis consists out of the determination of the convex and concave parts of the contour from the smoothed change in direction of the contour (in 94% of the cases succesfull). Another approach is a skeleton analysis, which computes a line figure (skeleton) with the same connectivity as the original chromosome. The several line parts of the skeleton are then analysed in a "linguistic" manner, resulting in the lengths of the arms of the chromosome (in 96% of the cases succesfull).

These features are used for several classification programs, which give about 10% mistakes.

Except length measurements, dna-content determination is possible with chromosomes stained with the dye of Feulgen. The computed summation of the extinction of the chromosome arms is (with this dye) a measure for the dna-content of that arm.

About 1½ year ago a fluorescent dye (quinacrine) was discovered by Caspersson, which gives a banding pattern along a chromosome. This banding pattern looks different for each chromosome.

The principal axis or (if the chromosome is bend) the skeleton is determined for quinacrine stained chromosomes, the brightness of the chromosome is projected on to this axis or skeleton and the so-called Caspersson-line is obtained.

The data used for this research is obtained from a t.v. scan of photographs (Rotterdam), from scans with a Zeiss cytoscan/PDP 12 (Leiden) and from magnetic tapes made available to us by the groups of dr. Rutovitz and dr. Neurath.

Automatic interpretation of vectorcardiograms

The investigations into the possibilities of automatic interpretation of vectorcardiograms (VCG's) has as its most important purpose the support of the cardiologist by diagnosing and evaluating cardiograms. At a population-check concerning heart deviation, the computers could be used to make a preselection. The cardiologist than only would have to look at cardiograms of which something is expected to be wrong. Maybe that little variations in the VCG, which appear after years by one person, could be detected.

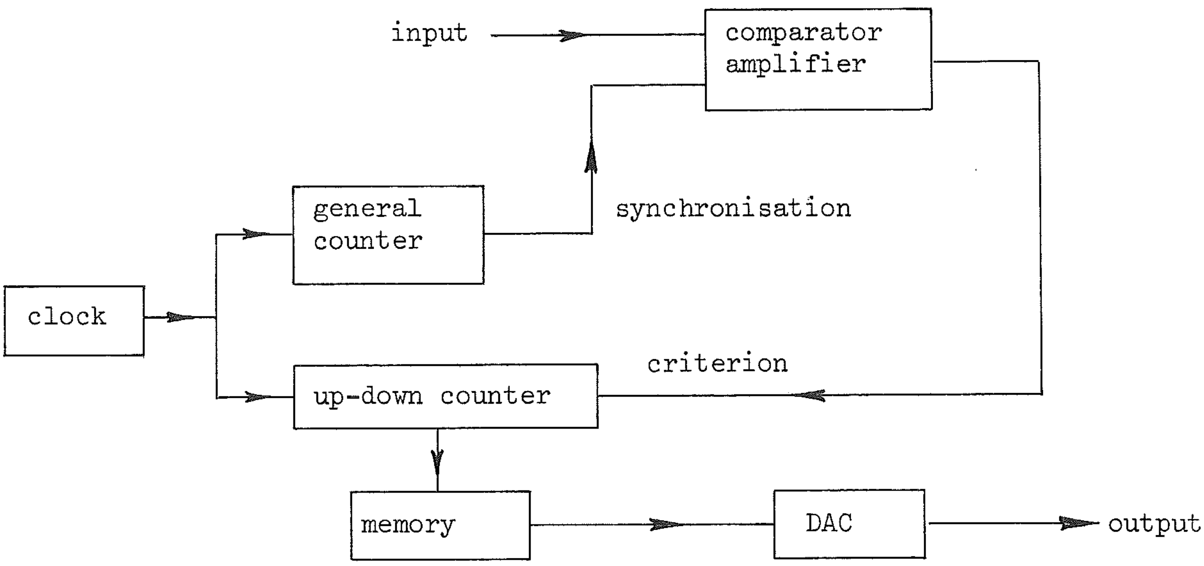
The realization of an automatic analysis of VCG's creates many problems, especially because there is a large variation owing to age, sex, race, physique etc. There are various methods which are expected to lead to automatic analysis. With the help of a statistical comparison of a lot of VCG's with known diagnosis, criterions could be looked for to postulate the diagnosis. One of the difficulties in this technique is that the number of available cardiograms has to be very large. Another possibility is to imitate the criterions the cardiologist uses. These however, are often difficult to formulate in an exact manner.

It especially has been investigated in what way all kinds of techniques used in "pattern recognition" can be applied here. The attention was mainly pointed at the shape of the QRS-complex. In this investigation there is cooperation with the Institute of Medical Physiscs, TNO, Utrecht.

Besides the afore mentioned population check another application can be patient-watching: the automatic checking of VCG's of patients with a heart disease in a hospital, or of sportsmen during heavy exertion, etc. Particularly in the future attention will be paid to the latter. If something must be checked, one first has to know which are the right criterions. Therefore sportsmen will be placed on a bicycle ergometer. It will be verified if by increasing the load, obvious changes in the VCG are visible and if these changes occur generally.

Hybrid Differential Analyser

The research done on the H.D.A., is aimed at obtaining an integrator, in which use is made of "hybrid" signals. These signals contain analog-as well as binary (digital) information. These signals however look just like ordinary logic voltages. The difference, with regard to ordinary logic signals, is that their levels are defined exactly. The analog value now is a function of the high/low ratio and the voltage levels. The block-diagram of the H.D.A. is depicted below.



A pulsgenerator feeds pulses to the two counters. The general counter is used to synchronise the comparator amplifier. This amplifier so provides a hybrid signal with a constant period time. The high/low ratio of the comparator signal is used as the criterion to determine whether the counter is in up or down counting mode. The most significant bits of this counter are connected to a digital memory. At the end of each period the memory is set at the count of the up-down counter. The count of e counter, and so also the setting of the memory, is proportional with integral of the input with regard to time. A digital to analog convertor r provides the analog output signal.

Thick-film hybrid microelectronics

Present thick film technology is a very important part of todays electronics industry. It is characterized mainly by the use of conductive, resistive and dielectric pastes printed on a substrate with silk screening techniques. Together with miniature active elements a maxium packaging density has been reached. These hybrid devices are very reliable and endure rugged environmental conditions. They can be made with relatively low cost equipment and relatively unskilled labor, although supervision requires a great deal of experience. The thick film facility of the Delft University of Technology is and can be very helpfull in developing special purpose electronic equipment.

This thick film facility consists in principle out of a screen printer and two belt furnaces. For special close tolerance resistors and capacitors very acurate trimming equipment has been developed. Also active elements are sometimes part of an electronic circuit and therefore die- en wire-bonding equipment and many other handling tools are there.

Visitors:

Explanation about and demonstration of:

1. Thick film hybrids.
2. Ball bonding equipment.
3. Solutions of some multilayer interconnection problems.

Insulating layers by sputtering

Thin layers of SiO_2 can be deposited on suitable substrate material by means of r(adio) f(requency) sputtering. During sputtering a quartz cathode is bombarded in a gas discharge that pulverises the cathode and a thin layer of quartz is deposited on the substrate. The sputtering apparatus will be shown as well as the gas discharge.

This investigation partly is a continuation of work started more than a year ago concerning the study of undoped SiO_2 layers. For the other part the work however is essentially different in that we also want to investigate the possibility of producing SiO_2 layers that are intentially doped with B and compare these with undoped layers.

Purpose is to check the possibility of producing these layers and subsequently to measure the electrical properties such as the resistance of sandwich structures with applied electric fields in the order of $10^6 Vcm^{-1}$. Related to this the Poole-Frenkel effect is of special interest. Other properties should also be investigated as for example the B and Ar content in the SiO_2.

The layers thus made can be applied as the dielectric in thin film capacitors if the SiO_2 is not doped and as diffusion source in semiconductor technology if the SiO_2 is B doped. Both types can also be used as a passivating layer.

The measurement of the thermal diffusivity of thermal isolators with a dynamic method - R. van Mastrigt

The thermal diffusivity is measured with a non-stationnary method based on a sinusoïdal temperature wave going along the length axis of a semi-infinite probe bar. In two places in the bar the sine wave is measured and from amplitude attenuation and phase shift the thermal diffusivity can be computed.

It is difficult to generate a sinusoïdal temperature variation. However a square wave can be applied, the low pass properties of the bar will filter this and thus produce a sinusoïdal temperature wave. After a certain distance the signal contains very few higher harmonics.

A special purpose computer calculates the coefficients of the fundamental harmonic by Fourier analysis. Instead of multiplying by sine and cosine, the measured temperatures are multiplied by so-called "shoulder functions". These functions only have the levels -1, $-\frac{1}{2}$, 0, $+\frac{1}{2}$ and +1 while the 2^{nd},3^{rd},4^{th},5^{th} and 6^{th} harmonic are zero. If the measured temperature is frequency modulated the multiplication and integration can be realized with backward-counting, non-counting and forward-counting, and dividing by two.

Complex phase velocity through a collapsible tube - C. Scholten

The mathematical description of blood flow through veins are the transport equations of an incompressible fluid through tubes with highly elastic walls (collapsible tubes). The form of the tube changes during the transport. Assessments of the possible forms and their equivalent mathematical representation have to be obtained from physical experiments. The object of this investigation is to measure the phase velocity of pulse transmission through a collapsible tube. With this information two questions can be answered:

1. What is the effect of shape changes on phase velocity and
2. is the phase velocity of the proper magnitude in order to explain observed instabilities of flow in collapsible tubes?

The complex phase velocity is given by the equation:

$$c^2 = \frac{A}{\rho \frac{dA}{dP}} \left[1 - \frac{2I_1(R)}{RI_o(R)} \right]$$

$$R = \sqrt{j\omega \frac{\rho A}{\pi\mu\gamma}}$$

A = cross-sectional area

c = complex phase velocity

P = pressure

I_o = zero order modified Bessel function

I_1 = first " " " "

γ = shape factor

μ = viscocity of the fluid

ρ = density of the fluid

ω = frequency

The shape factor γ is postulated to take into account shape changes. Theoretically it is a function only of area, it is real and independent of frequency and varies between 1 and 2. By measuring the phase velocity for different cross-sectional areas, γ can be found experimentally. With nearly all experiments in collapsible tubes, flow instabilities have been found. Sometimes these are seen as oscillating changes in shape with flow and pressure. One possible mechanism for these instabilities is the fluid velocity approaching the phase velocity. When the phase velocity is measured it will be possible to directly compare measured values of phase velocity with measured values of flow at which the tube form became unstable.

The phase velocity is obtained by measuring the variations in cross-sectional area at two locations by a capacitive technique.

Climate control in incubators - H.Dane

A. ten Have

Premature infants are kept in incubators in order to maintain their body temperature. If we wish that the child not only survives, but also grows at maximum rate, the food-energy balance becomes important:

$$\left[\text{Food intake}\right] = \left[\text{Metabolism}\right] + \left[\text{Growth}\right]$$

The food intake is limited. So for maximizing the growth the metabolism should be minimized. The metabolism is influenced by a number of factors, of which infant temperature control is the only one that can be manipulated, viz. by the climate of the incubator. The incubator climate must be controlled such that the infant's temperature control has hardly any work to do. This means coupling of the two control systems, and the need of some knowledge about the performance of the infant's system. Its parameters must be computed from measurements of the temperatures of air, skin, incubator wall, deep body temperature, metabolism and humidity.

For adults simple models are available. For premature babies these models can be tested. An incubator for these experiments is being constructed in Rotterdam at the Medical Faculty. In the meantime the performances of two commercially available incubators (one of them currently used in Rotterdam in "Sophia kinderziekenhuis" of the Medical Faculty) are compared.

Monte Carlo experiments with an Ising lattice
An example of interaction between a general purpose computer and a special purpose processor - E.J. van der Schee
L.J.J.Speet

With the Ising model macro-properties of solids, like sudden phase-transitions, can be explained quantitatively from the statistical properties of spin orientation in the elementary structures. In the model spins can be directed up- and downwards only and interaction is restricted to nearest neighbours. Similar states and different states of the nearest neighbours give two different contributions to the total lattice energy. The computing problem could be solved by producing all possible patterns of spin orientations and counting the number of similar neighbours as a measure of the lattice energy and the total amount of similar spins as a measure of magnetization. Since the number of possible lattice configurations is very large this cannot be realized. However, estimates of energy and magnetization can be computed with Monte Carlo techniques. Using a general purpose computer the experiment is very time consuming even with small two-dimensional isotrope lattices.
A very fast special purpose computer based on the algorithm of Yang is relatively easy to implement. The external processor is interfaced with the IBM 1130 which sets the temperature anisotropy and external magnetic field parameters and which takes care of the bookkeeping of the results. Experiments are done with two dimensional lattices of different seizes (maximum 100 x 100). At a clock-pulse command the computing procedure for one point of the lattices is carried out. The repetition frequency of the clock-pulse is 10 MHz maximum with the TTL logic used. This is about 100 times faster than the most advanced general purpose computer experiments.

A special purpose computer for Monte-Carlo experiments on a crystal-growth model - E.J. van der Schee
S.W.H. de Haan

Recently the interest in crystalgrowth has been increased because of the grown use of mono crystals for electronical (semi-conductor) and optical purposes. One is particulary interested in the relationship between microscopic surface structure and growthrate as a function of supersaturation and bondenergies between the particles.

To study this growth problem qualitatively a model is introduced, which is able to grow in one direction. We only consider nearest neighbour bonds. Because of the great number of equations, it is impossible to compute the growthrate directly from this model. A Monte-Carlo estimate is measured: a condensation- or evaporation event occurs with a probability which is related to the change of energy involved.

Simulating the process on a general-purpose computer is very time consuming. The special purpose computer which is built is expected to run about 80 times faster. The clockfrequency will be 3 MHz. At each clockpulse one lattice surface position is observed and a particle may be added or substracted. The machine is connected to the IBM 1130 to set the temperature, anisotropy, bondenergies and to store the intermediate results.

In the future the machine may be extended for the evaluation of surface diffusion.

A digital echo-generator, for in-line use with the measurement of speech intelligibility - A.Hoogland

A. van Scheepen

The intelligibility of speech is appreciably influenced by echos or groups of echos after the primary sound wave. Early echos improve the intelligibility, late reverberating detoriate this. Connected to the SAC-channel of the IBM 1130 a special purpose computer generates in-line ten echos from one audio signal. Delay times are variable in steps of 40 μs from 40 μs up till 300 ms.
The signal is sampled (sample frequency 25 kHz) and put in the core-memory of the 1130. The input address is determined by a ringcounter which circulates the successive samples through the whole memory.(1-2-3-...8192-1-...etc.)

Ten echos are obtained for each input sample by taking words from ten previously specified addresses in the ringcounter. A special preset-system enables the user to change the ten output-addresses instantaneously during the experiment.

To avoid folding distorsion the bandwidth of the input signal is cut off at 8 kHz (filter 72 dB/oct). The sampling frequency is removed from the ten outputs by low pass filters of 8 kHz bandwidth and a slope of 48 dB/oct.

Using fifteen bits analogue-to-digital and digital-to-analogue converters a low distorsion and a signal to noise ratio better than 50 dB is obtained.

The main characteristic of the system is the convenient man-machine interface for changing the delay times. This enables the experimenter to use ranking order methods in evaluating quality measures.

A universal data acquisition system - P.Lindhout

Purpose

Accurate sampling and digitizing at high repetition rate of ten analog input signals according to a flexible programm.

Description

The analog input signals are fed into sample and hold units through buffer amplifiers. All channels are sampled simultaneously. A gated multiplex counter successively switches the samples to a 15 bits A/D converter. During conversion time the next multiplex channel in use will be indicated. This is made possible by using an extra sample and hold unit between the multiplexer and the A/D converter module. Unwanted channels are skipped in a fast mode.

The digitized samples are stored into FF-registers by means of a gated demultiplex counter. A count memory stores the number of channels in use, in order to achieve proper output to a Tally 120 puncher or to a IBM 1130 computer.

When the digitizing of all samples has been accomplished the output process starts automatically. The demultiplex counter will now function as an output sequencer. The contents of the FF-registers are gated one at a time to a scaler and code converter module (complement -2 to BCD). After the code has been converted a serializer feeding a Tally 120 puncher will be triggered.

When the contents of all FF-registers in use have been punched, a new sample of the input signals can be taken.

With the puncher connected the sampling-rate will be determined by the punching speed and the number of channels in use. When ten channels in use the maximum possible sampling-rate will be 2 Hz for each channel. In combination with the IBM 1130 computer the sample-rate depends on the conversion time of the A/D converter. In this case a 35 kHz sampling frequency can be reached in the one-channel mode.

Short specifications

D/A converter "Redcor 610"

coding speed (15 bits) 1,5 μsec/bit

coding linearity ± 1/2 least sign.bit

bipolair operation ± 10Volt

füll scale accuracy ± 0,01 %

10 channel multiplexer Redcor 770-730

accuracy ± 0.01 % FSR

cross talk ± 0,01 % FSR

settling time 2 μsec

Sample and hold Redcor 770-715

accuracy ± 0,01 %

hold decay 1 mV/10 ms

input imp. 10 meg. at 1 kHz

aperture time 50 ns

settling time 5 μsec

freq. response DC-50 kHz

output level ± 10 Volt

Digital controlled multi-character XY-photo-table - F. van 't Hof

The XY-photo-table is used for automatically producing photographic negatives from papertape. With the aid of these negatives printed circuits and thick- and thin-film circuits are produced. The usual technique consisting of tape-sticking on a sheet of paper and reducing the picture so obtained is tedious and time-consuming. Automation of this process is desirable. This is realized as follows:

First the information about the circuit that has to be constructed is interactively fed into a digital computer by means of a graphical input device. The computer produces a papertape for control of the XY-photo-table.

The set up consists of three parts:

1. Control unit.
   This unit contains a papertape reader and decodes the papertape information into control signals for the XY-table and its projection unit.

2. XY-table.
   The table contains of photo-cassette which can be moved by means of stepping motors (48 steps = 0,1") in the X- or Y-direction or under a 45^{o} slope if both motors are active.

3. Projection unit.
   This unit consists of four parts:
   a. a light source to which the cassette can be exposed.
   b. a shutter placed between lamp and cassette.
   c. a revolving character disk placed directly under the shutter.
   d. a system of lenses which projects one of the characters of the character disk on the cassette.

The character disk contains alphanumeric-characters and special symbols such as squares and dots for soldering points.
A line can be drawn by projection of a dot while moving the cassette in a appropriate direction.

Generation of random sequences having specified correlation and distribution

P.Verloren

The aim of this research is to investigate the practical feasibility of an algorithm due to Broste (1971) for generation of sequences of random numbers having a specified autocorrelation function (acf) and a specified probability density function (pdf). Applications of the algorithm are generation of test signals for fatigue testing and generation of special processes for Monte Carlo simulations.

The algorithm may be summarized as follows. The specified pdf is realized by passing a normal process through a memoryless nonlinear device. The nonlinear characteristic of this device follows from the specified pdf at its output and the normal pdf at its input. Since the input is normal the relation between the acf of the output and the acf of the input is established by Price's theorem. See Price (1958). The acf of the output is the specified acf. Thus with the aid of Price's theorem the acf at the input of the nonlinear device can be computed from the specified acf at the output once this input acf has been calculated. A normal process with this acf is realized by passing a normal white process through an appropriate linear dynamical system.

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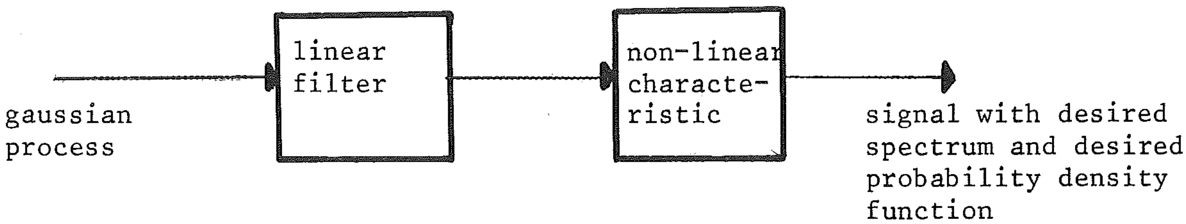


A noise generator with arbitrary probability density function and arbitrary power density spectrum - A.C.Mieog

A noise generator is developed which produces an input signal for an electro-hydraulic test bench. The required properties of this test signal are:

- The first derivative of the signal has to be constant. This is to use the test bench in an optimum way (maximum velocity) to make the experiments (fatigue) as short as possible (experiments take several weeks).
- An arbitrary spectrum. Anyhow a flat spectrum and a spectrum containing one or two peaks.
- A rectangular and a triangular (symmetric and asymmetric) probability distribution function.

The basic generator is a maximum length feedback shift register. This signal is fed into a shift register and an analog-to-digital converter. This forms together a digital filter. The signal out of this filter is multi-level and keeps its value between two clock pulses. This signal is converted into a signal with a constant positive or negative slope and a duration proportional to the difference in amplitude of two succeeding levels of the multi-level signal. It is possible to derive some relations between the weight factors in the digital filter and the frequency spectrum and amplitude density of the output signal.

An alternative approach is to start with gaussian noise (or pseudo-noise) and to use a function generator (diode characteristic) for the desired amplitude density. Calculate for the then given non-linear characteristic of the function generator with the theorem of Price the relation between input auto-correlation function and output auto-correlation function. Derive thus the desired input spectrum and realize this with linear filtering (preservation of gaussian properties).

Estimation of Parameters of Linear Systems Using Periodic Test Signals

A. van den Bos

This research deals with estimation of parameters of linear systems from noisy responses to periodic test signals. The parameters are the coefficients of the differential equation and the time delay. A computationally simple, consistent estimator for the system coefficients has been derived. Time delay is estimated by repeating the procedure and comparing the goodness of fit.

Most estimators of coefficients of differential or difference equations are implicit and require relatively complicated recursive algorithms. The estimator proposed here is explicit and involves solution of a set of linear equations only. As a consequence the algorithm is fast and convergence problems are avoided.

The elements of the covariance matrix of the estimator are functions of the spectrum of the test signal, the spectrum of the noise and the system parameters. So for given system and noise characteristics this covariance matrix can be manipulated by selection of the input spectrum. In this way spectra have been computed, which minimize the generalized variance of the estimator, i.e. the determinant of its covariance matrix. The aim is to establish general rules with respect to selection of the input spectrum.

On-line Correlator and Fourier Analyzer - B.Veltman

The principal advantage of a polarity-coincidence correlator is the simplicity of its hardware (delay by means of a one-bit shift register; multiplication by means of a coincidence gate; counting instead of integration). On the other hand the relation between the true correlation function and the polarity correlation function is not always known. This difficulty can be circumvented by adding certain auxiliary signals to the correlator inputs before clipping. In that case the output of the polarity correlator equals the relay correlation function or the true-correlation function.

For a broad class of two-dimensional probability density functions the relay correlation function is proportional to the true correlation functions (the requirements to be met are given by Nuttall's theorem).

The demonstration comprises the measurement of the autocorrelation of a sinusoïdal signal. The polairy-correlation function is a periodic triangle. After addition of the auxiliary signal the true correlation function is obtained. The true correlation function of a sinusoïdal signal is cosine-shaped. As opposed to a triangle a cosine has no higher harmonics. So in the power-density spectrum the higher harmonics will disappear after introduction of the auxilairy signal. The on-line Fourier analyzer is hybrid. The required sine and cosine functions are realized by varying the input resistances of the operational amplifier integrators.

For each frequency point of the power density spectrum the Fourier analyzer scans the output of the correlator, multiplies by sine and cosine and integrates.

Somewhat at the expense of frequency resolution filter side-lobes can be suppressed by multiplication of the correlation function by an appropriate window.

A timecompressor/correlator - S.H.Fakkel

With the computation of auto- and crosscorrelation functions of low frequency signals (0 to 6 kHz) it is convenient to use a time compressor for collecting the signals samples first and for rapidly computing the correlation function immediately afterwards.

Acoustical delay lines are used for the sequential memory in the timecompressor. They are very economic ($ 250.- for 16.000 bits) although to-day MOS-registers become competitive. They work at a clock frequency of 1,6 MHz, this implies that the content of the memory repeats itself every 10 msec. So every 10 msec (or multiple of this value) one or more signal samples can be read from a buffer into a line.

The instrument contains two parallel delay lines for both signals to be correlated. If only the polarity of the signals is recorded the correlator measures the polarity correlation function addition one auxiliary signal during recording produces the relay correlation function. With two auxiliary signals the undistorted correlation function is obtained. In all these cases the signals are represented by one bit samples!

After recording the correlation procedure starts by adding one extra delay element in one of the lines, this causes a measuring time shift with every signal repetition. Coinciding polarities are counted and converted into analog voltages for display. Up to 1000 time shifts as well in positive as in negative direction are calculated in 20 seconds (100 points per second over 16.000 signal samples).

A maximum length sequence generator with preset time shifts - S.H.Fakkel

For research in acoustical spaces it is desirable to have a wide band testsignal (0-10 kHz) for measurement of the dynamic responses and due to long reverberation times it is necessary to have a time shifted replica of this testsignal for very long time delays (up to 2.5 seconds).

By using two identical maximum length sequence generators (pseudo random noise generators), and inhibiting the clock pulse in one of these generators long time shifts in the testsignal can be obtained.

A serious drawback is that the amount of time shift is no longer controlled after reaching the preset shift. With long lasting measurements it is therefore uncertain whether the actual time shift (many thousands of clock pulses) is the same as the desired one.

To overcome this a second pair of maximum length sequences is added, this pair runs at maximum clock pulse frequency. With every repetition of the sequence of this fast running pair it is possible to set them again at the desired time shift. Once per repetition of the fast pair the slower pair (used in the experiment) is verified to be in accordance with the desired shift present in the fast pair.

Synchronisation pulses for every complete repetition of the testsignal and the possibility for an automatic shift over 1,2,4,8,05,16 pulses per repetition of the testsignal make this generator very convenient for crosscorrelation measurements in acoustics.

A demonstration shows the application of this automatic shift with echo experiments.

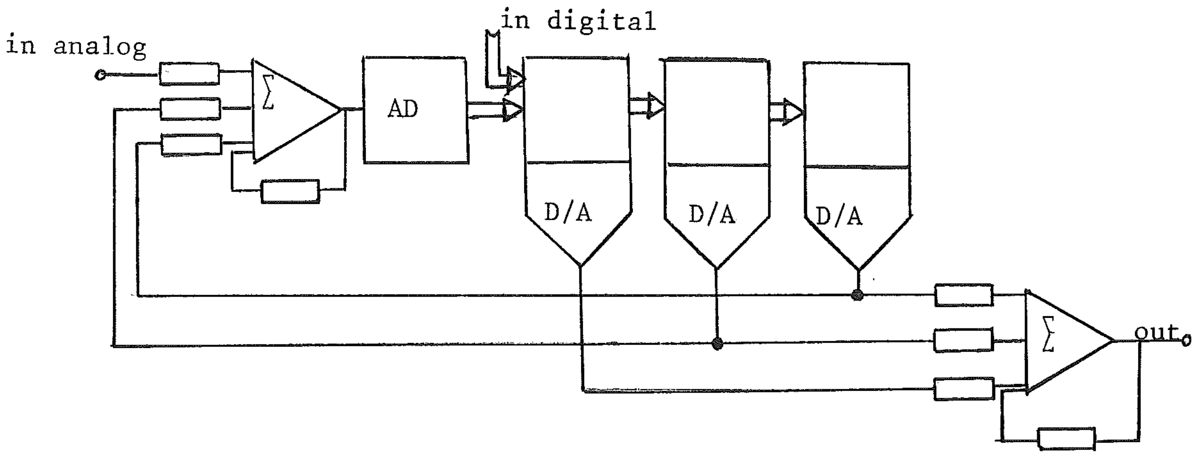
Position detecting by measuring transit times of noise - A.C.Mieog

The position of a shipmodel somewhere on a water surface has to be detected. Therefore a spark which emits acoustical energy is mounted on the ship. The noise emitted by the spark is received by three microphones placed along the water. The pulses are emitted at the positive flank of a maximum-length binary sequence (MLBS). After the microphones the pulses are reshaped according to the clockpuls duration of the MLBS. Crosscorrelation of the original MLBS and the lengthened pulses of one of the microphones produces a correlation function which is approximately the derivate of the correlation function of the original MLBS and a time shifted version of the same MLBS. From the position of the zerocrossing of the "derivate" the transit time of the noise between the emission of the spark and the reception by the microphones can be calculated.

Correlation is done by a one point polarity correlator in a feedback configuration. After a searching procedure the analog voltage which represents the correlation function controls (after inversion) a voltage controlled oscillator which generates the shift pulses for the delay shift register shift register. The analog voltage is positive if the zerocrossing is located to the right of the lag value for which the correlation is computed. After inversion this results in a decreasing shift pulse frequency. Consequently the zerocrossing shifts to the left. Similarly the zerocrossing shifts to the right if it is located to the left of the correlation point. In this way the measured point always corresponds to the location of the zerocrossing. The lag value of the zerocrossing is inversely proportional to the input of the voltage controlled oscillator. If in this way the transit times of the noise between the spark and the three microphones is computed (this takes three correlators), and if we presume that the Mach-velocity is known and that the positions of the microphones is given, then we are able to calculate the position of the shipmodel. The response of the feedback system has to be fast in order to follow the ship when it is moving. This demands a careful design of the controllersetting.

A digital filter in hybrid implementation - J.A.Carp

The expensive items of a digital filter, the coefficient registers and the multipliers-summators, are circumvented in a hydrid design. The digital signal registers are connected to DA converters and coefficient multiplication is attained with resitor networks and operational amplifiers. The properties of the filter depend upon the ratio of these resistors and not on their absolute value. It is well possible to design thick film resistor networks in any configuration with an accuracy of 10^{-4}. The temperature coefficient of such resistors are very equal. So the accuracy and flexibility in time scale of a digital filter is maintained, while the circuit is less complicated than a pure digital one. The design is based on two-pole and two-zero networks. Higher order filters are formed by series of this basic type.
The filter can be used for more than one signal if extra registers are added.
It is also possible to use this filter for performing many "recyclings" of the signal trough the same filter.
In order to study the quantization effects the AD converter has a variable quantization scale (from 1-12 bits).



Applications are ultra low frequency filtering and interpolation filtering of digital input signals.

Computer aided design of printed circuit lay-outs - W.P. Schlotter

In spite of the promises thick-film techniques hold for the production of interconnection patterns for electronic circuits, there will stay a need for common printed circuits. These prints have the advantages of being easily drilled (which means that any component can be connected) and of being easily corrected later on e.g. by scratching away a copper track. A design method, which still needs human ingenuity to avoid crossing wires, however at a more modest level and less time consuming, is realised. The lay-out in which no crossing wires are allowed is fed into the computer by means of a graphical input device. It may be roughly drawn and repetitions of certain parts of the circuit may be left out. A number of standard lay-outs are be available on disk memory.

The computer delivers a paper tape for a numerically controlled X-Y table with a projection head. This table produces a photographic negative of the proper size.

An extension of this method with a higher degree of automation is now being developed. The scheme of the circuit is fed into the computer. The functions or components are either identified by means of a table of standard components or, if it concerns a new type, defined at that moment. The points to be connected are given in pairs.
The computer displays the components as points and the connections between them as straight lines on a display unit. The designer then shifts the components until a satisfying distribution of connections is obtained. (The selection of the position of components can also be optimized due to certain criteria). The computer then generates the connections avoiding crossings and without through-plating For these calculations a modified Lee-algorithm is used. Connections left over because they cannot be realised on one side of the board, have to be applied manually after presentation of the solution offered by the computer.

An economic and accurate XY-tablet and stylus for the digital conversion of graphical data - F. van 't Hof

An XY-tablet and a freely movable stylus are demonstrated which enable a digital conversion of indicated positions. The apparatus can be used as an input device for computer processing of drawings such as UV recordings or for the input of data for the design of printed circuit layouts.

The novelties in this instrument are the accurate interpolation procedure for obtaining a high resolution with a simple tablet construction and the independency of paper thickness and stylus attitude.

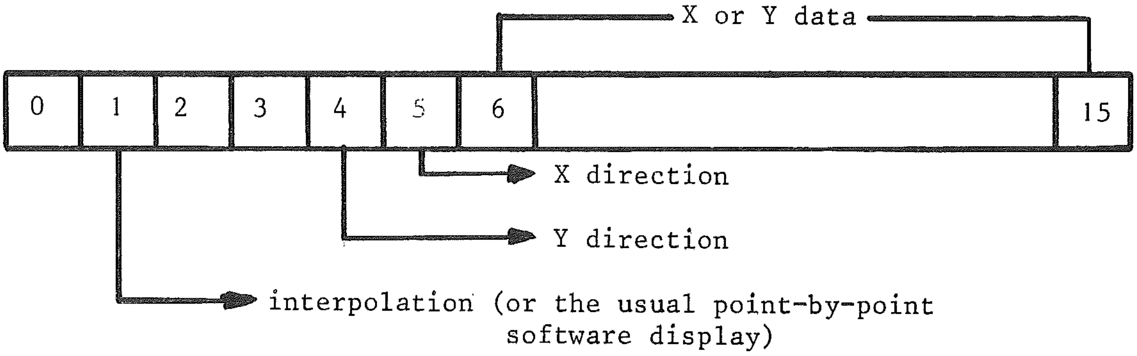
One of the tablets measures 24 in. x 16 in.; it has 240 horizontal and 160 vertical isolated wires at 0,1 in. distance. A system of scanning pulses through the wires converts the position measurement into a time shift measurement. The occurrence of a pulse at the indicated position in the grid is measured by a capacitive pick-up, and compared to a clock frequency.

A 90^{o} phase shift between pulses on neighbouring wires allows an interpolation of the stylus position between two wires. In this way 0.01 in. can be distinguished; the measuring density is then 10.000 points in^{-2}. The scanning speed is 100 in. ms^{-1}, sequentially along the x- and y-wires.

The combination of analogue and digital techniques allows an inexpensive construction.

Interface for a storage display unit - W.Smaal

For interactive work with the IBM 1130 it is required to change a picture quickly. With the use of a storage display unit and obtaining data point-by-point from the computer (cycle-steal) it takes about 25 seconds to fill the screen at maximum resolution. By using an interpolator this speed can be increased; moreover less data points have to be stored in the computer. In that case the chang of pictures do not take more than 1 second. With an external interpolator the speed is no longer limited by the computer but by the DA conversion and the dot writing time of the oscilloscope (6 μs alltogether).
The interpolator needs three words from the computer, one for the X direction and startposition, one for the Y direction and startposition and one for the length of the line and its angle with the horizon.
All registers are up-down counters which are brought to zero by the dot writing pulses.



The DA convertors are 10 bit. The diameter of the generated points is 0,27 mm.

Electrical properties of a thick-film interconnection-pattern for an electronic circuit, phase I - P.E.Schansman

Thick-film techniques have enabled the automation of the design of interconnection-patterns for electronic circuits, the computer produces papertape for a papertape-controlled phototable in order to make photo-negatives. Data of the circuit are put into the computer with the help of a graphical inputdevice.

The thick-film circuit consists of 2 conductor-layers and 1 insulation-layer in between. The photo-negatives are necessary to make three screens through which a Pd/Ag conductor paste and an insulator paste is printed upon a ceramic substrate of 4"x4" in the following order:

1st layer

Contains all horizontal conductor paths (width 10 mil, interspace 10 mil, resistance 2,5Ω per inch), including four "lanes" (width 0,25", interspace 0,4", resistance 0,25Ω per inch) for the supply voltage; also the in-and output lines that lead to the connector.

2nd layer

This is the insulation layer in which are situated the 0,015"x0,015" sqaure holes, which will be filled with conductor paste when the 3rd layer is printed, and serve as through-connections.

3rd layer

Contains a vertical conductor paths and the standardised layouts for the Texas Instruments TTL integrated circuits (Dual inline) which are positioned in two horizontal lines of 7 IC's along two opposite edges of the substrate.

The layers are dried (150°C) and backed (900°C) in an oven. It took 5 hours to produce the screens, printing and soldering the components on the substrate.

The result of the thick-film print is a crossover capacitance between two conductors paths of 1pF. And 1nF has been found as an estimated tolerable value which did not cause false triggering of a gate. This means 1 conductor path can tolerate 1000 crossovers.

As for the resistance of the conductor paths, it could give trouble in a wordt-case situation with a max Fan-Out of 30 causing too high a voltage drop, but using a different paste with lower resistance can solve this problem.

The test-circuit is a Maximum length sequence generator with one of the conductor paths with 160 crossovers. The MLS generator functioned quite satisfactory at a frequency of 10 MHz.

Computer aided design of interconnection patterns,phase II- A.F.Baldinger

The computer aided design of thick-film layouts is improved by some additional programs:

- substrates in Europrint size may contain two rows of 14 dual inlines. Double sided substrates with special connectors allow the design of function with 56 dual inlines. By-pass capacitors for each dual-in-line.
- dynamic connecting zones are introduced for connections within rows, between rows, within dual in lines components and between dual in lines components.
- interactive redesign on oscilloscope display by changing position of components,

  deleting components
  adding components
  deleting connections between components
  adding connections between components
  deleting connector connections
  adding connector connections
- verification of open connecting pins,
  of fan out
  and of boolean algebra relation are made by appropriate listings.
- bibliography of circuits is extended. Medium and large scale components are allowed.

Improved address organisation of the cycle-steal interface - B.de Priester

Data transfer with a cycle-steal channel to or from the 1130 core memory occurs in a 3,6 μs "stolen cycle", for each 16-bit word, during which the 1130 CPU is stopped. This transfer bypasses the CPU and the cycle-steal channel has to present a 13-bit address with each data word. This is the address in core memory where the transferred word has to be fetched or stored. In the user program an array is specified, of which the begin address and the word count(array length) has to be known to the interface. The interface cycle-steal gets this information during the initiation phase by execution of an instruction XIO Initiate Read or Initiate Write. Two CPU cycles and one "initiate cycle-steal" are used to transfer the channel number, channel function, begin address and word count to memory registers of the concerned cycle-steal channel. Each of the four channels now gets a begin address memory, a word count memory and a displacement counter.
In each cycle-steal the channel displacement counter is incremented by one. Displacement is equivalent to subscript number in the array.
The address for the next cycle-steal has to be stable before this cycle-steal and is written into the central Address Input Buffer register.
For each cycle-steal the concerned displacement counter (DC) is chosen by a multiplexer and is subtracted in a single 13-bit subtractor from the selected Begin Address Memory (BA) output. The result is the address A = BA - DC. In the same time the multiplexer output DC is presented to both of two 13 bit comparators, which receive at the other input the selected Word Count Memory (WC) output. One of the comparator connections is shifted one bit, so that here the DC is compared with WC/2. Thus we get comparator signals if the array if half transferred (WC/2) and fully transferred (WC). These signals switch Status Bits in the Device Status Word, which normally result in an Interrupt Request to the 1130.

Two channels have the possibility of external address generation. In this case the displacement is presented externally (ED) via the channel connector to a displacement register and this will be selected at cycle-steal instead of the displacement counter. Now the address A = BA - ED. The multiplexer output ED is compared with the selected Word Count and the comparator will give a signal if ED>WC, which means that the address would be outside the defined array. Such an address will not be written into the Address Input Buffer, so that we will have a corememory protect feature with external addressing.

The complete circuit has been built on thick film multilayer substrate made at the Microcircuits Group. The four displacement counters and the 8-part multiplexer are built on two 4x4" substrates, with 3 conductor and 2 isolator layers. The eight memories and two comparators are located on a 4x4" substrate with 5 layers plus a layer with 32 thick film resistors.
The substractor finds itself on a 2x4" 3 layer substrate.
The thick film substrates are mounted on two 9x6" epoxy printed circuits with commercial connector edges attached, to connect in the interface slots.

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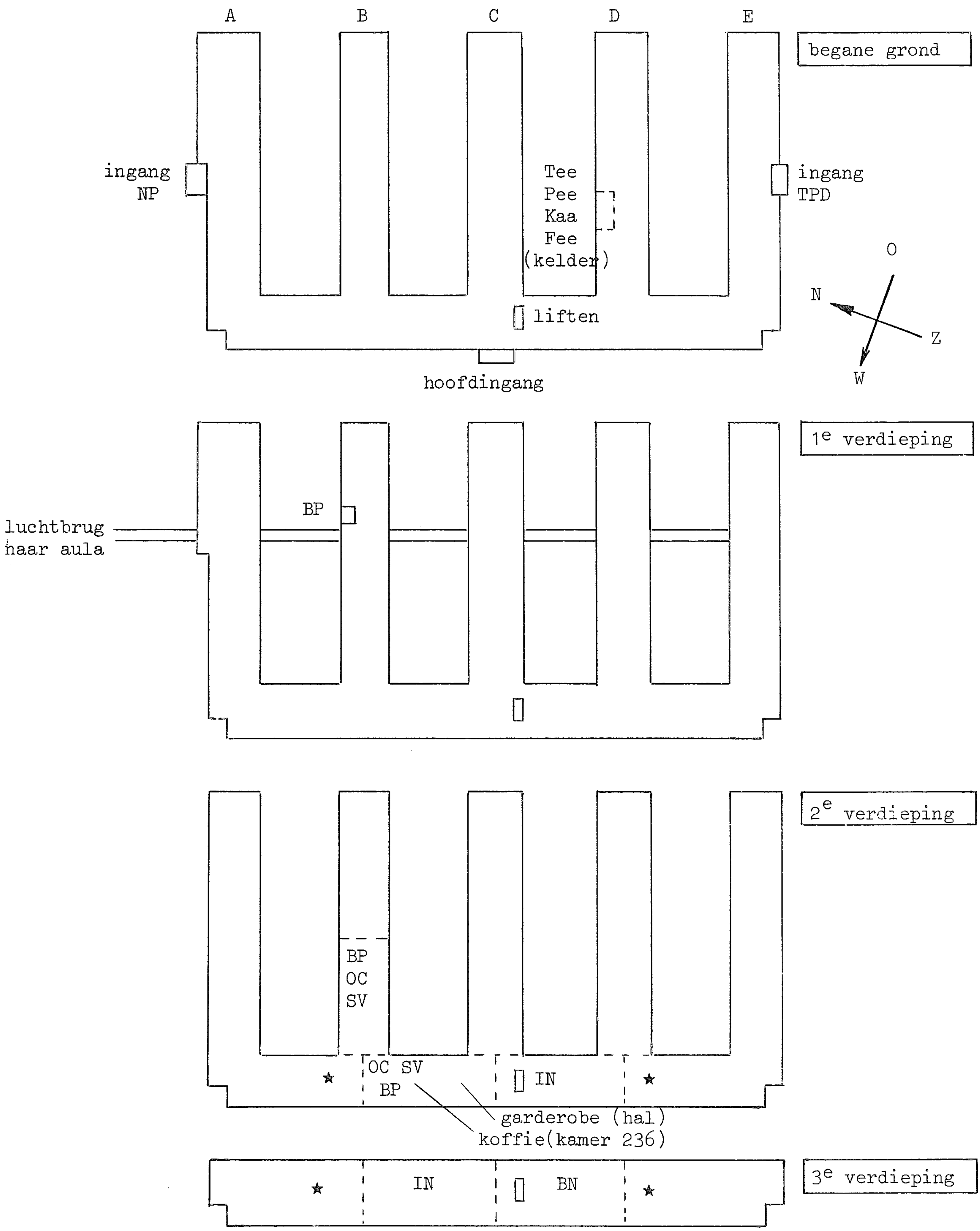

De letters A t/m E geven de vleugels aan.
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AFDELING DER TECHNISCHE NATUURKUNDE

A THREE TERM SAMPLED DATA CONTROLLER FOR USE IN HIGH SPEED ELECTRONIC ANALOG SIMULATION

Prof.ir. O. Rademaker
J.W. van Drie / Ir. G. Dekker

- maart 1966 -

THE SIMULATION OF A THREE-TERM SAMPLED DATA CONTROLLER

Introduction

To enable the study of sampled-data control systems with the high-speed repetitive simulator described in the preceding parts, a sampling controller was developed. In this article, we shall first define the functions of this controller and consider the requirements that have to be satisfied. Then we shall discuss the block diagram that we found to be most effective. Finally, some attention is paid to the most important electronic circuits and a few typical results are shown.

Functions and requirements

The controller implements the following functions (see also Fig. 1):

a. sampling
b. proportional action
c. integral action
d. difference action

The function of the sampler is to relay the signal value at the sampling moments $t = nT$ for a very short time interval p. The sampling period T is continuously adjustable between 100 and 3300 μsec; the sample duration (pulse width p) is 10 μsec.

The function of the proportional action is to provide a contribution proportional to the signal value at the last sampling moment:

$$V_p(t) = K.\ V_i(nT) \text{ for } nT < t < (n + 1)T.$$

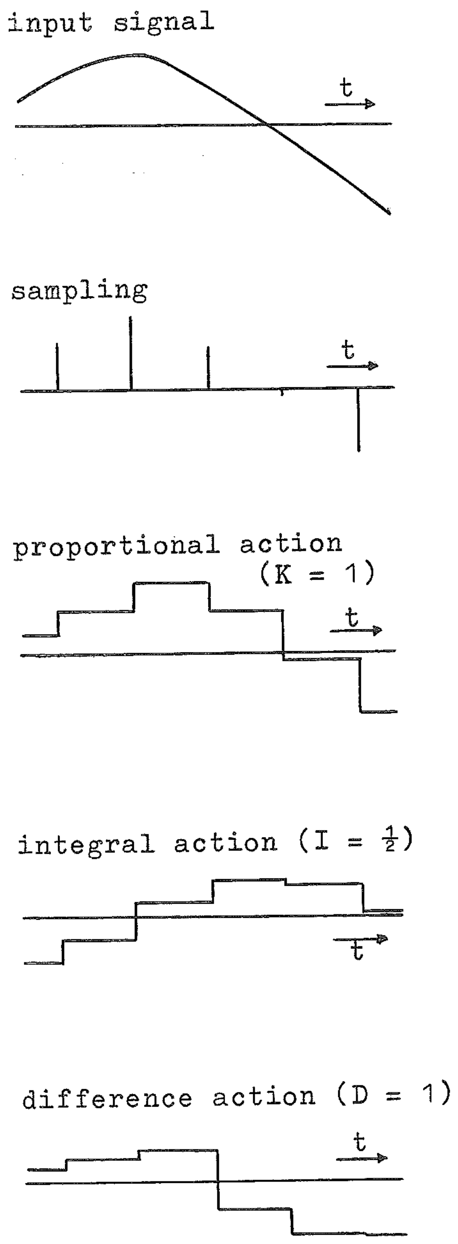


Fig. 1 Controller functions

This is accomplished by a zero-order hold circuit.

The contribution of the integral action to the controller output signal is proportional to the sum of all preceding sample values:

$$V_I(t) = I_o \sum_{K=-\infty}^{\infty} V_i(kT) \quad \text{for} \quad nT < t < (n+1)T.$$

This is accomplished by integration of the sampled input signal (As a consequence, I depends on the sample duration p).

The function of the difference action is to add a contribution proportional to the difference between the last sample and its predecessor:

$$V_D(t) = D \left[V_i \left\{ nT \right\} - V_i \left\{ (n-1)T \right\} \right] \quad \text{for} \quad nT < t < (n+1)T.$$

If D were made equal to 1/T, the resulting expression would be a difference quotient approaching the time derivative dV_i/dt for $T \rightarrow o$.

The controller is made-up of two standard-size units, the controller unit which produces the individual contributions as voltageson separate output terminals, and a conventional summing amplifier with adjustable weighting factors. The signals produced by the first unit have fixed coefficient values: $K = 1$, $I = 1/\sqrt{10}$ and $D = 1$; adjustments in steps of $\pm$ 1 dB are made possible by the summing unit.

The principal requirements are that the controller unit must operate in the voltage range of the simulator (i.e. between $\pm$ 25 V) with an accuracy in the order of 0,25 V, and the sampling period T must be compatible with the simulation time scale. The latter requirement is subjected to two contraints, the maximum computing time on the one hand and the minimum sample duration on the other hand. On the one hand, the sampling period should be so small, that the simulator responses can be largely completed within 8 msec. Longer computation runs are possible with external excitation, but then the simulator is only just as convenient as any other analog computer and the time scale ranges of the individual units (time constants between 10 μsec and 10 msec and dead times between 10 μsec and 1 msec) may also be less convenient. On the other hand, the integration constant I depends upon the sample duration p and the time constant of the integrator. To obtain a reasonable value of I, p should be 10 microseconds.

The sampling and hold circuits can easily be made fast enough.

The best compromise was achieved when using this sample duration in conjunction with a sampling period continuously adjustable between 100 and 3300 μsec. The lowest sampling rate is employed when only few samples are required to complete the response; at the highest sampling rate the responses may last more than 80 sampling periods. When designing the controller we felt that if so many samples were really needed, the responses would be hardly different from those under continuous control. Consequently, neither the lower, nor the upper limit of the sampling period would impose an essential limitation. This was confirmed by an extractive study of the performance of sampling control systems, in which hundreds of processes were investigated and only minor time-scaling difficulties were encountered.

Structure of the controller unit

The controller unit consists of two parts, the clock unit that provides the driving signal for the various switching circuits and the computing part. At first thought, one might arrange the computing part as shown in Figure 2a, but the block diagram in Figure 2b was found to be more convenient.

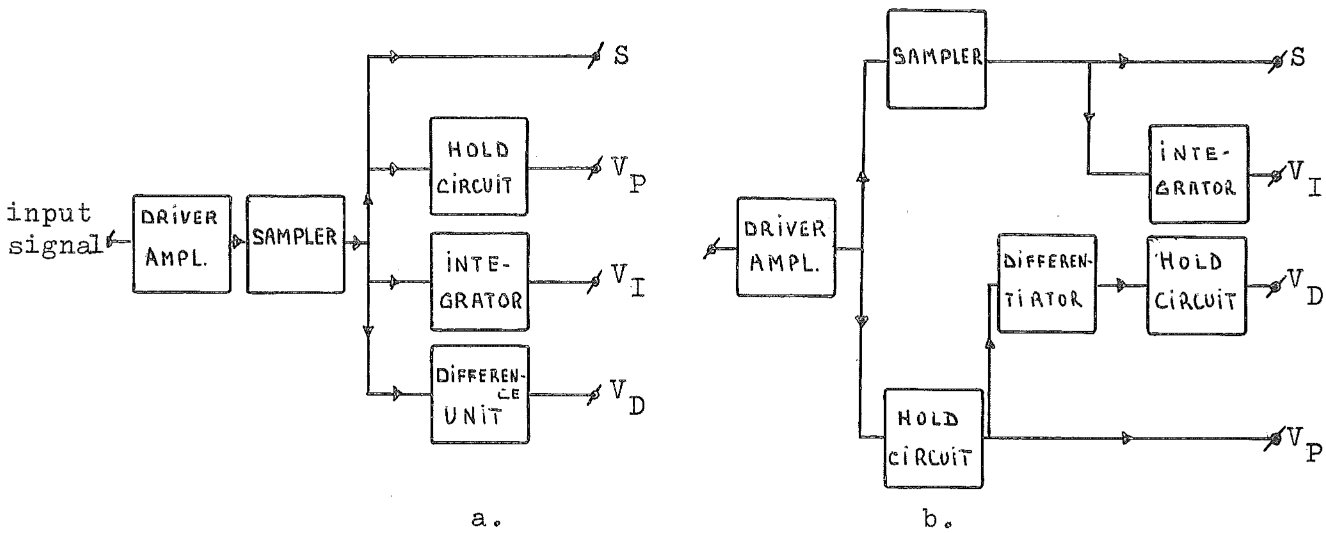


Figure 2. Two possible controller set-ups

This is partly because it is easier to make a sample-hold circuit operating on a continuous signal than a hold circuit that must operate on a pulse signal, but mainly because the output signal of a sample-hold circuit is more suitable for deriving a difference signal.

Circuitry

The controller circuit diagram is shown in Figure 14.

Principal elements of the computing part are samplers and hold circuits. A transistor, conducting when an impuls is applied between base and emitter, can be employed as a switch (see Fig. 3).

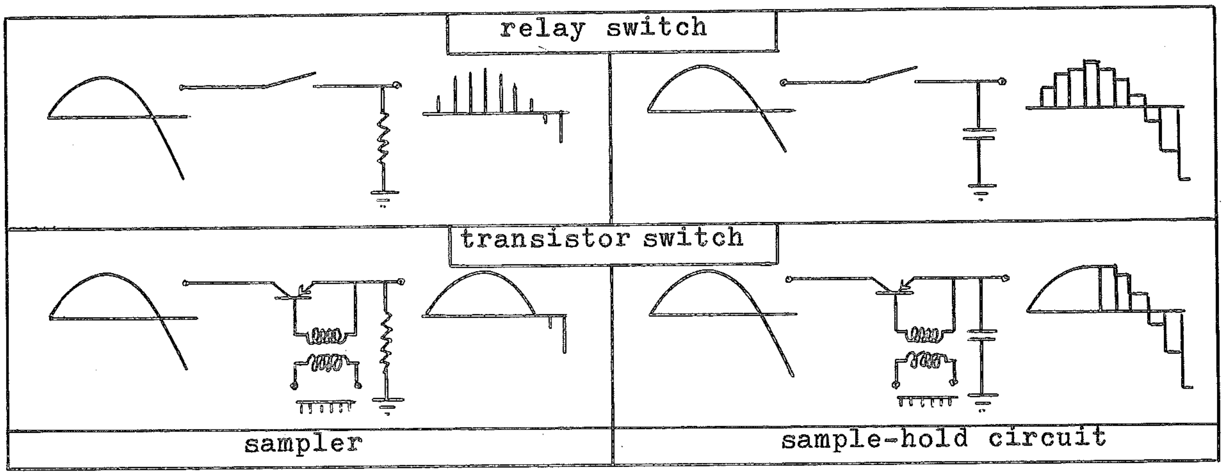
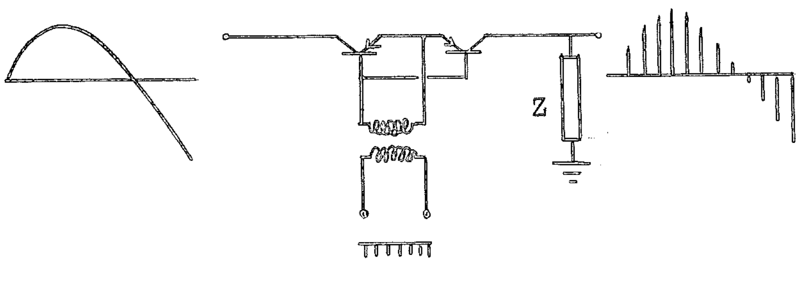


Figure 3. Sampler and sample-hold circuit

Such a switch passes positive input signals unchanged and samples negative input signals. The converse happens if collector and emitter connections are interchanged. If the input signal can have both polarities, both switch versions have to be used in series. Thus the circuit shown in Figure 4 is obtained.



sampler: Z = resistance
sample-hold: Z = capacitance

Figure 4. Bipolar electronic circuit

The hold circuit must have a switch with a very high isolation resistance and a read-out amplifier with an equally large input impedance. With silicon BCZ 11 transistors, an isolation resistance of 10,000 Mohms at 10 V can be obtained; using a cathode follower with the same or an even higher impedance and a capacitor of 1000 pF, a holding time constant of 5 seconds is realized. The read-in time of this hold circuit can be made less than 0.5 μsec. For the simple sampling circuit, the isolation resistance should also be high because this circuit is followed by an integrator, and any leakage will be integrated during the relatively large non-conducting time. The parasitic capacitances and the residual resistance of the conducting transistor should be small to ensure sufficient speed of operation. Therefore, silicon BSX 29 transistors are employed.

As mentioned before, the integral action is made simply by feeding the sampled signal into a conventional integration circuit. The result is:

$$V_I = \frac{p}{RC} \sum_{K=-\infty}^{\infty} V_i(kT), \quad RC = \text{ integrator time constant.}$$

A small error is introduced by the finite impulse width, V_I is rising from initial to final value from $t = nT$ to $t = nT + p$ instead of changing discontinuously at $t = nT$. The same error would be introduced by addition of the signal shown in Fig. 5 to the output of a perfect integrator.

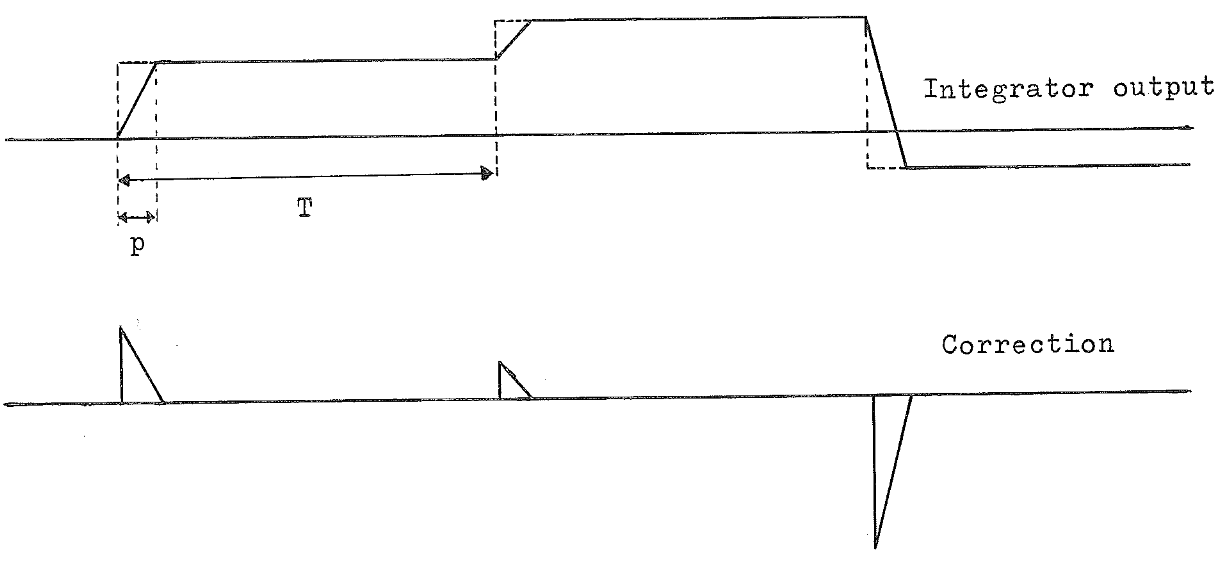


Figure 5. Integrator output signal and correction signal

It is easily verified whether such an error would affect the results of a particular simulation; as a rule, the error is completely negligible. Note that the integral action coefficient I (see eq. 2) corresponds to p/RC. This implies on the one hand that p must be accurately constant and on the other hand that p can be employed for precise adjustment of the value of I, provided the other actions are not affected by minor changes in p.

The difference action is realized by shaping and subsequent holding of the proportional action output signal V_p. The shaping filter (Fig. 6) is equivalent to a differentiator with two first order lags in series; its step response is shown in Fig. 7.

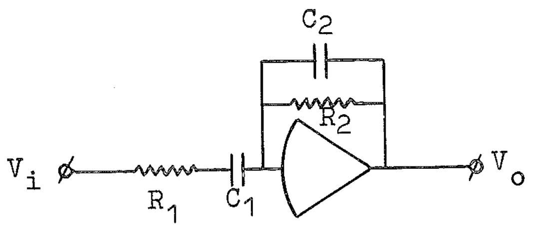


Fig. 6 Differentiator
$R_2C_1 = \tau_d$; $R_1C_1 = \tau_1$;
$R_2C_2 = \tau_2$.

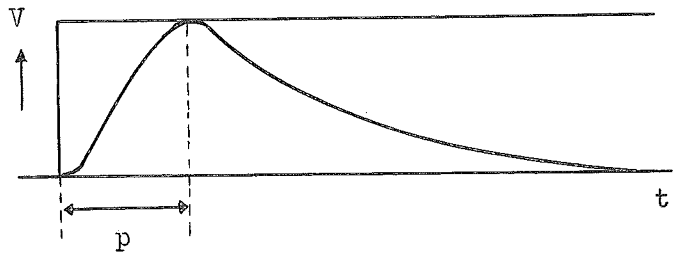


Fig. 7 Stepresponse of second order differentiator

Transfer function: $\frac{s\tau_d}{(1+\tau_1 s)(1+\tau_2 s)}$

The input signal of this filter is a series of steps occurring on the sample moments, of which it is desired to extract a signal proportional to the step sizes ΔV. Introducing for simplicity a new time scale t' starting at t = nT, we have

$$V_o(s) = \frac{\tau_d}{\tau_1 - \tau_2} \left\{ \frac{1}{s + \frac{1}{\tau_1}} - \frac{1}{s + \frac{1}{\tau_2}} \right\} \qquad \text{with} \quad \begin{array}{l} \tau_d = R_2C_1 \\ \tau_1 = R_1C_1 \\ \tau_2 = R_2C_2 \end{array}$$

and correspondingly:

$$V_o(t') = \frac{\tau_d}{\tau_1 - \tau_2} \left(e^{-t'/\tau_1} - e^{-t'/\tau_2}\right) . \Delta V,$$

which has a maximum value:

$$V_o(t'_m) = \frac{\tau_d}{\tau_2} e^{-t_m'/\tau_2} \cdot \Delta V,$$

at time:

$$tm' = \frac{\tau_1 \tau_2}{\tau_1 - \tau_2} (\ln\tau_1 - \ln\tau_2).$$

By choosing:

$\tau_1 = 33\mu sec$ $\tau_2 = 4\mu sec$* $\tau_d = 37\mu sec$

the maximum value is exactly equal to the step size and occurs just before the end of the sample duration. Hence the output hold circuit operating synchronously with the other units will maintain the proper output signal during the rest of the sampling period. Only during the transition interval p, an error occurs; its influence can be assessed as indicated for the integrator. As a rule, it is completely negligible. Note that the output signal is not critically dependent upon the precise value of p, so that minor changes to adjust the integration constant I are tolerable. The input current of the samplers during conduction time can be very high, so that an amplifier is needed to avoid excessive loading of the controller input signal. This amplifier is made to saturate (by using Zener diodes OAZ 204) at about 22 V in order to protect the transistor switches.

The clock unit drives all transistor switches simultaneously by means of a periodic impulse signal, the repetition frequency being continuously variable between 300 c/s and 10 kc/s. The pulse width of about 10μsec is constant but adjustable and direct or delayed synchronization is possible. The signal driving the samplers and hold circuits is generated by a monostable flip-flop (driving flip-flop). As all transistor-switches have to be transformer coupled to the driving unit, the driving flip-flop is followed by an amplifier with a transformer output stage. The input stage of this amplifier serves as a zero level clipper.

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* including the effect of amplifier capacitance

The driving flip-flop is triggered by the impulses of a conventional blocking oscillator having three frequency ranges (0,3 - 1; 1 - 3 and 3 - 10 kc). Unfortunately, if a synchronization impulse arrives, the charge of the grid capacitor determining the repetition frequency is altered, so that the resulting period is slightly different from the preceding and following (unsynchronized) periods. To avoid this, the capacitor voltage is limited by a Zener diode.

The blocking oscillator can be used in two modes: the free running mode and the synchronized mode. In the free running mode, the sample sequence starts at random with respect to the simulator disturbance signal. In the synchronized mode, the blocking oscillator is synchronized by a signal derived from the simulator disturbance signal. Usually, the synchronization signal is an impulse at the beginning of the disturbance signal (direct synchronization). In many practical problems however, the sample pulse sequence does not necessarily start at the same moment as the disturbance signal. Therefore, it must be possible to delay the synchronization impulse. In this case (delayed synchronization) the blocking oscillator is synchronized by the positive slope of a delaying flip-flop output signal. This monostable flip-flop is then triggered by the disturbance signal. The pulse width of the flip-flop (and therefore also the synchronization delay) is continuously adjustable between 10μsec and 2 msec.

To prevent interference from blocking oscillator pulses of previous computing cycles, the driving flip-flop is not triggered directly, but through a gate that is closed while the delay flip-flop is activated (see Fig. 8). Hence no pulses can pass and no samples are taken while a synchronization signal is being delayed.

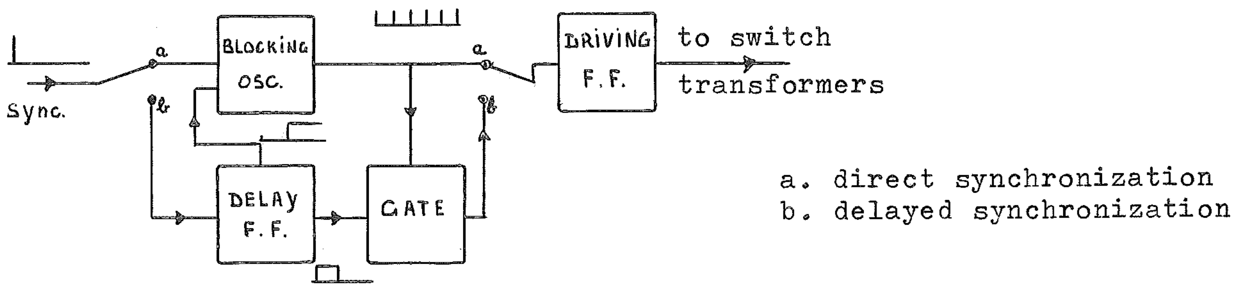


Figure 8. Delayed synchronization

The use of vacuum-tube circuits in the clock unit was preferred solely with a view to the available power supplies.

Illustrative results

Some typical results are shown in Figure 9 through 13. In Figure 9, 10 and 11, respectively, proportional, difference and integral action, signals are shown with the computer working in the normal mode (computing cycle 8 msec). The sample period is 1 msec, so that the ratio p/T is 0.01. In this case the influence of the sample duration is negligible. In Figure 12, the output signal of the shaping filter, the sampled signal and the difference signal are shown. The sample period is 200 μsec. Figure 13 shows integral action together with sampling action. In order to demonstrate the influence of finite sample duration, a very short sample period of 100 μsec was employed.

As the sample period is one of the performance parameters of a sample data system, it has to be constant. Since the sample period is directly determined by the (stable) blocking oscillator, it is possible to ensure a long term drift in the sample period T of less than 0.5 % without special precautions. Drift in the width of the sample pulses directly influences the integration constant I, so that the integrator output signal will drift accordingly. The long term integrator output drift was found to be less than 2 % (after a warm up of half an hour). Proportional and difference constants do not depend upon p or T, so that proportional and difference signals are drifting less than the integral signal. An accuracy of 1 % was easily realized.

Further work

The sampled-data controller, described in this article, has now been in daily use for more than a year. It has enabled us to make extensive studies of the performance of sampled data control systems. In view of the usefulness of frequency domain techniques in continuous systems, the question was raised whether such techniques are equally practical in simulating sampled data systems. For such purposes, an important requirement is that transfer functions can be measured simply and rapidly. The next article analyzes various methods of measuring transfer functions of sampled data systems.

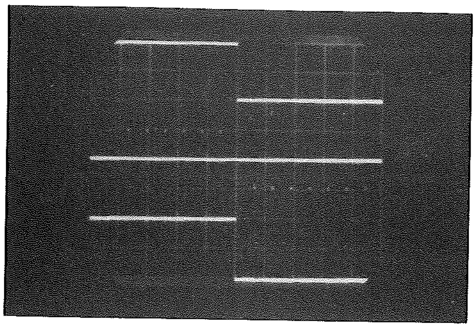


Fig. 9 Sample and sample hold action

u. disturbance signal
m. disturbance signal sampled
l. disturbance signal hold

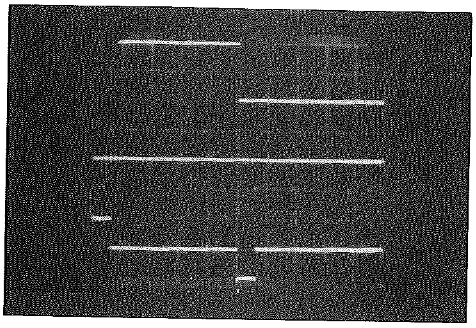


Fig. 10 Sample and difference action

u. disturbance signal
m. disturbance signal sampled
l. difference signal

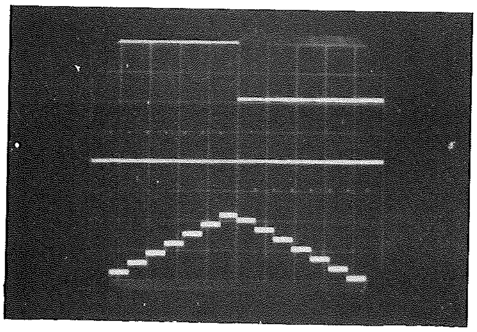


Fig. 11 Sample and integral action

u. disturbance signal
m. disturbance signal sampled
l. integral signal

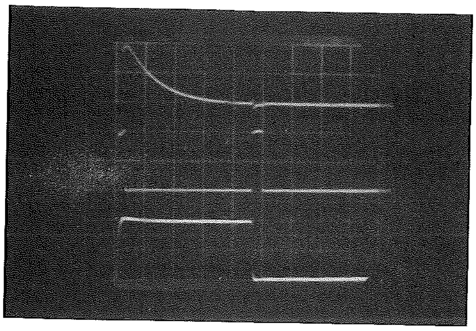


Fig. 12 Difference action (expanded time-axis)

u. second order differentiated hold signal
m. disturbance signal sampled
l. difference signal

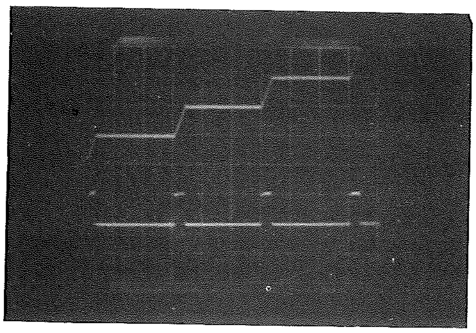


Fig. 13 Integral action (expanded time-axis)

u. integral of sampled step function
l. sampled step function

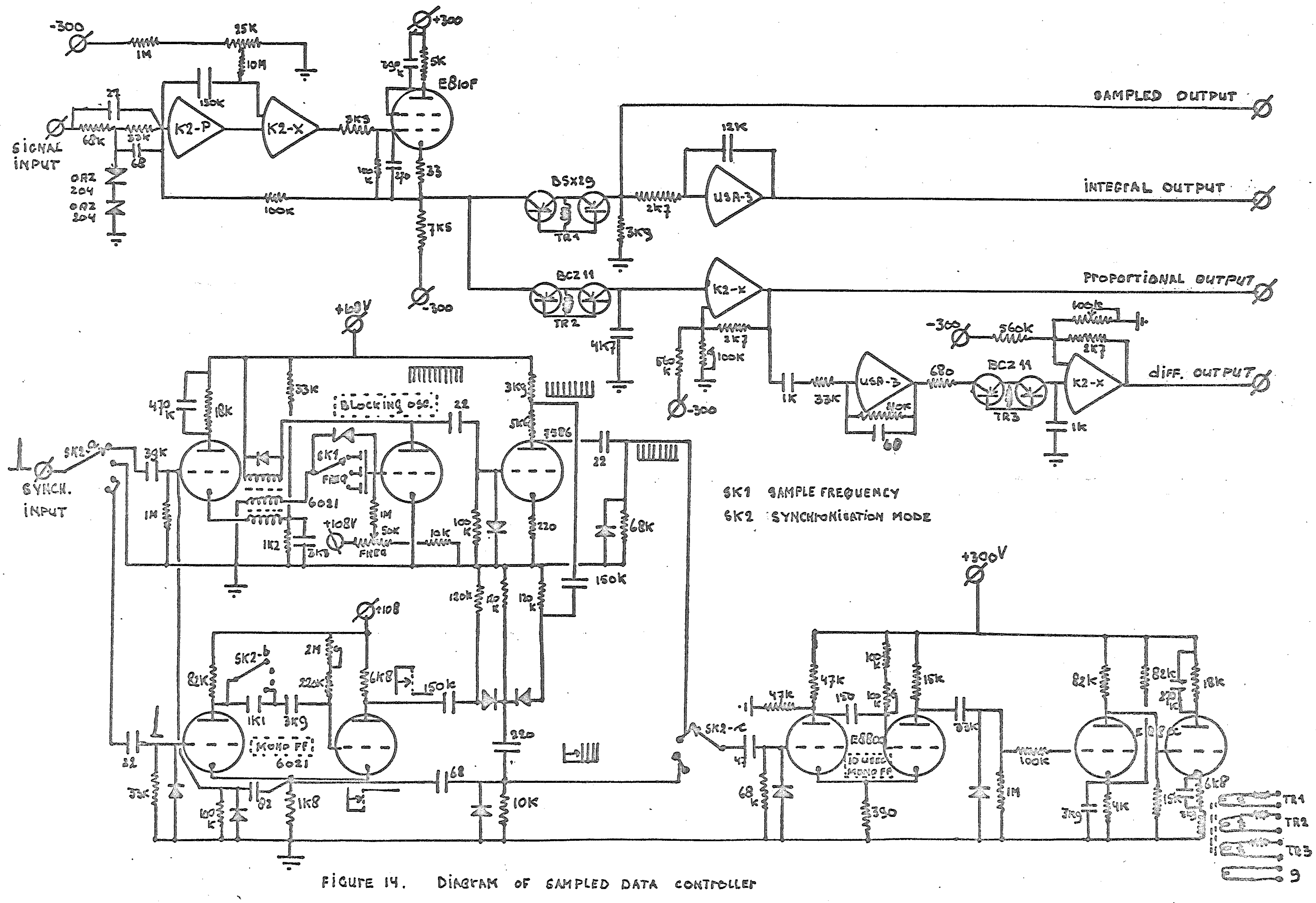


FIGURE 14. DIAGRAM OF SAMPLED DATA CONTROLLER

Inertial Techniques and Telemetry

Because of the very high degree of precision attainable in the manufacture of contemporary inertial sensors and the high accuracy of electronic integrators it makes sense to use inertial systems for relatively long term navigation purposes. On the other hand miniaturization of components opens up new application possiblities for inertial measurement and control techniques.

Our aim is to keep up with the advancements in this field and to seek and study new solutions and applications. A part of these activities are educational, a part research oriented. At the same time they put us into the position to advise others or to help them solve their measurement problems by the application of inertial methods where this may be expedient.

Telemetry is a concept covering a number of activities in various fields, and as such it defies concise definition. Our aim is simply to do occasional work in this field on limited problems carried to us by others.

The following survey of activities will serve to elucidate the abovementioned.

1. Inertial techniques

1.1. Educational and background activities.

Keeping up with the relevant literature;

Visiting exhibitions and symposia;

Studying the known more or less conventional inertial measuring and control systems in order to gain insight into the theory and application thereof.

These studies are mostly assigned to students. They frequently result in demonstration models, but also in reports. During the last years the emphasis has gradually shifted away from purely didactic subjects to more research oriented subjects.

Examples of work carried out:

Flight instruments	(demonstration setups)
Aircraft autopilots and stabilizers	(")
Schuler tuned pendulum	(demonstration model)
Gyros powered by rectangular line current	(report)
Strap down navigation system survey	(report)

Present subjects:

Electronic long duration integrators (report)
Small Foucault-pendulum with digital electronics (model)

Possible future subjects:

Digital integrating techniques for inertial sensors
Hybrid navigation and Kalman filtering

1.2. Research activities

Studying the usefulness of new principles and ideas, mainly of inertial sensors, but incidentally also of systems with inertial sensors. 90% of the work is given out as student assignments.

Subjects finished:

● Image stabilization in a TV-handcamera.
* Precession paths of gyro with torque compensation

Subjects being treated:

* Tuning forks as rate sensors.
Polygon laser as rate sensor
* Beat frequency processor for digital sensors
* Gyros with torque compensated Hooke's joints
* Stabilized acceleration-free test table

Possible future assignments:

Test and calibration setup with ultra precise rate gyro
* Ikonostat for cameras and field glasses
Vibrating string accelerometer
Ergonometric movement analysator

---

* publication considered or under preparation
● publication completed

1.3. Advices, assistance, contacts with others.

Mainly as a result of the activities mentioned under 1.1. we are able to discuss with others the feasability of certain inertial measuring methods. If desired and possible we then give assignments to students to build the necessary implements.

Services rendered:

Level control for draining pipe trencher (advice to article writer)
Measuring set for stability studies in automobiles (student assignment)

Present subjects:

Miniature accelerometer for handwriting analysis (student assignments)
Satellite experiment proposal for relativity theory check (discussions with a publicist-expert)
Precision rate of turn measurements on ships (advices, possibly future assistance)
Report exchange, mutual visits and research assistance (inertial hardware makers and users)

Future activities:

Who knows?

2. Telemetry and miscellany

No specific program. Occasional work is done upon request and following student interest.

Work finished:

A Wien-bridge analogue to digital convertor (student work)
A brushless DC tachogenerator (")

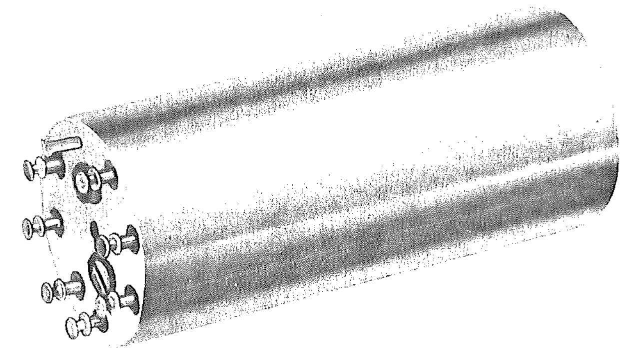
Work on hand:

Light beam telemetry link from reactor to control computer (300 meters) (student assignment)
Optimal control of ignition time of automobile engine. (student assignment)

A student is requested for:

Position stabilization of received light-spot of telecommunication link (3 km).

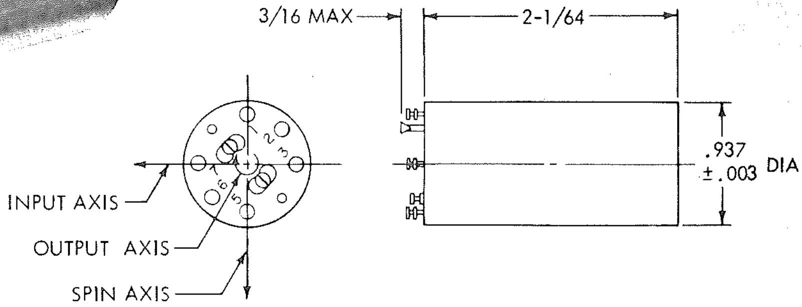
C. Huber
8 december 1970



RATE GYROSCOPE

DAMPING COMPENSATED

MODEL CD 000



TYPICAL OUTLINE

U. S. TIME RATE GYRO WITH VARIABLE-ORIFICE COMPENSATED DAMPER

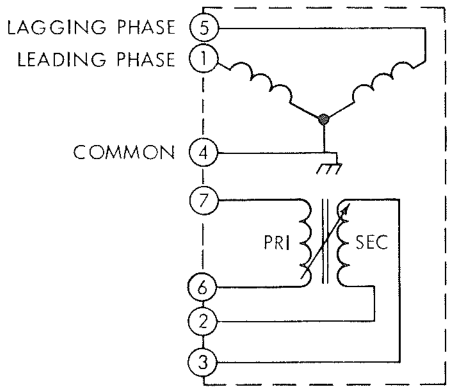
The major components of this instrument are: the gyroscopic element housed in a hermetically sealed cylindrical shell (gimbal) filled with an inert gas, the gimbal suspension, the gimbal position pickoff and the temperature-compensated damping mechanism. The gimbal shell and other components are contained in a cylindrical gyro case, and are immersed in the high viscosity silicone oil with which the case is filled.

The gyroscopic element is an inertia wheel driven by a synchronous hysteresis motor. The co-axial arrangement of gimbal shell and outer case provides a thin, fluid filled annular gap between these two elements, and achieves excellent damping of transverse shock and vibration inputs. Similarly the fluid between the end faces of the case and gimbal shell cylinders permits the gyro to tolerate high axial shock.

The gimbal suspension restricts the motion of the gimbal to rotation about the output axis and provides elastic restraint in this mode by means of a torsion bar attached to one end of the gimbal. A shaft extending from the other end is supported by a ball bearing.

The pickoff measuring the angular displacement of the gimbal is a rotary differential transformer producing an AC output voltage proportional to the angular rate input.

An outstanding feature of this gyro is the damper mechanism, which maintains the damping ratio substantially constant over a wide range of temperatures, as shown by the accompanying plot. Rotation of the gimbal forces silicone fluid to flow through variable-aperture orifices. The resulting energy dissipation provides the damping action. The resistance to the flow of fluid is determined by the effective aperture of the orifices which is controlled by temperature sensitive elements in such a manner as to compensate for the large changes in fluid viscosity with temperature.



SCHEMATIC DIAGRAM

NOTES:

1. With motor connections as shown, wheel rotates CW looking along spin axis.
2. For an angular rate input in the CW direction (looking along input axis), the gimbal rotation is CW (looking along output axis), and the voltages at pins 3 and 7 are nominally in phase (pins 2 and 6 joined).

CHARACTERISTIC	UNIT	VALUE					
MODEL NO.		CD-010	CD-040	CD-060	CD-100	CD-200	CD-400
Full Scale Input Range, nom.	deg/sec	10	40	60	100	200	400
Min. Detectable Rate	deg/sec	< 0.01	< 0.01	< 0.01	<0.01	< 0.01	< 0.01
Non-Linearity, max.							
To Half Scale	% of F.S.	±0.2	±0.1	±0.1	±0.1	±0.1	±0.1
To Full Scale	% of F.S.	±0.4	±2	±2	±2	±2	±2
Zero Offset at 20°C., max.	% of F.S.	0.2	0.05	0.05	0.05	0.05	0.05
Change of Zero Offset with temperature (from 20°C to either extreme of oper. temp.), max.							
a) Uncompensated	% of F.S.	0.5	0.14	0.14	0.14	0.14	0.14
b) Compensated*	% of F.S.	0.18	0.05	0.05	0.05	0.05	0.05
Mass Unbalance, max.	deg/sec/g	0.05	0.05	0.05	0.05	0.05	0.05
Hysteresis, max.	% of F.S.	0.15	0.15	0.15	0.15	0.15	0.15
Scale Factor, nom.	mv rms/deg/sec	140	140	93	56	28	14
Scale Factor Variation							
a) with temperature**	%/deg C	0.07	0.07	0.07	0.07	0.07	0.07
b) with motor supply frequency				Directly proportional			
c) with pickoff supply voltage				Directly proportional			
d) with pickoff supply frequency				Independent***			
Total Output at Null, max.	mv rms	25	25	25	25	25	25
Noise, 0-100 cps, peak-to-peak, max.	% of F.S.	1.2	0.3	0.3	0.3	0.3	0.3
Typical Damping Ratio and tolerance over operating temp. range				0.7 ±0.3 (See typical damping curve)			
Undamped Natural Frequency, nominal (operating, at 20°C)	cps	23	23	29	37	52	74
Sustained Acceleration, max. (any axis, either direction)	g	50	50	60	100	150	> 200
Shock, max. (Amplitude of 6 millisec. half sine pulse)	g	50	50	100	150	200	300
Vibration, 20-2000 cps	g	15	15	20	25	30	> 30
Operating Temp. Range	°C			−55 to +85			

STANDARD OPERATING CONDITIONS:

Motor Excitation: 400 cps, 26 volt, two-phase. (May be operated from single phase line with series capacitor in leading motor phase). Three-phase motor available.

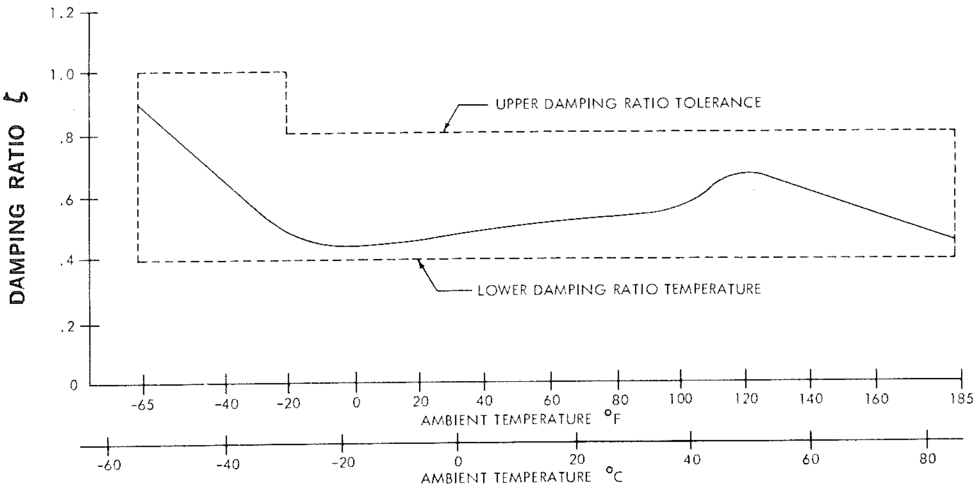
Pickoff Excitation: 400 cps, synchronized with motor excitation. Pickoff excited from 26 volt supply through series choke of 50 millihenry (nom.); Q = 15 (min.)

Pickoff Secondary Load: (external) 10,000 ohm, resistive.

* Compensation by means of external trim components.
** Variation of Scale Factor with temperature may be reduced to 0.02%/deg C (at slight sacrifice in scale factor) by decreasing the standard 10,000 ohm external load resistance across the pickoff secondary.
*** Pickoff excited through series choke, see Standard Operating Conditions.

NOTES:
1. Special models with tighter tolerances and exceptional ruggedness are available. Additional features such as self-test capability and fast run-up may be incorporated.
2. Data above apply to standard operating conditions (excitation and load) listed at end of table. Many other operating conditions can be accommodated. At pickoff excitation frequencies of 800 cps and higher the series choke can often be omitted and larger output signals may be obtained.

TYPICAL TEMPERATURE DEPENDENCE OF DAMPING RATIO AND TYPICAL TOLERANCE BAND



THE UNITED STATES TIME CORPORATION
US TIME
EASTERN SALES 375 PARK AVENUE NEW YORK, N.Y. 10022 PHONE 212-759-5665
WESTERN SALES 346 TEJON PLACE PALOS VERDES, CALIF. 90274 PHONE 213-375-9526 AND 9540

PREPARED FOR
TECHNOLOGICAL UNIVERSITY-EINDHOVEN
Performance Specification
for
2 Bar Shear Damper Rate Gyroscope
60°/sec.

Full Scale Input Range	± 60 deg/sec.
Min. Detectable Rate	$<$ .001 deg/sec.
Non-Linearity	
to 1/2 FS	± .1% FS
to FS	± 2.0% FS
Zero Offset at 25°C	± .03 deg/sec.
Change of Zero Offset from +25°C	.002% FS/°C
Mass Unbalance	.05 deg/sec. max.
Hysteresis	.09 deg/sec. max.
Scale Factor	93 $\frac{mv}{^{o}/sec.}$ ± 10% across 10 K load
Scale Factor variation in temperature	.07%/°C
Total Output at Null	25 mv rms max.
Noise (0-100 Hz)	.3% FS p-p max.
Damping Ratio at +25°C	.5 ± .1
Undamped Natural Frequency	32 ± 3 Hz
Maximum Sustained Acceleration	50 g
Maximum Shock	100 g 6 ms half sine
Max. Vibration (20 - 2000 Hz)	15 g zero to peak
Operating Temperature Range	-55°C to +85°C
Pickoff Excitation	26 V, 400 Hz thru 50 mh choke
Motor Excitation	26 V, 400 Hz 2 phase or split phase with a 1.0 mfd capacitor.

E-555

~~PREPARED FOR~~

TECHNOLOGICAL UNIVERSITY-EINDHOVEN

Performance Specification

for

2 Bar Shear Damper Rate Gyroscope

<u>60°/sec.</u>

TIMEX

Full Scale Input Range	± 60 deg/sec.
Min. Detectable Rate	< .001 deg/sec. = 17,5 μr/sec = ,24 ERU
Non-Linearity	
to 1/2 FS	± .1% FS
to FS	± 2.0% FS
Zero Offset at 25°C	± .03 deg/sec.
Change of Zero Offset from +25°C	.002% FS/°C
Mass Unbalance	.05 deg/sec. max.
Hysteresis	.09 deg/sec. max. = 1,6 mr/s ≈ 20 ERU
Scale Factor	93 $\frac{mv}{°/sec.}$ ± 10% across 10 K load
Scale Factor variation in temperature	.07%/°C
Total Output at Null	25 mv rms max.
Noise (0-100 Hz)	.3% FS p-p max.
Damping Ratio at +25°C	.5 ± .1 voor de single ...
Undamped Natural Frequency	32 ± 3 Hz
Maximum Sustained Acceleration	50 g 60 g
Maximum Shock	100 g 6 ms half sine 200 g
Max. Vibration (20 - 2000 Hz)	15 g zero to peak 20 g
Operating Temperature Range	-55°C to +85°C
Pickoff Excitation	26 V, 400 Hz thru 50 mh choke
Motor Excitation	26 V, 400 Hz 2 phase or split phase with a 1.0 mfd capacitor.

E-555

TIMEX
CORPORATION

GYRO SALES OFFICE
250 STATION PLAZA
HARTSDALE, N.Y. 10530
PHONE (914) 472-3334 TELEX 137426

13 November 1970

Technological University Eindhoven
Department of Electrical Engineering
P. O. Box 513, Eindhoven
The Netherlands

Attention: Mr. A. J. W. Sweep

Reference: Your Letter Dated 21 October 1970 - ER/Sw/WM/3739

Gentlemen:

We acknowledge with thanks the receipt of your captioned letter.

With regard to the differences between the single and two bar versions of the SD series Gyros, please be advised that the single bar gyro has a pivot and bearing supporting one end of the cylindrical gimbal and a torsion bar on the other end, whereas the two bar gyro (as the designation suggests) utilizes a second torsion bar in place of the pivot and bearing. The two bar gyro avoids the uncertainty torques inherant in the ball bearing and is, in general, capable of providing a lower and more stable zero offset, a lower change in zero offset with vibration, and can be balanced more precisely. The only disadvantage of the two bar gyro is that, for a given range and natural frequency, it is not as rugged as the single bar gyro: it can survive shock and vibration levels of from 60 to 75% of the single bar gyro.

Further, the CD Model Gyros are only available in the single bar construction.

We hope we have adequately answered your questions and request that you please call on us further for any additional help you may require.

Very truly yours,

TIMEX CORPORATION

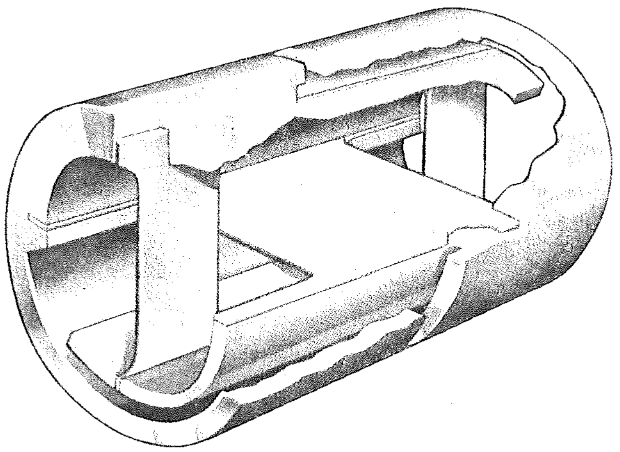
H. D. Armstrong
Eastern Sales Manager
Gyro Division

HDA:jdd

Bendix

FREE FLEX PIVOTS
KREUZFEDERGELENKE

Baureihe 5000 und 6000



ANWENDUNG

Das Kreuzfedergelenk — Free Flex Pivot® — ist ein modernes Bauelement für alle Lagerstellen, bei denen ein Zapfen nur eine geringe Drehung (bis zu ± 30 Grad) ausführt, dafür aber große Querkräfte oder Stöße übertragen soll. Kreuzfedergelenke sind serienmäßig in 10 Größen mit einem Durchmesser von 1/8 Zoll bis 1 Zoll lieferbar, und zwar einseitig oder beidseitig eingespannt (zwei- oder dreiteiliges Gelenk) für drei Drehwinkelbereiche: bis ± 7,5 Grad, bis ± 15 Grad und bis ± 30 Grad. Auf Wunsch können auch Spezialausführungen mit anderen Abmessungen und Charakteristiken geliefert werden.

Wegen ihrer vielen Vorteile haben sich Kreuzfedergelenke in kurzer Zeit einen großen Anwendungsbereich erobert. Sie werden als Lager, Kupplungen und Torsionsfedern in Instrumenten und Maschinen überall da eingesetzt, wo es auf hohe Genauigkeit, bequeme Montage und Gewichtsersparnis ankommt, d. h. in Miniaturmeßgebern und Spezialwaagen ebenso wie bei der schwenkbaren Aufhängung großer Raketentriebwerke.

TELDIX

BESCHREIBUNG

Ein Kreuzfedergelenk besteht aus zwei ineinander drehbaren Hülsen, die über zwei rechtwinklig zueinander stehenden Blattfedern miteinander verbunden sind. In der Standardausführung sind Hülsen und Blattfedern aus rostfreiem Stahl hergestellt. Durch die unterschiedliche Stärke der Blattfedern ergeben sich verschiedene Federkonstanten, die den drei Drehwinkelbereichen angepaßt sind.

BESONDERE VORTEILE

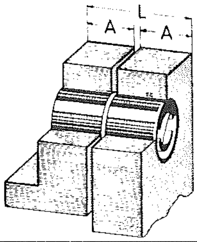
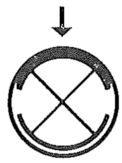
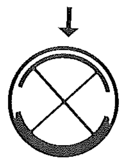
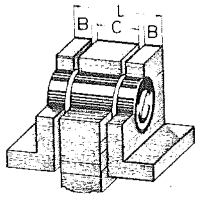
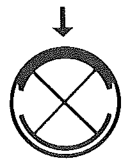
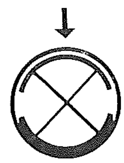
Bendix Kreuzfedergelenke haben keine Reibung. Sie benötigen keine Schmierung, und ein Fressen der Lager ist unmöglich. Sie sind strahlungsbeständig und unempfindlich gegen Verunreinigungen. Sie sind für das Hochvakuum geeignet. Ihre Eigenschaften sind in einem großen Temperaturbereich beständig. Die Standard-Baureihe gestattet die Auswahl des geeigneten Kreuzfedergelenks für Torsionsmomente zwischen 0,013 und 500 kpcm/rad bei gleichzeitiger radialer Belastung zwischen 1 kp und 800 kp. Darüber hinaus sind Spezialausführungen auch für andere Belastungen, in anderen Abmessungen und Werkstoffen lieferbar.

Besonders vorteilhaft hat sich die einfache Konstruktion des Federgelenks erwiesen. Sie ermöglicht eine sehr kompakte Bauform und hohe Präzision und vereinfacht die Montage im Vergleich zu herkömmlichen Lagerungen.

Bei den Kreuzfedergelenken ist das einwirkende Drehmoment dem Drehwinkel bis zu 15 Grad fast direkt proportional. Die Hysterese ist normalerweise vernachlässigbar. Die Lebensdauer der Kreuzfedergelenke ist groß (siehe Diagramme).

TECHNISCHE DATEN DER STANDARDAUSFÜHRUNG

Durchmesser		Gesamtlänge	Länge	Länge	Länge	Gewichte (Richtwerte)	
Zoll	− 0,013 mm	L ± 0,075 mm	A ± 0,013 mm	B ± 0,013 mm	C ± 0,013 mm	zweiteiliges Gelenk g	dreiteiliges Gelenk g
1/8	3,175	5,08	2,41	1,14	2,29	0,14	0,12
5/32	3,969	6,35	3,05	1,45	2,92	0,27	0,24
3/16	4,763	7,62	3,60	1,70	3,43	0,47	0,42
1/4	6,350	10,16	4,83	2,29	4,57	1,1	1,0
5/16	7,938	12,7	6,05	2,84	5,71	2,2	2,0
3/8	9,525	15,3	7,24	3,43	6,85	3,8	3,4
1/2	12,700	20,4	9,65	4,57	9,14	8,8	8,3
5/8	15,875	25,4	12,1	5,71	11,4	17,2	16,2
3/4	19,050	30,5	14,5	6,85	13,7	29,5	28,6
1	25,400	40,6	17,0	8,13	16,3	69,0	68,0

			ZWEITEILIGES GELENK einseitig eingespannt			**DREITEILIGES GELENK** zweiseitig eingespannt		
								
	maxim. Drehung	Feder-konstante C**	Bestell-nummer	Druck-belastung V_c ***	Zug-belastung V_t ***	Bestell-nummer	Druck-belastung V_c ***	Zug-belastung V_t ***
Größe	± Grad	kp cm/rad	Baureihe 5000	− kp	+ kp	Baureihe 6000	− kp	+ kp
1/8″	7,5	0.922	5004-400	11.341	11.341	6004-400*	12.702	12.702
	15	0.115	5004-600	3.992	5.671	6004-600	8.030	11.341
	30	0.013	5004-800	0.499	1.588	6004-800*	0.998	2.132
5/32″	7,5	1.844	5005-400	17.692	17.692	6005-400*	19.960	19.960
	15	0.230	5005-600	6.260	8.846	6005-600	12.521	17.692
	30	0.029	5005-800	0.789	2.495	6005-800*	1.588	3.357
3/16″	7,5	3.12	5006-400	25.404	25.404	6006-400*	28.580	28.580
	15	0.376	5006-600	3.982	12.702	6006-600	17.964	25.404
	30	0.047	5006-800	1.180	3.085	6006-800*	2.223	4.083
1/4 ″	7,5	7.54	5008-400	45.364	45.364	6008-400	51.262	51.262
	15	0.941	5008-600	16.059	22.682	6008-600	32.073	45.364
	30	0.118	5008-800	1.905	6.351	6008-800	3.856	8.619
5/16″	7,5	14.75	5010-400	70.768	70.768	6010-400*	79.841	79.841
	15	1.89	5010-600	24.950	35.384	6010-600	49.901	70.768
	30	0.235	5010-800*	3.221	9.935	6010-800*	6.351	13.156
3/8″	7,5	25.4	5012-400	102.070	102.070	6012-400	114.772	114.772
	15	3.17	5012-600	36.291	51.262	6012-600	72.129	102.070
	30	0.381	5012-800	4.491	14.290	6012-800	8.982	19.053
1/2″	7,5	59.9	5016-400	181.457	181.457	6016-400	204.140	204.140
	15	7.49	5016-600	63.964	90.729	6016-600	128.381	181.457
	30	0.937	5016-800	8.030	25.540	6016-800*	16.059	34.023
5/8″	7,5	122.0	5020-400*	283.527	283.527	6020-400	318.911	318.911
	15	15.0	5020-600*	100.255	141.537	6020-600*	200.510	283.527
	30	1.95	5020-800*	12.521	39.830	6020-800*	24.950	53.076
3/4″	7,5	210.0	5024-400	408.279	408.279	6024-400*	459.541	459.541
	15	26.3	5024-600	144.259	204.140	6024-600*	288.517	408.280
	30	3.28	5024-800*	17.647	57.613	6024-800*	35.384	76.666
1″	7,5	497.0	5032-400	725.829	725.829	6032-400	816.558	816.558
	15	62.0	5032-600	256.762	362.915	6032-600	513.071	725.829
	30	7.76	5032-800	32.073	102.070	6032-800*	63.964	136.093

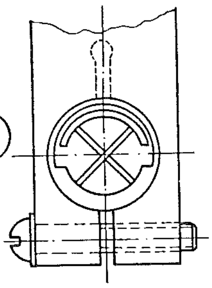
* Nicht in der Preisliste enthalten, bitte gesonderte Anfrage.
** Toleranz der Federkonstante innerhalb 10%.
*** Belastungswerte V_c und V_t gelten bei radialer Krafteinwirkung und bei Nullage der Federn.

EINBAURICHTLINIEN

Nachfolgend sollen einige konstruktive Lösungen für den Einbau von Kreuzfedergelenken der Normalausführung aufgezeigt werden.

Für die meisten Anwendungsfälle wird der Einbau entsprechend der Belastungsart V_c empfohlen, d. h. das Gelenk sollte möglichst druckbelastet werden.

1

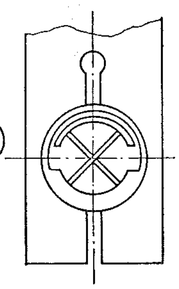


1. Montage mit Klemmschraube

Der Bohrungsdurchmesser soll etwa 0,013 mm bis 0,038 mm größer sein als der Außendurchmesser des Kreuzfedergelenks. Beim Auftreten von Vibrationen wird empfohlen, unter den Schraubenkopf einen Federring zu legen.

Die Spannung kann verringert werden, wenn gegenüber der Klemmschraube ein Schlitz mit Bohrung, wie die strichpunktierte Linie andeutet, vorgesehen wird.

2



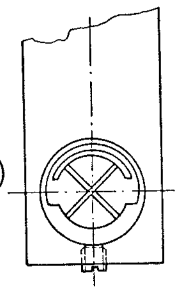
2. Festklemmen durch Vorspannung

Diese Anordnung kann bei kleinen Drehmomenten gewählt werden.

Die Spannkraft muß hoch genug sein, um eine Verdrehung innerhalb der Bohrung zu vermeiden.

Um das Einführen des Gelenks in die Bohrung zu erleichtern, muß am Schlitz gespreizt werden. Dabei ist Vorsicht geboten, damit die Elastizitätsgrenze nicht überschritten wird.

3

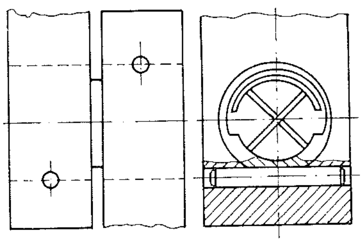


3. Montage mit Gewindestift

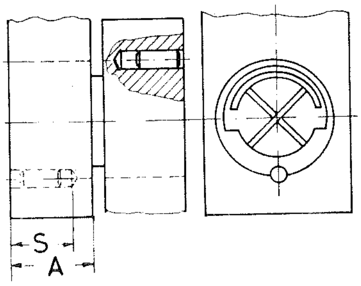
Der Bohrungsdurchmesser ist etwa 0,013 mm bis 0,038 mm größer zu wählen als der Außendurchmesser des Kreuzfedergelenks. Bei dieser Anordnung erfolgt die Fixierung mit einem Gewindestift. Um eine Deformierung des Kreuzfedergelenks zu vermeiden, wird empfohlen, den Gewindestift mit flacher Kuppe vorsichtig anzuziehen.

Beim Auftreten von Vibrationen ist die Verschraubung zu sichern.

4



4



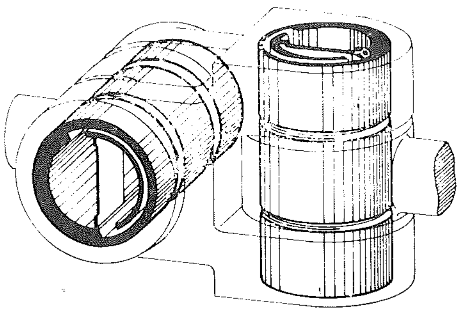
4. Montage mit Paßstift in Quer- und Axialrichtung

Der Bohrungsdurchmesser soll etwa 0,013 mm bis 0,038 mm größer sein als der Außendurchmesser des Kreuzfedergelenks.

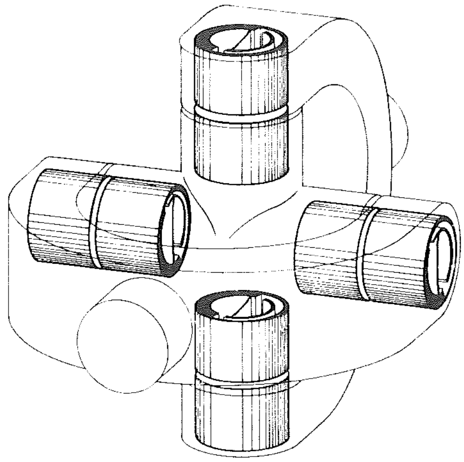
Nach dem Einpressen mit einer Führungsbuchse verbohren und anschließend verstiften. Zweckmäßige Lage der Bohrung in der dicken Gelenkwandung unter 45° zu den Federn. Durchbrechen der Gelenkinnenwand beim Bohren soll verhütet werden.

Sacklochtiefe S nicht größer als 75% der Länge A.

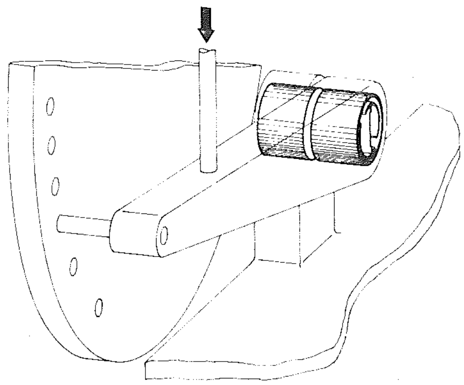
ANWENDUNGSBEISPIELE



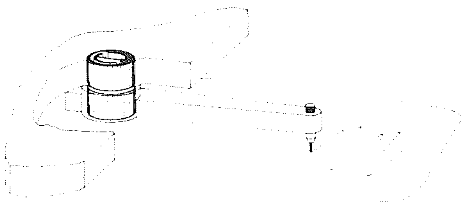
Kardangelenk als Adapter für eine Zugfestigkeits-Prüfmaschine, durch den Kräfte bis zu 23 000 kp übertragen werden. Durch Fehlausrichtung bedingte Versetzungen des Prüflings werden durch die reibungsfreien Kreuzfedergelenke ausgeglichen, ohne das Prüfergebnis zu beeinträchtigen.



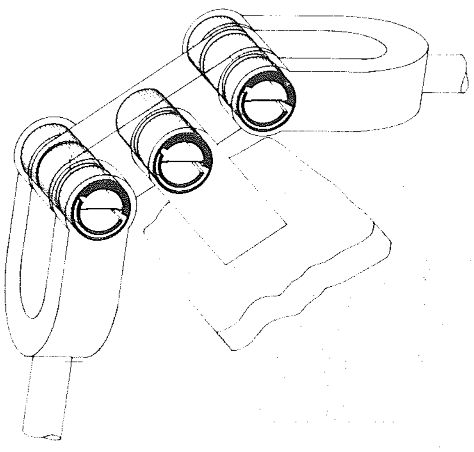
Kardangelenk für rotierende Wellen, bei denen die Schmierung und Sauberhaltung schwierig sind. Die gezeigte Anordnung ist für relativ kleine Belastungen ausgelegt.



Federnder Hebel in einem Druckmeßgeber. Der als Kreuzfedergelenk ausgebildete Drehzapfen läßt keinen toten Gang zu und gewährleistet, daß der Hebelausschlag dem Druck proportional ist.

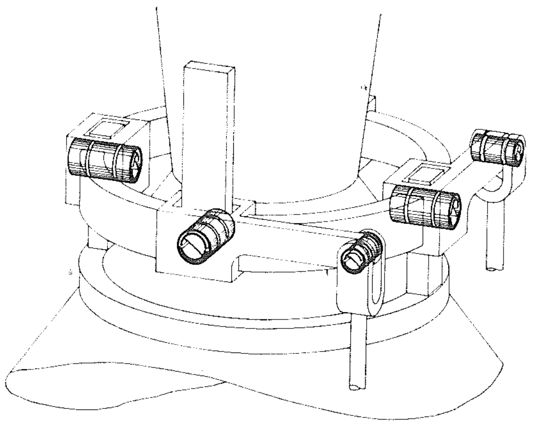


Federnder Arm in einem Schreibgerät. Das Kreuzfedergelenk stellt den Arm mit dem Schreiber fast hysteresefrei auf Null zurück und sorgt für großen und konstanten Anpreßdruck.

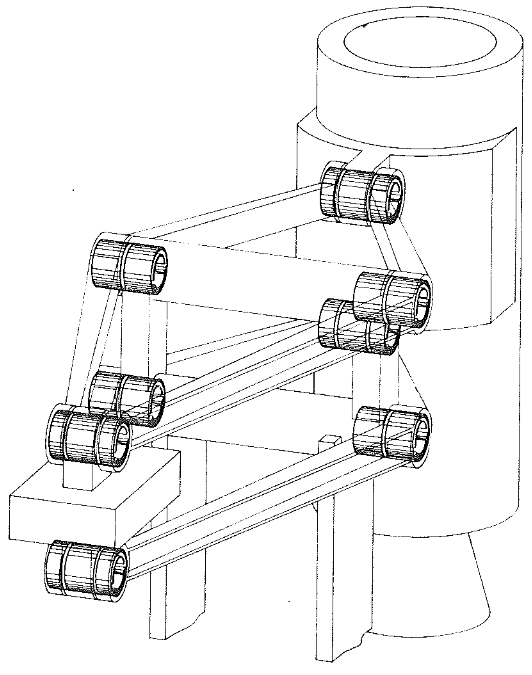


Steuergestänge für die Leistungsregulierung von Triebwerken. Die kompakten und temperaturunempfindlichen Kreuzfedergelenke, die überdies nicht geschmiert zu werden brauchen, vereinfachen die Konstruktion.

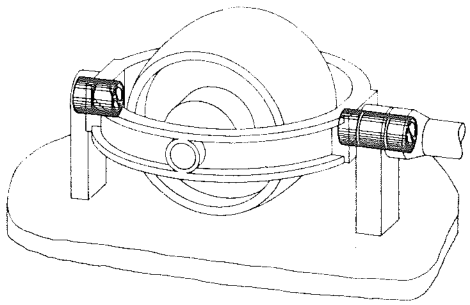
WEITERE ANWENDUNGSBEISPIELE



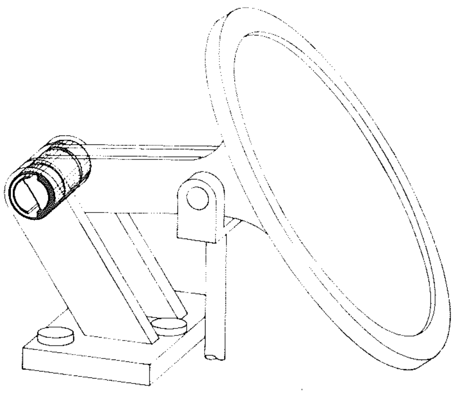
Schwenkbare Aufhängung eines Raketentriebwerks, die auch im Hochvakuum und unter der Einwirkung von kosmischer Strahlung nicht verschweißt. (Bekanntlich versagen unter diesen Bedingungen die meisten Schmiermittel.) Die Kreuzfedergelenke können bei dieser Anwendung den tiefen Temperaturen von Flüssig-Gas-Treibstoffen oder den hohen Temperaturen der Brennkammer ausgesetzt werden, und trotzdem bleibt die Proportionalität zwischen Stellkraft und Ausschlagwinkel (hierbei ein weiterer Vorteil!) und die ungewöhnliche Steifigkeit gegenüber der großen Radialbelastung durch den Triebwerksschub erhalten.



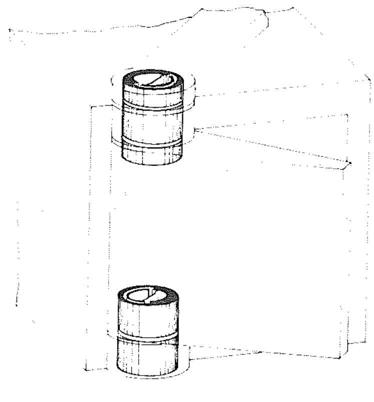
Raketen-Prüfstand. Der Schub kann aus dem Drehwinkel der Kreuzfedergelenke wegen der reibungsfreien Aufhängung genau ermittelt werden. Diese Anordnung ist typisch für die Umwandlung geradliniger Kräfte in Drehwinkel, die oft gewünscht wird.



Abgriffachse eines Wendekreisels mit Kreuzfedergelenken als Federfesselung. Der Ausschlag ist dem Drehmoment und damit der Winkelgeschwindigkeit genau proportional. Die große Quersteifigkeit der Feder macht den Wendekreisel nahezu unempfindlich gegen Beschleunigungen.



Abtastspiegel für die Raumfahrt. Der Spiegel führt eine Abtastbewegung über ± 13,5 Grad durch. Das Kreuzfedergelenk garantiert die genaue Wiederholbarkeit des Winkelausschlags und eine lange wartungsfreie Lebensdauer.



Lagerung einer Drosselklappe. Diese einfache Konstruktion mit einem einseitig und einem beidseitig gelagerten hysteresefreien Kreuzfedergelenk gewährleistet, daß die Drosselklappe immer die richtige Stellung einnimmt und ermöglicht erheblich reduzierte Herstellungskosten.

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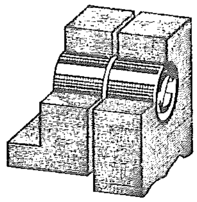
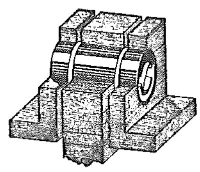


ZWEITEILIGES GELENK
einseitig eingespannt

Lfd. Nr.	Größe (Zoll)	Drehung (± Grad)	Bestell-nummer	Stückpreise in DM bei den gestaffelten Stückzahlen			
				1–14 Stck.	15–49 Stck.	50–199 Stck.	200–999 Stck.
1	1/8"	7,5	5004-400	64,50	60,70	56,60	48,20
2		15	5004-600	64,50	60,70	56,60	48,20
3		30	5004-800	66,80	63,90	59,–	50,50
4	5/32"	7,5	5005-400	61,30	57,50	54,–	45,60
5		15	5005-600	61,30	57,50	54,–	45,60
6		30	5005-800	66,80	63,–	59,–	50,50
7	3/16"	7,5	5006-400	61,–	58,10	53,70	44,40
8		15	5006-600	61,–	58,10	53,70	44,40
9		30	5006-800	62,20	59,–	55,20	45,90
10	1/4"	7,5	5008-400	63,90	60,40	56,40	45,30
11		15	5008-600	63,90	60,40	56,40	45,30
12		30	5008-800	71,50	68,–	63,90	54,60
13	5/16"	7,5	5010-400	77,90	74,10	70,30	58,70
14		15	5010-600	77,90	74,10	70,30	58,70
15		30	5010-800*	–	–	–	–
16	3/8"	7,5	5012-400	65,10	61,30	57,20	45,60
17		15	5012-600	65,10	61,30	57,20	45,60
18		30	5012-800	78,40	74,70	70,60	60,40
19	1/2"	7,5	5016-400	90,10	86,–	81,30	65,10
20		15	5016-600	90,10	86,–	81,30	65,10
21		30	5016-800	102,30	98,20	93,50	78,70
22	5/8"	7,5	5020-400*	–	–	–	–
23		15	5020-600*	–	–	–	–
24		30	5020-800*	–	–	–	–
25	3/4"	7,5	5024-400	123,50	119,10	114,20	97,60
26		15	5024-600	123,50	119,10	114,20	97,60
27		30	5024-800*	–	–	–	–
28	1"	7,5	5032-400	142,60	137,70	133,–	116,50
29		15	5032-600	142,60	137,70	133,–	116,50
30		30	5032-800	142,60	137,70	133,–	116,50

* Preise auf Anfrage



DREITEILIGES GELENK
zweiseitig eingespannt

Baureihe 6000

Lfd. Nr.	Größe (Zoll)	Drehung (± Grad)	Bestell-nummer	Stückpreise in DM bei den gestaffelten Stückzahlen			
				1–14 Stck.	15–49 Stck.	50–199 Stck.	200–999 Stck.
31	1/8"	7,5	6004-400*	–	–	–	–
32		15	6004-600	75,50	71,50	67,40	56,40
33		30	6004-800*	–	–	–	–

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Lfd. Nr.	Größe (Zoll)	Drehung (± Grad)	Bestell-nummer	Stückpreise in DM bei den gestaffelten Stückzahlen			
				1–14 Stck.	15–49 Stck.	50–199 Stck.	200–999 Stck.
34		7,5	6005-400*	–	–	–	–
35	5/32"	15	6005-600	72,60	68,30	63,90	53,50
36		30	6005-800*	–	–	–	–
37		7,5	6006-400*	–	–	–	–
38	3/16"	15	6006-600	72,–	68,–	63,90	52,30
39		30	6006-800*	–	–	–	–
40		7,5	6008-400	76,40	72,30	68,30	54,90
41	1/4"	15	6008-600	76,40	72,30	68,30	54,90
42		30	6008-800	90,60	86,60	82,20	70,30
43		7,5	6010-400*	–	–	–	–
44	5/16"	15	6010-600	94,40	90,10	86,–	72,–
45		30	6010-800*	–	–	–	–
46		7,5	6012-400	82,20	78,70	74,10	60,10
47	3/8"	15	6012-600	82,20	78,70	74,10	60,10
48		30	6012-800	99,10	95,–	90,90	78,10
49		7,5	6016-400	111,–	106,30	101,10	82,20
50	1/2"	15	6016-600	111,–	106,30	101,10	82,20
51		30	6016-800*	–	–	–	–
52		7,5	6020-400	113,90	108,90	104,–	85,70
53	5/8"	15	6020-600*	–	–	–	–
54		30	6020-800*	–	–	–	–
55		7,5	6024-400*	–	–	–	–
56	3/4"	15	6024-600*	–	–	–	–
57		30	6024-800*	–	–	–	–
58		7,5	6032-400	155,40	149,90	144,40	123,50
59	1"	15	6032-600	155,40	149,90	144,40	123,50
60		30	6032-800*	–	–	–	–

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