National Radio Astronomy Observatory
Tucson, Arizona

June 1, 1982

25 METER MILLIMETER WAVE TELESCOPE
MEMO No. 151

MEMORANDUM

TO: Buck Peery

FROM: John Payne

SUBJECT: Readout system for 25-m telescope

I don't know whether the 25-m memo series is being continued, but in case it is here is some information on the readout system being used on the 30-m German telescope. It's basically an inductosyn system capable of 24 bits of accuracy. It comes packaged and, according to Alan Moffet, only costs about 5K.

Enclosure

HEIDENHAIN

The name HEIDENHAIN is long associated with precise measurement or positioning of length and angle.

HEIDENHAIN's skills and expertise lie in the manufacture of precision graduations, linear and rotary scales and graticules.

The first major step was the development of the lead sulphide process (METALLUR) in 1928 which, for the first time, made the exact reproduction of a master graduation possible. After the destruction and loss of the Works in Berlin, Suhl (GDR) and Gars (Austria) DR. JOHANNES HEIDENHAIN established the new Works in Traunreut, Bavaria.

A pioneer achievement was the DIADUR process, making it possible to produce extremely durable reproductions of master graduations. The company grew steadily. Optical projection systems (for machine tools, rotary tables, testing and calibration equipment) became part of the product range. Completely new was the display of a complete measuring value in numerical form (up to 0.001 mm/1 second of arc).

For the past 15 years HEIDENHAIN has also manufactured digital readout systems for linear and angular measurement on machine tools, testing and allied equipment.

In the production facilities at Traunreut, Berlin, Chicago and São Paulo HEIDENHAIN employs 1200 people, of which more than 100 are involved directly in Research and Development.

HEIDENHAIN CORPORATION
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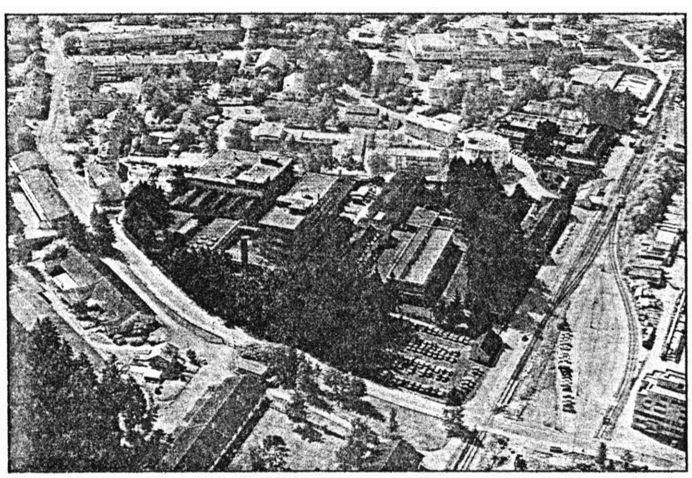
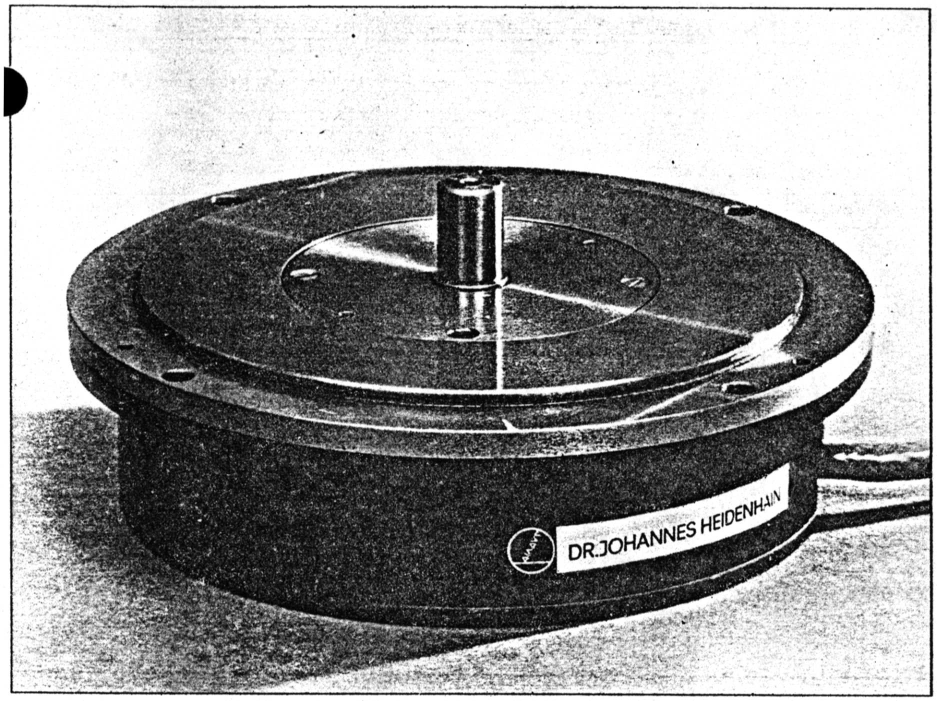
Elk Grove Village, Illinois
Tel. 312-5936161
Telex 280513 heidenhain elgr



Bertram-Luftbild, München-Riem. Freigabe Reg. v. Obb. G 4/30.901

Modifications reserved   Made in West Germany   7/80   208 163 22

ROD 800



Auflösung
max. 36 000 Striche ≙ 0,0001° (0,36″) nach 25-fach-Interpolation und 4-fach-Auswertung

Spannungsversorgung
+ 5 V

Ausgangssignale
sinusförmig

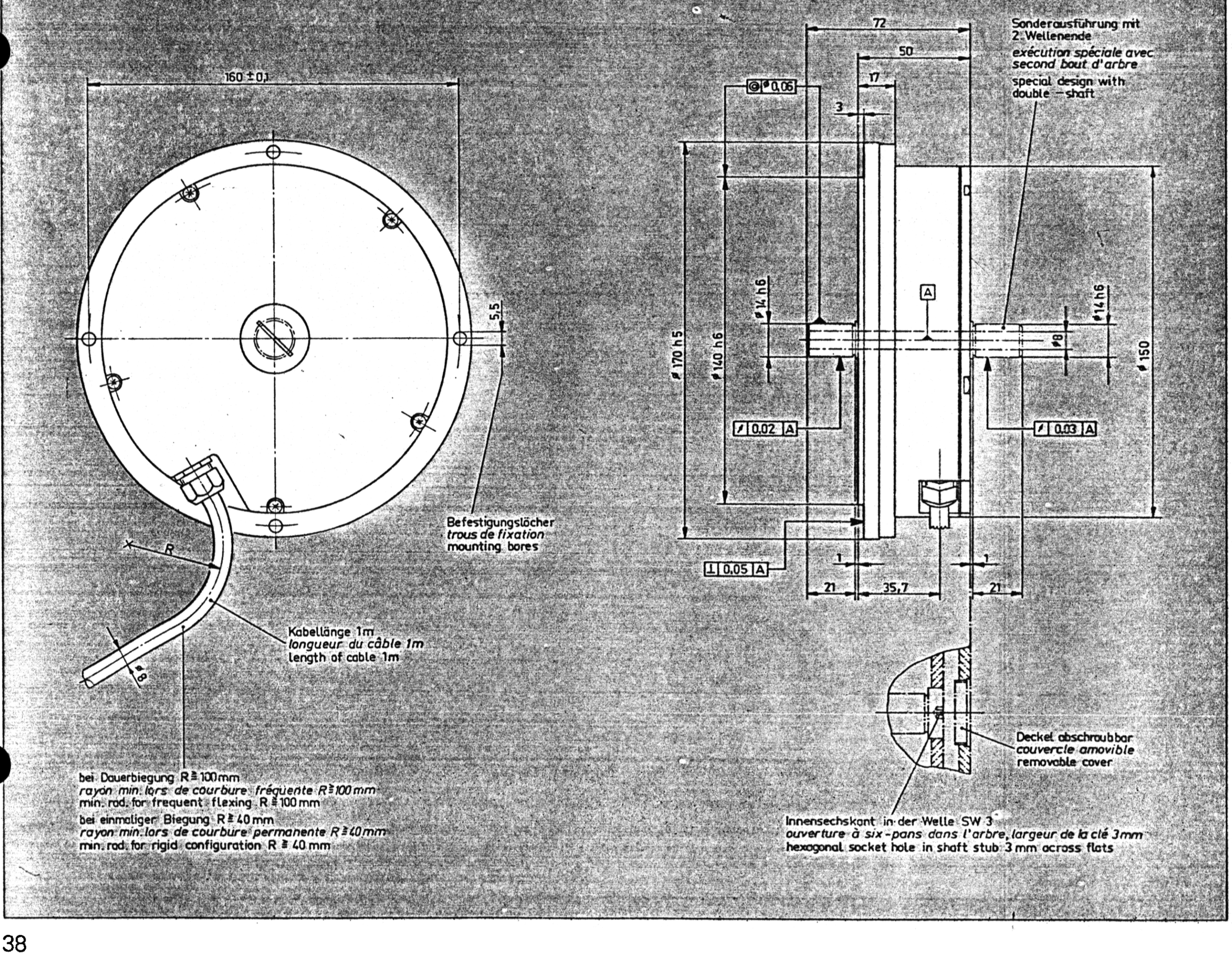
Referenzsignal
standard

Impulsformer-Elektronik
extern – der Drehgeber ROD 800 arbeitet nur in Verbindung mit bestimmten EXE-Ausführungen, (siehe EXE-Druckschrift)

Mechanische Ausführung
flache Bauweise,
hohe Wellenbelastbarkeit,
durchgehende Welle auf Wunsch,
Kabelausgang radial oder axial

Besonders hohe Genauigkeit.

Abmessungen mm



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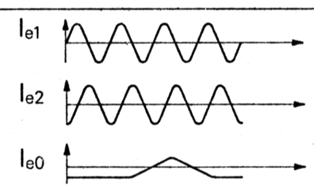
Technische Daten

Standardstrichzahlen (elektronische Vervielfachung möglich)		25 920 und 36 000 Striche pro Umdrehung		
Referenzsignal		standard		
Mechanische Kennwerte				
Zulässige Drehzahl (abhängig von der Strichzahl und der Folgeelektronik):				
Auflösung	Strichzahl pro Umdrehung	Signal-interpolation	Auswertung	Drehzahl U/min.
0,5″	25 920	25-fach	4-fach	34
1″		25-fach	2-fach	34
0,0001°	36 000	25-fach	4-fach	25
0,0002°		25-fach	2-fach	25
0,0005°		5-fach	4-fach	33…41 je nach verwendeter EXE
0,001°		5-fach	2-fach	33…41 je nach verwendeter EXE
0,002°		5-fach	1-fach	33…41 je nach verwendeter EXE

Trägheitsmoment des Rotors	3140 gcm²	
Anlaufdrehmoment bei 20°C	≦1,2 Ncm (120 cmp), ≦1,9 Ncm (190 cmp) bei 2. Wellenende (Sonderausführung)	
Zulässige Beanspruchung der Welle	Flanschseite	Rückseite (nur bei Sonderausführung mit 2. Wellenende)
axial	30 N (3 kp)	30 N (3 kp)
radial (am Wellenende)	30 N (3 kp)	15 N (1,5 kp)
Staub- und Spritzwasserschutz nach DIN 400 50 Bl. 1	IP 64	
Gewicht	ca. 3,5 kg	
Temperaturbereich	Arbeitstemperaturbereich	0°…50°C
	Lagertemperaturbereich	−30°…80°C
	erweiterter Temperaturbereich	auf Anfrage
Vibration	100 m/s² (bis 500 Hz)	
Stoß	300 m/s² (6 ms)	
rel. Feuchte	bis 98%	
Elektrische Kennwerte		
Lichtquelle	4 Miniaturlampen 5 V/0,6 W	
Spannungsversorgung	Lichtquelle 5 V ±5%/500 mA	
Abtastelemente	Si-Photoelemente in Gegentakt-Anordnung	
Impulsformer-Elektronik	in separatem Gehäuse, siehe ›EXE‹ (Seite 57) not applicable to very high resolution	

Ausgangssignale



2 annähernd sinusförmige Signalfolgen I_{e1} und I_{e2}

Referenzsignal: 1 Signalspitze I_{e0} pro Umdrehung

Signalgröße:
I_{e1} ca. 11 µA$_{ss}$
I_{e2} ca. 11 µA$_{ss}$
I_{e0} ca. 5,5 µA*
} bei Last 1 kOhm

* Nutzanteil

Abtastfrequenz	je nach Folgeelektronik, siehe Prospekt ›EXE‹ bzw. ›VRZ‹
Genauigkeit Accuracy	± 1″ über 360° bezogen auf einen Mittelwert ± 0,5″ über 5° bezogen auf einen Mittelwert ± 0,1″ Schritt zu Schritt (über 0,5″ bzw. 0,0001°) Die angegebenen Werte ergeben sich aus dem Fehler der Teilung, dem Fehler durch Exzentrizität und Taumel, sowie durch den elektronischen Unterteilungsfehler. Der Kupplungsfehler ist dabei nicht berücksichtigt.
Zulässige Kabellänge Permitted Cable Lengths	7 m zwischen ROD 800 und EXE (Standardkabel [3(2 x 0,14) + 2 x 0,5] mm²) 10 m zwischen EXE und Folgeelektronik

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Prof.A.T.Moffet
CALTEC
Radio Astronomy

Pasadena,Cal 91125
USA

Dear Alan! Januar 6,1981

In reply to your letter from December 16,1980 let me give you the following explanation:

We will be using the ROD 800 as encoders for the position and the velocity of the antenna axes. The ROD 800 has an output of a sine and a cosine signal. The full period of each corresponds to 36 seconds of arc with the model selected. We intend to interpolate by a factor of 360, so that each count corresponds to a tenth of a second of arc. This interpolation is a phase comparison between the amplitude of the signals and a sine table. In case of strong deviations of the signal from a sinusoidal shape the table could be modified and adjusted for each encoder separately.

The whole electronics is designed around the spsecifications of the IRAM 30m-telescope. The maximum angular range will be only 450 degrees. This gives almost exactly 24 bits maximum count. The maximum velocity will be 60 degrees/minute and the accuracy driven for will be .1"/sec. We need a time base and this is designed around the basic servo cycle time of 10 msec. Furthermore we are integrating the interface directly into a single slot CAMAC module per encoder interface, which will allow us to use a block transfer for input of all encoders, the ones for the axes and the ones for the motor shafts with one computer intervention.

The details are completely application dependent. If you want to use the CAMAC modules with almost identical specifications we could send you the printed circuit outlays. But I have the suspicion that you might have other design specifications and interfacing methods. Therefore Herr U.Beckmann includes a schematic diagram that shows the principles of operation. If you need more detailed information, please let us know.

Best wishes

Johann Schraml

Further details, concerning the block-diagram:
The sine and cosine signals from the ROD 800 are amplified by a low-drift chopper-stabilized amplifier because of the very small amplitude of ~11 uA in 1 K from the ROD 800. The sine and cosine signals are then mixed (in M1,M2) with a carrier frequency ω_c (1.6 kHz) and then added in order to get a signal $U1 \sim A * \sin(\omega_c + \omega_R) * t$ (ω_R = frequency of the sine and cosine from the ROD 800). The signal U2 is produced in a similar way but the sine and cosine signals come from a table, stored in a prom. The phase difference θ of U1 and U2 is detected in the mixer M5. The output of this mixer, after a lowpassfilter, is $U3 \sim \cos\theta$. This voltage is then integrated and rectified in order to get a positive control voltage for the V/f converter. The binary output of the up/down counter I is connected to the adress-lines of the proms.
If $U3 \neq 0$, the V/f converter produces the clock pulses for the up/down counter I which increase (decrease) the adress for the proms, until U3 = 0. The output pulses of the V/f converter are also counted in the up/down counter II. It is a 24 bit counter. The binary data output gives the position of the antenna.

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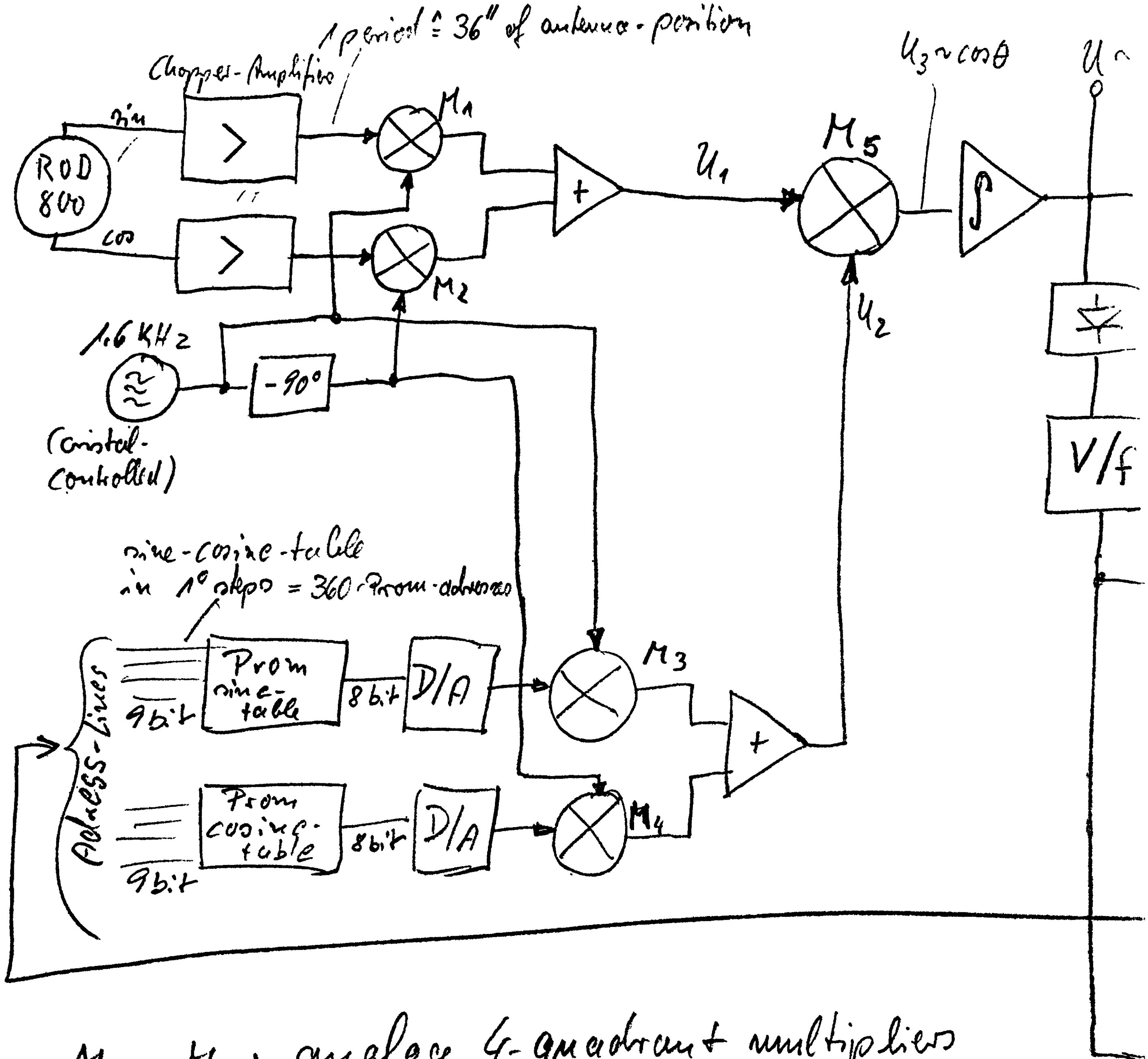
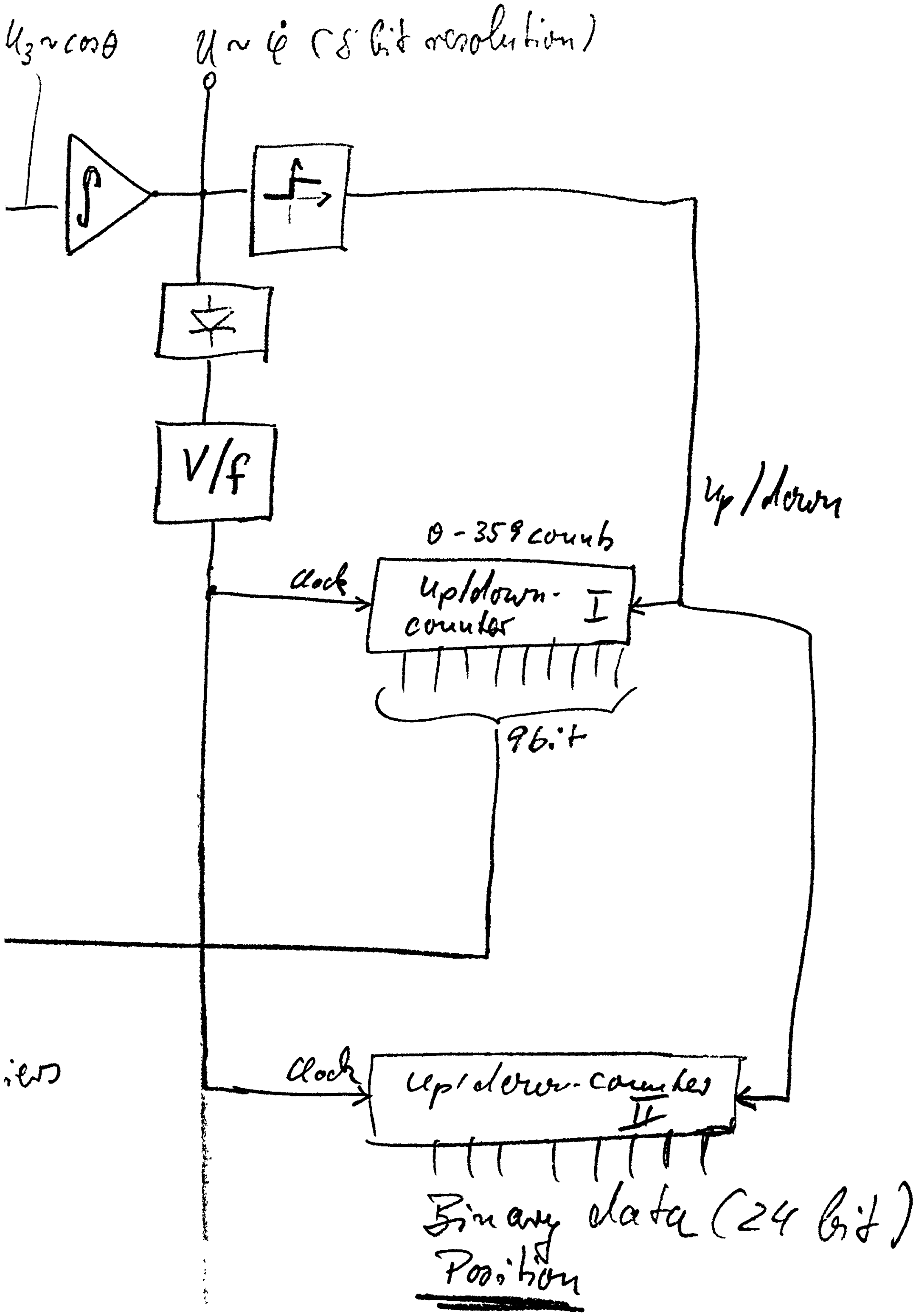


$M_1 - M_5$: analog 4-quadrant multipliers

Simplified block-diagram for the position-measurement


U3 ~ cosθ
U ~ φ̇ (8 bit resolution)
V/f
up/down
0 - 359 counts
clock
up/down-counter I
9 bit
clock
up/down-counter II
Binary data (24 bit)
Position

iers

r the

MAX-PLANCK-INSTITUT f. RADIOASTRONOMIE
ABTEILUNG 4
J.SCHRAML

April 3, 1981

Dr. Alan T. Moffet
Cal. Institute of Technology
Owens Valley Radio Observatory

Pasadena, Cal. 91125, USA

Dear Alan:

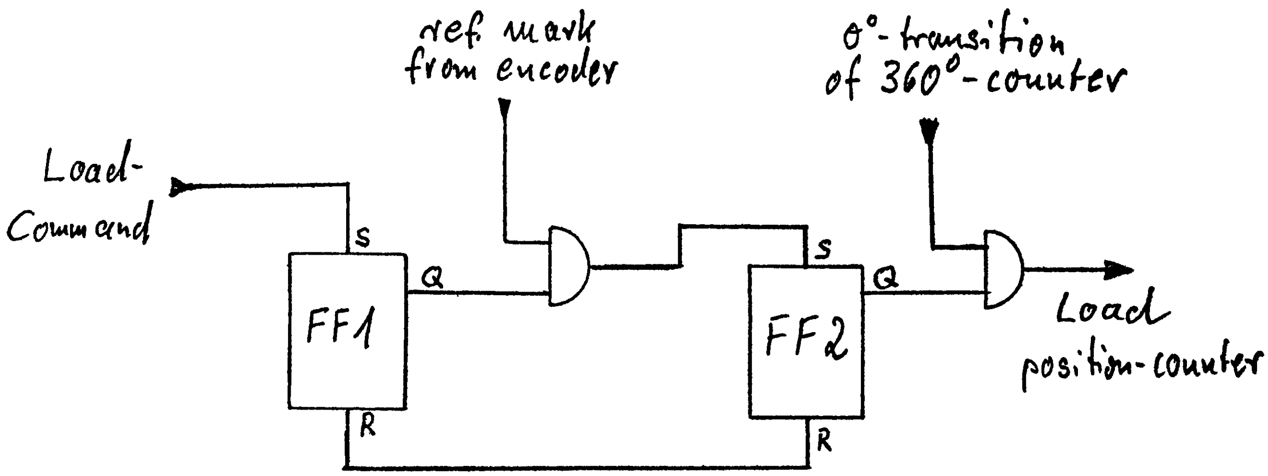
Your letter created activity in order to solve the problem of setting the encoders all to the accurate position. That is the main reason why we have not respondet earlier. We have to mount encoders on the motors, too and part of the discussion was the syncronization between the axis and the motor shafts, which rotate faster by the gear ratio.

You find a manual setting that is for test purposes, and the accurate setting of the encoders under computer control that is only possible in one direction in order to avoid an ambiguity of 18 or even 36 arcseconds. Information on the occurance of the setup is available to the computer, so that the procedure can also be automated.

Herr Beckmann has listed the delicate IC's that he has selected. We will receive an encoder sometime next week, they have arrived at Krupp. Herr Beckmann has built a Camac module for a ROD 630, that provides already digital signals and the reset pulse. He counts up-down and derives the velocity. We have tested it now since December connected to the VAX and have found advantages and small problems with the initial design, especially with spikes due to the 10 kW airconditioner. These experiences will all be incorporated in the design of the prototyp that is under construction right now. We have ordered a storage oscilloscope especially suited for the optimization of the table of sines and cosines. So we are working on the problems, but cannot report details of the behavior now. I let you know when the prototyp works.

Thus far we have not written any internal reports on this particular aspects of the 30m-project.

Sorry for the long delay in responding, and best wishes



The above circuit shows the zeroing of the angle-counter with 0.1" accuracy. When the "LOAD-Command" is on logic "1", FF1 is set, so the Q-output is "1" and when the encoder-reference mark comes, FF 2 is set.
Now, when the 360 degrees-counter (described in my previous letter) reaches 0 degree, that means the transition from 359 degrees to 0 degree, the "RESET" pulse for this counter is used to make the "LOAD" for the position-counter. At the same time FF1 and FF2 also get a reset-pulse so the Q-outputs of the FF's go to "0" and another pulse from the 360 degrees-counter can't make a new "LOAD"-pulse for the position-counter, until a new "LOAD-Command" is given.

IC's: In the analog part we'll use IC's from "ANALOG DEVICES", for example:

Mixers.........AD 534, AD 533
V/f-converter..AD 537
OP-Amp's.......AD 517 or OP01, OP09, OP10 from PMI
D/A converter..AD 1408