Chapter VI

Related conversion products

INTRODUCTION

So far we have discussed mainly components which are used to convert synchro, resolver and Inductosyn information into digital form and vice versa. However, a number of related products exist and a few of these and their application will be discussed in this chapter. These products are:

API 1620	Angle Position Indicator.
DTM 1716, DTM 1717	Digital Vector Generators.
SAC 1763	Synchro/resolver to D.C. converter.
DDU 1714	Solid State Dummy Director.

ANGLE POSITION INDICATOR API 1620

Introduction

The angle position indicator API 1620 is an instrument which is used for measuring and setting synchro or resolver angles. The input is electrical signals in either synchro or resolver form at any of the standard voltages and frequencies. Besides giving a visual indication of angle with a maximum reading of 359.99 degrees, the API 1620 provides angular data in either BCD of Natural Binary form at TTL levels. This output permits its use for setting up digital angles. The schematic arrangement of the API 1620 is shown in Fig. 6-1.

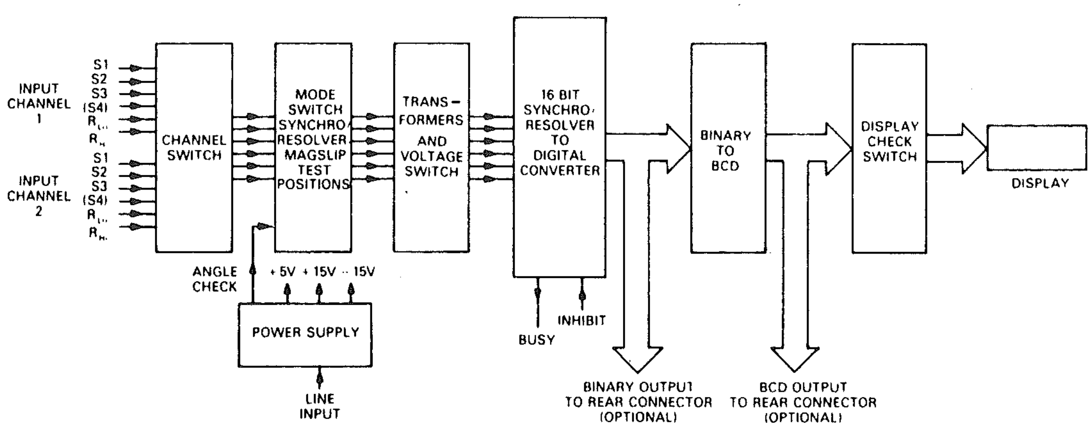

Fig. 6-1 Schematic arrangement of the API 1620.

Applications of API 1620

Visual display of angles from synchro or resolver format inputs

In many fields of engineering:- aircraft, military, naval, radar, navigation etc. angles of shafts are controlled and monitored by the use of servo control loops using synchros or resolvers for sensing the angular positions. For servicing and testing, the API is as universal in its application as the universal voltmeter is in other fields. The API has been designed to

be portable and can be powered from any supply capable of giving either 220 volts ± 15% or 115 volts ± 15% at any frequency in the range from 45 Hz – 400 Hz. This means that the synchro or resolver system supply can often be used to power the API.
The front panel of the API 1620 is shown in Fig. 6-2.

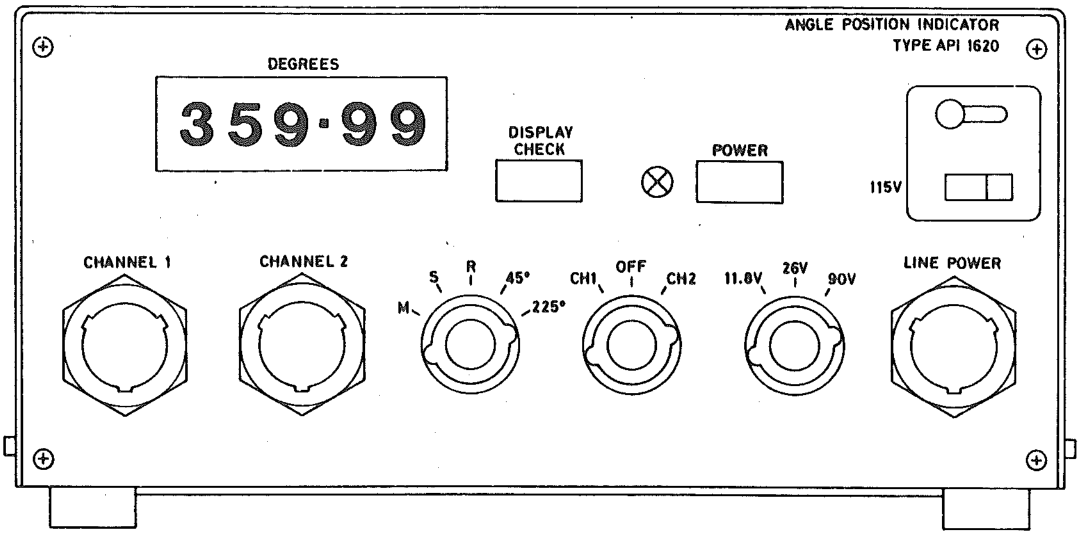

Fig. 6-2 Front panel of the API 1620.

The API has provision for two separate inputs (which may be working on different reference frequencies). The different inputs can be switched so that the API displays either of the angles represented by the signal inputs. This facility is very useful in checking retransmission units where the reference is different and it is required to check errors in retransmission.

The use of the API for setting angles in binary form
In checking computer interfaced synchro control systems it is often necessary to set angular inputs in natural binary form. Often this is done by using a row of switches representing the binary angle to be set; this method can be tedious for angles other than the ones requiring simple binary codes. The API 1620 can be used for this purpose. A synchro or resolver with a vernier dial is connected to the API and the required angle is set using the API visual readout to indicate the angle. The Binary angular information is available at TTL levels from the rear connector of the API. The synchro or resolver required for setting the input angles need not be accurate since the API will produce an accurate binary representation of the displayed angle independently of how it is produced. The BCD version of the API can be used for producing BCD angular data inputs but since this can be done with BCD decade switches with no decoding it does not give the advantages that are obtained for producing binary inputs.

The API 1620 used for checking loading errors in synchro systems
Fig. 6-3 shows several control transformers connected to a single control transmitter.
In a practical system the wires connecting the transmitter to the receiver may be long and as a consequence the individual wires may not be the same resistance. Also the CX is permitted to have out of balance impedances (the control of the degree of balance on the output winding impedances is not normally printed in the synchro data sheets and different manufacturers have given widely differing figures). Due to the possible out of balance of the source and loading resistors there will be a change of angle represented by the synchro data between its loaded and unloaded condition. Balancing the loads, or making them match the existing unbalance in impedances will be necessary to get the best accuracy out of the system. The API is the ideal instrument for this purpose; its high resolution and accuracy make what

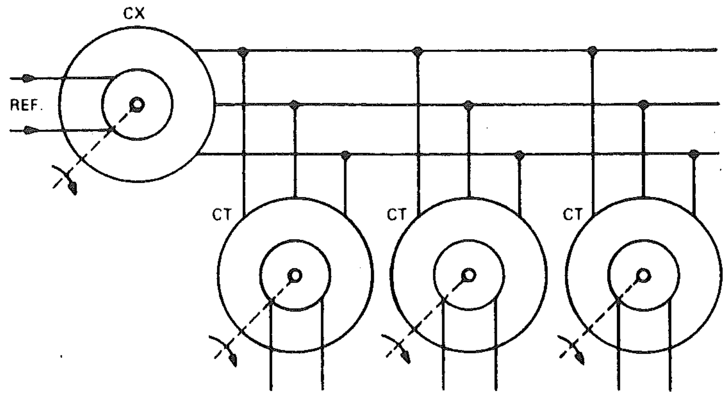

Fig. 6-3 A single CX driving several CTs.

would otherwise be a difficult problem into one that can be carried out by relatively unskilled personnel.

The procedure to be adopted in the case shown in Fig. 6-3 would be as follows:

Using the API connected across the CX, check the angle represented by the CX data with no load and an exactly balanced load approximating in value the impedances of the three CTs in parallel, if there are differences the CX winding impedances are not matched and should be balanced.

At the first CT station the angle should be checked with no load and with the CT connected. If the readings are not the same, balancing resistors should be inserted between the main signal wires and the CT to give the correct angular reading when the API is connected across the CT.

The same procedure must be repeated at each CT station.

The API should be used to check the angles at each CT station and at the CX; if the balancing has been carried out correctly they should all be the same.

Use of the API for checking Scott connected transformers

Since the API can take as inputs either synchro or resolver form signals it can be used for checking the accuracy of Scott connected transformers.

The test method is shown in Figure 6-4. The input to the transformer can be conveniently provided by a Synchro CX. The two inputs to the API are connected; one to the synchro side of the transformer and the other to the resolver output side. Appropriate loads are applied to the resolver outputs.

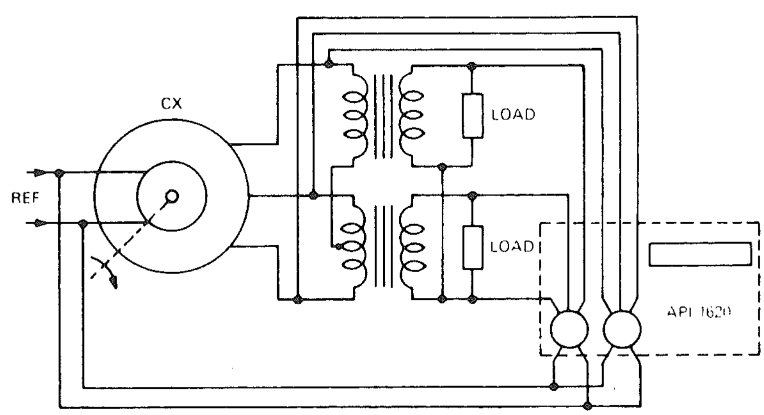

Fig. 6-4 The API 1620 used for checking Scott-connected transformers synchro to resolver.

By rotation of the CX the input and output angles can be compared for various input angles. Fig. 6-4 shows the arrangement being driven from a Synchro CX, an alternative arrangement showing the transformer being activated from resolver form signals is shown in Fig. 6-5.

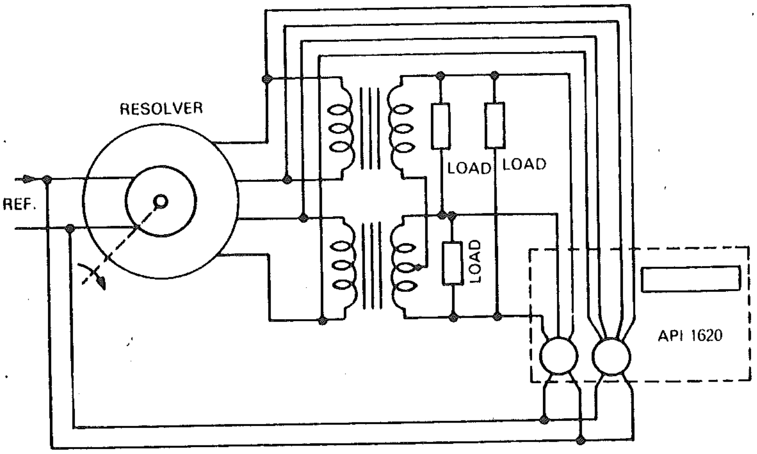

Fig. 6-5 The API 1620 used for checking Scott-connected transformers resolver to synchro.

This application again demonstrates the usefulness of the two input connectors to the API, all the changes necessary to compare the input with the output are carried out by means of the switches on the API front panel.

Checking tuned systems using the API

It is often convenient to drive several CTs from a single CX; when this has to be done it may be necessary to use tuning to reduce the loading effect of the CTs. The tuning is carried out by putting capacitors across the CT windings. If the CTs are local to each other three capacitors will be sufficient to tune all the CTs which are in parallel. If there are long interconnecting wires between the CTs it will be better to tune them individually. In either case the angular accuracy can be upset if the tuning is not correct.

If the three windings of the CTs were driven from zero impedance voltage sources, capacitors can be put across the windings to reduce the current taken from the source and since the windings are from voltage sources no angular errors will be caused if the capacitors are not equal. There would simply be more current supplied by the generator to one circuit than the other.

In the real situation the CX is not a zero impedance source; Fig. 6-6 shows a typical system with the values of the impedances shown.

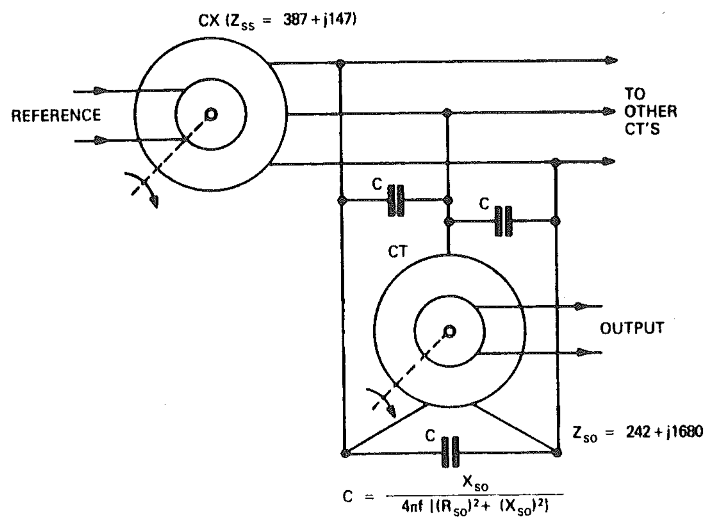

Fig. 6-6 A CX driving tuned CTs. The values of Z are for a typical 115 volt system.

When the windings of the CT are being driven from source impedances which are not zero it is usual for the impedances to be equal or balanced. In this circumstance, i.e. with non zero source impedance it is much more important that the capacitors should be accurately chosen. The reason is that there will be differences in voltage drop in the source impedances if the circuits are not similar.

The required condition is that each winding should be tuned to be resistive and that when this is done the dynamic impedances i.e. L/CRs of each of the tuned circuits should be the same.

As will be apparent there is plenty of scope for angular errors to be caused by tuning. The API can be used to measure any inaccuracy so caused; all that is necessary is to connect the API across the synchro which is being tuned whereupon it will indicate the inaccuracies and thus enable the appropriate corrections to be made.

When resistors are used for balancing there is a danger that quadrature signals will be produced. The API has a high precision phase sensitive detector and an internal synthetic reference generator. This means that the readings on the API will not be influenced by large quadrature signals. The phase sensitive detector in the real system being tested may not be as immune to quadrature signals and reference phase shift as the API itself. Separate checks should therefore be carried out to observe the quadrature signals produced by any out of balance in the tuning capacitors. This can be done by observing the CT rotor outputs on an oscilloscope and rotating the CT shaft for minimum in-phase component. Tests should then be carried out to determine the effect of these quadrature voltages in the presence of any reference phase shift likely to be encountered. (See the section on "Quadrature errors and reference phase shift" in chapter 4.)

Use of the API in general engineering

Apart from applications in fields of engineering where the use of synchro data transmission systems is established the API can be used in general engineering where angular measurements have to be made to a few minutes of arc. Before use can be made of the API, signals must be available in synchro or resolver form. Synchros giving a few minutes of arc accuracy are not very expensive and most mechanical engineers would have no difficulty in coupling a shaft angular movement to rotate a synchro. Having done this there are six key points about the API which could make it more useful than existing angular measuring devices. They are:

The API gives a clear, easy to read digital display of the angle.

The displayed angle can be remote from the shaft being measured.

The API can provide outputs which are in BCD form suitable for driving printers to provide hard copy of measurements.

One API can be used sequentially to display the outputs from several synchros. (This means that the cost per channel is not high).

The API can provide pure binary output data representing the angle for making tapes for computer inputs.

The BCD or Binary outputs can be decoded to give signals corresponding to particular angles. This point would probably be more appropriate to the use of synchro to digital converters in mechanical engineering where the decoders could give outputs corresponding to particular shaft angles to replace cams etc.

APPLICATIONS OF THE DIGITAL VECTOR GENERATORS DTM 1716 AND DTM 1717

Introduction

Function of the Digital Vector Generators

The DTM 1716 and DTM 1717 are modular devices which make use of the precision sine and cosine multipliers developed for the synchro and resolver conversion products. The modules are equivalent to high speed, high accuracy, solid state sine/cosine potentiometers. The function of the Digital Vector Generators is illustrated in Fig. 6-7.

The input angle covers the full revolution 0 to 360° and the digital input word defining this angle is presented in parallel natural binary form. For the 14 bit DTM 1716 shown in Fig. 6-7, the LSB represents 0.022°. The speed at which the digital input can be changed is limited only by the slew rate of the internal operational amplifiers and in a typical converter this would be about 40 microseconds for the output to reach 0.1% of the correct value in a case where the input required the maximum output change.

The input V_i is the one that makes the important difference between this module and a digital sine/cosine look-up followed by a D/A converter. V_i is an analog bipolar input which

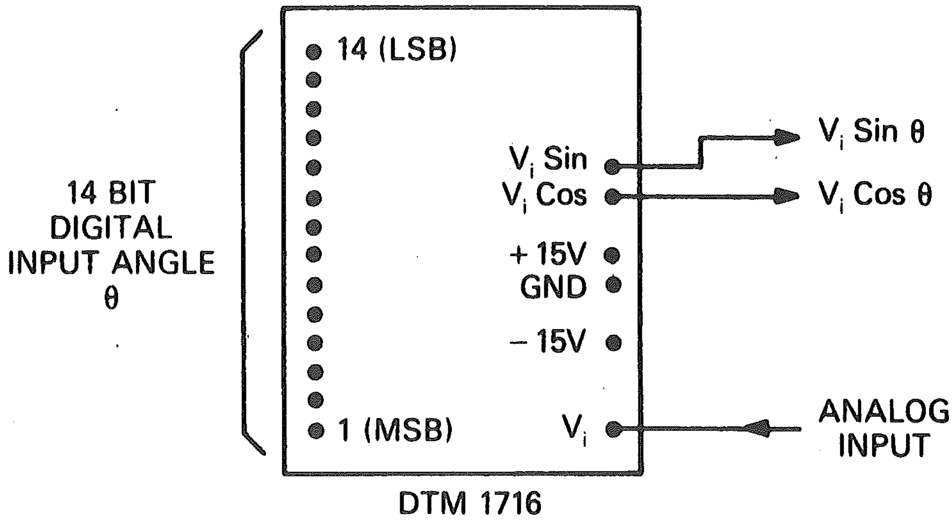

Fig. 6-7 Function of the DTM 1716 and DTM 1717.

provides the multiplying input for the two outputs. The speed with which V_i can be changed is again determined by the bandwidth of the internal operational amplifiers. A typical module will give full power output to 0.1% accuracy at frequencies up to 8 KHz. The relatively high speed of the digital and analog response means that it is possible to multiplex either the digital input and outputs for a common V_i or to multiplex V_i and the outputs for a common angle, or a combination of the two, where both inputs and outputs are multiplexed. As with any multiplexed system, it will only be applicable when the data inputs are changing slowly relative to the scanning speeds.

DTM 1716 and DTM 1717 anti-glitch circuit

The DTM 1716 and 1717 provide analog outputs V_i Sin θ and V_i Cos θ from the analog input V_i and the digital input θ. At the major transition points of 0°, 90°, 180° and 270° the internal operational amplifiers are required to slew through large voltages. The effect of this is to produce glitches on the outputs at the major transition points in much the same way as a conventional Digital to Analog converter. For most applications these glitches can be removed by simple smoothing circuits on the outputs. However in applications where the smoothing is not an acceptable solution, sample and hold amplifiers such as the Analog Devices type AD 582 can be used to remove the glitches.

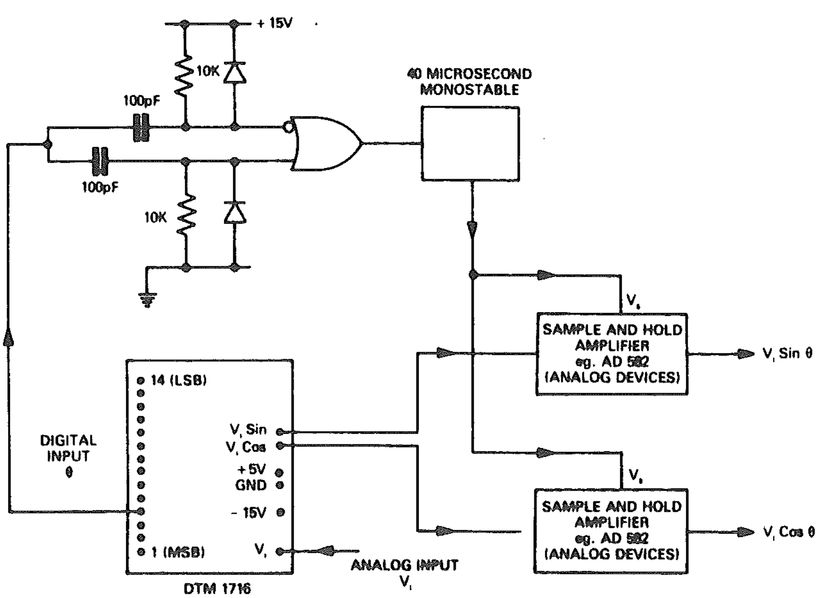

Fig. 6-8 Circuit for removing the major transition glitches in the Digital Vector generator outputs.

The AD 582 is put into the hold mode by a monostable which is triggered by either the 0 to 1 transition or the 1 to 0 transition of bit 4. Fig. 6-8 shows a typical arrangement using sample and hold amplifiers to remove the output glitches.

Applications of the Digital Vector generators

High resolution stepping motor drive

Stepping motors are used in many applications for providing precise position control without feedback. The usual method of driving the motors is with square waveforms which are shifted with respect to each other by 90 degrees.

There are two problems which result as a consequence of the nature of the drive. These are:

(a) The possible angular positions are discrete.

(b) The pulsed nature of the waveforms under constant rotational velocity conditions can give rise to torsional vibrations.

Both of these above problems can be overcome if instead of using square waveforms shifted by 90 degrees, voltages or currents are used which are proportional to $V\sin\theta$ and $V\cos\theta$. Thus for each rotation of θ through 180 degrees, the stepper motor angle will move *smoothly* through half a cycle which may be 0.72 degrees up to 15 degrees according to motor type. Fig. 6-9 shows how the DTM 1717 can be used for this purpose.

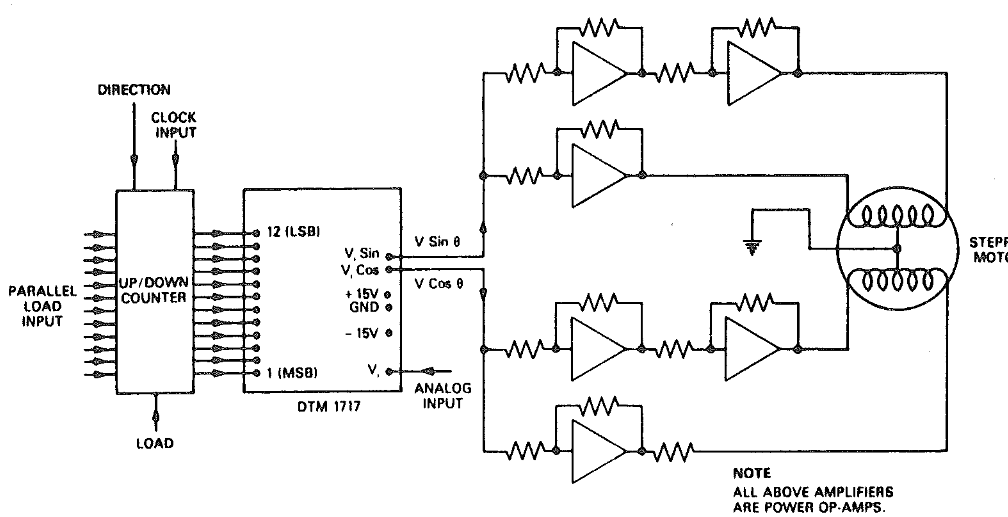

Fig. 6-9 A system for providing continuous positional control using a stepping motor and a Digital Vector Generator.

The precision with which the poles are interpolated is theoretically equal to the DTM 1716 accuracy which is ±3 Arc. Mins. However, the dimensional inaccuracy of the poles and the fact that the reluctance paths do not accurately vary sinusoidally limits the practical achievable positioning accuracy to much less than this. The lower resolution DTM 1717 (12 bits) is more than justified by the technique. In practice it is found that the resolution is for all practical purposes continuous and the positioning can readily be obtained to 1/200th of the step angle.

The torsional vibration at high speed is completely eliminated with no reduction in the maximum slewing speed.

The technique described is capable of extremely high accuracy angular control limited only by the mechanical precision and stability together with the law of reluctance variation with angle.

Polar to cartesian co-ordinate transformation for X Y Plotter inputs
Most plotters are of the *X Y* or *X Time* variety i.e. the mechanical means of moving the pen are by means of gantry systems where the motions are at 90° to each other. The DTM 1716 Digital Vector Generator can be used to convert such *XY* plotters to take R,θ inputs (see Fig. 6-10).

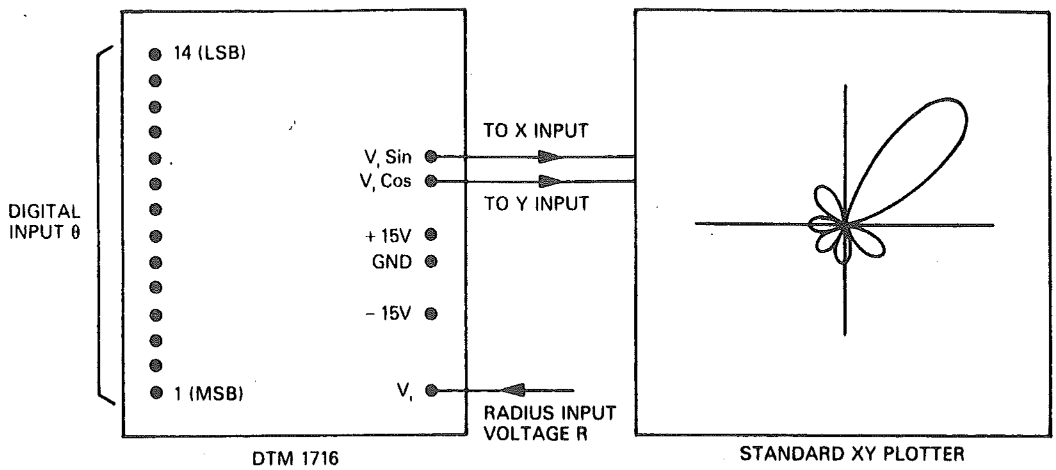

Fig. 6-10 DTM 1716 used to provide polar to cartesian coordinate conversion for X Y plotter.

Low-frequency precision amplitude quadrature oscillator
For testing the frequency and phase response of low-frequency control loops it is often necessary to use oscillators with quadrature outputs. The frequency involved can be very low; for control loops in chemical manufacture, for example, the periods may be hours. For such applications and also for higher frequencies the Digital Vector Generator provides an ideal solution. Fig. 6-11 shows how the DTM 1716 can be used as a quadrature oscillator to produce the required resolved components of the response.

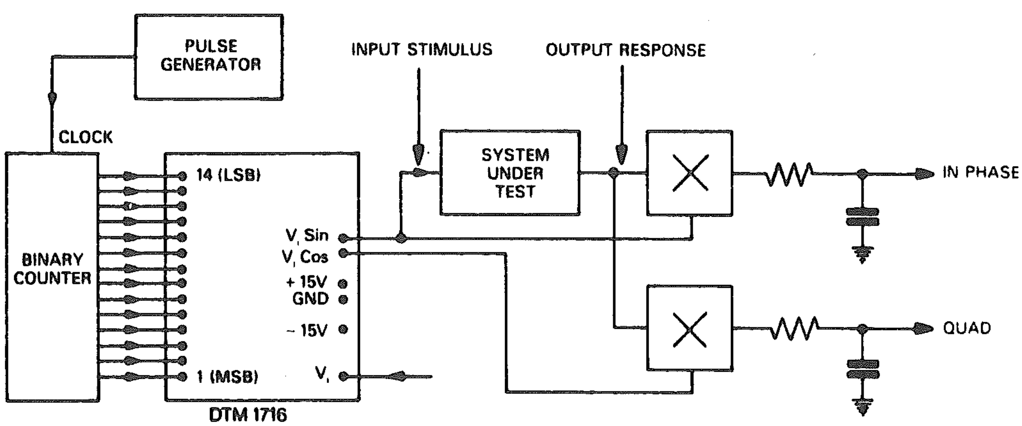

Fig. 6-11 DTM 1716 used as a low frequency quadrature oscillator to test system response.

Co-ordinate rotation by the use of Digital Vector Generators
In the control of guns, missiles etc, it is often necessary to obtain the co-ordinates of a point relative to one set of axes from inputs which are the co-ordinates of the point relative to a rotated set of axes. With more use of numerical control in industry and the use of robots for welding etc. this type of problem is no longer limited to the aviation and military field. Fig. 6-12 shows a very simple part of a manipulator where the problem of axis rotation would be involved. In the diagram of Fig. 6-12 there are four angular movements. The jib "A" can be rotated in azimuth and elevation relative to the base. The link "B" is able to hinge at point C and also to rotate about its new axis. (Such linkages are often required for example in positioning a small grinding wheel relative to a surface).

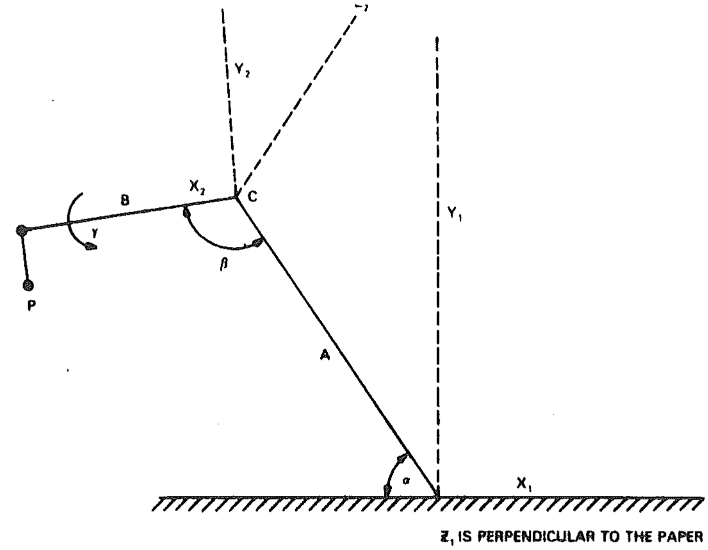

Fig. 6-12 Part of a manipulator.

In Fig. 6-12 the point P will remain fixed relative to the co-ordinate system $X_2Y_2Z_2$ but the co-ordinates $X_2Y_2Z_2$ can rotate due to the angles β and γ relative to the co-ordinates $X_1Y_1Z_1$. Because of this the positioning of P by adjustment of the angles α, β and γ will require the use of axis rotation on the positioning control data. Fig. 6-13 shows the simple problem and Fig. 6-14 shows how this is implemented by the use of the Digital Vector Generator. The technique can be extended to cover any number of rotations.

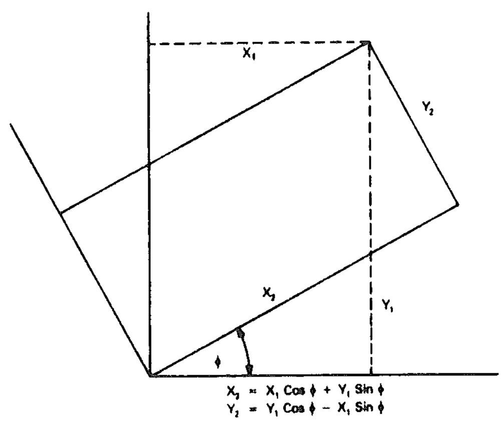

Fig. 6-13 Co-ordinate rotation.

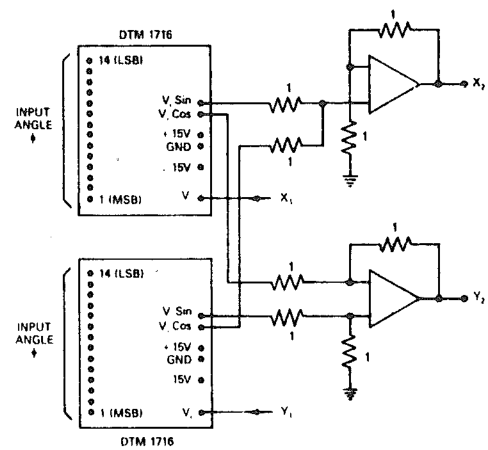

Fig. 6-14 Implementing co-ordinate rotation using DTM 1716.

Digital angular shift of resolver form angular data

In the measurement and control of angles resolvers are often used. In such cases it is often desirable to add or subtract an angle leaving the data in resolver form. The use of two Digital Vector Generators permits this angular shift.

Fig. 6-15 shows how this can be accomplished.

High resolution spectrum analysis

In many branches of engineering it is often required to obtain the power frequency spectrum of a time waveform, e.g. vibration of structures, airframes, engines, bridges, etc. Other examples occur in medicine, EEG waveforms and ECG waveforms, in the study of surfaces and also for finding hidden periodicities.

The DTM 1716 Digital Vector Generator provides a simple solution to this problem. Fig. 6-16 shows how with a digital converter, two analog multipliers and simple *low pass* filters, a

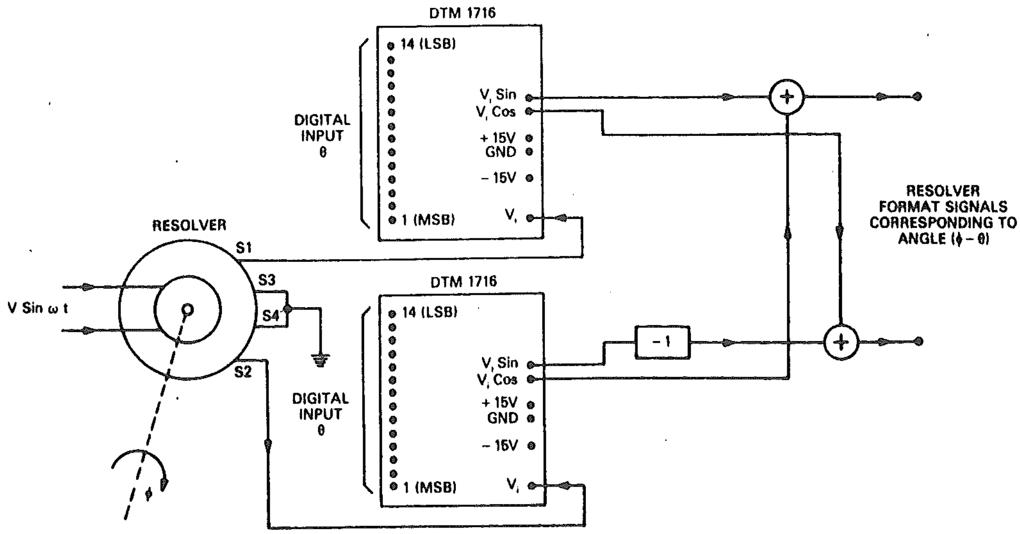

Fig. 6-15 Obtaining an angular shift in resolver format data.

very high resolution spectrum analysis can be accomplished. By multiplying the input to be analysed by Sin $2\pi ft$ and Cos $2\pi ft$ the energy of the input frequency is shifted so that the low pass filters can be used instead of the more usual bandpass filters. This has the important advantage that extremely high resolution can be obtained by simply reducing the low pass filter bandwidth. Since the oscillator is a *pulse* oscillator, digital frequency division methods can be used to count down from a standard high precision crystal oscillator. This leads to the further advantage of precise control of the effective filter mid frequency.

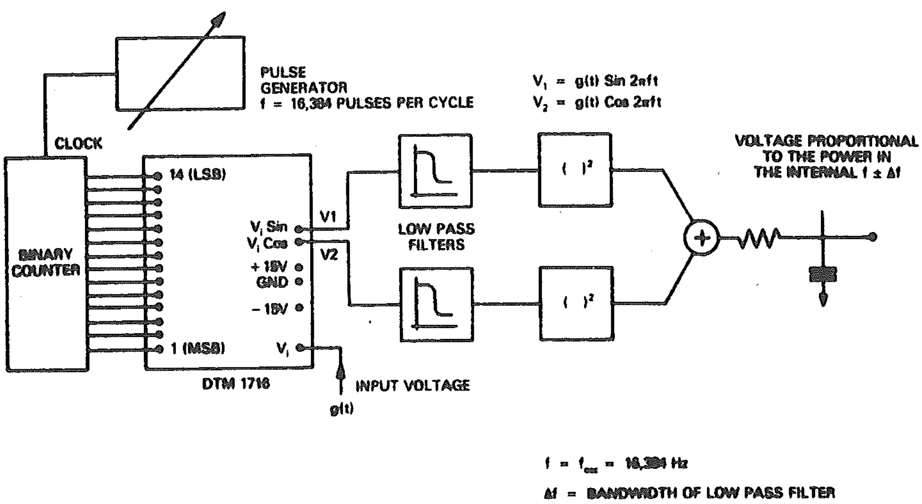

Fig. 6-16 High resolution spectrum analysis using the DTM 1716.

In Fig. 6-16 the input waveform from which the power spectrum is required is g(t), an analog voltage between ± 10V. Multiplication of this waveform by *Sin 2 πft* causes the energy in the waveform between $f - \Delta f$ and $f + \Delta f$ to be shifted to lie between $-\Delta f$ and $+\Delta f$. (The energy produced near $2f$ is removed by the low pass filter.) This part of the input energy is passed to the squaring multiplier. Two channels sine and cosine, are used for the case in which *g(t)* contains periodic components. Without the use of the two channels, the periodic component would produce an output dependent upon its phase. The use of two channels avoids this problem.

Very narrow band pass filtering

In some communication systems very narrow band-pass filters are required. The facility of being able to multiply by sine and cosine can be used to produce very narrow band pass filters, with a mid frequency determined by the frequency of a pulse oscillator. The method is similar to the narrow band spectrum analysis, except that extra sine/cosine multiplication converts the filtered signal back to its original frequency. Usually, the filter will be used in high frequency systems where the input of the system has been reduced in frequency by standard heterodyning methods to lie within the bandwidth of the Digital Vector Generators.

Use of the DTM 1716 module in Nuclear Magnetic Resonance testing of crystals
An unusual application of the DTM 1716 has been its use in the Nuclear Magnetic Resonance testing of crystals. By altering the digital input to the DTM 1716, the added magnetic field can be rotated through 360 degrees using fixed coils. The field due to the magnet can thus be modified in direction as well as magnitude by the fixed coil currents. Fig. 6-17 shows how this rotation is obtained.

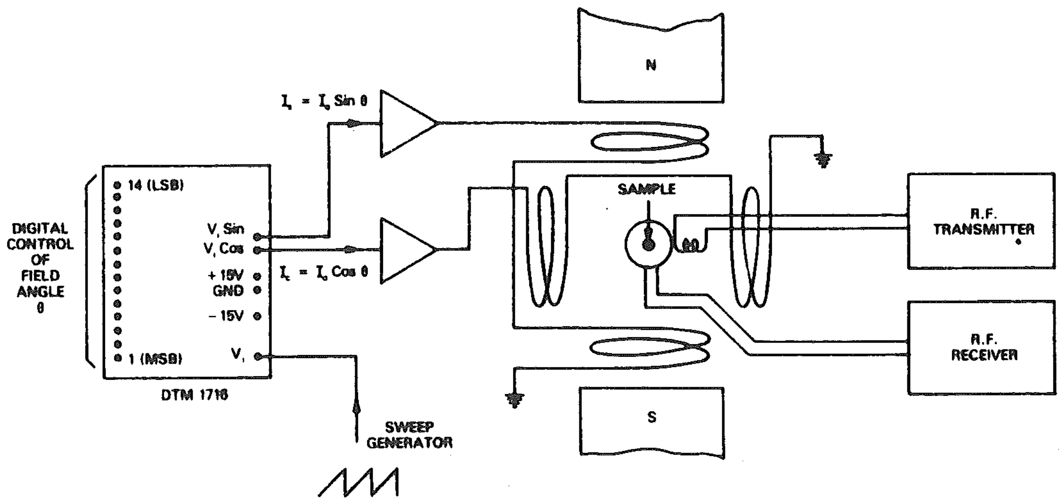

Fig. 6-17 Rotation of the sweep field in an NMR system by the use of the DTM 1716.

APPLICATIONS OF THE SYNCHRO/RESOLVER TO D.C. CONVERTER TYPE SAC 1763

Introduction

Function
The SAC 1763 converts synchro or resolver information into a DC voltage representing angle, where ± 10 volts represents ± 180°.

The unit is based on the SDC 1700 Tracking converter and therefore it possesses many of the features of this unit such as ability to resistively scale the inputs, velocity output, tolerance of reference frequency etc.

Relationship between input and output
The relationship between the input and output of the SAC 1763 is shown in Fig. 6-18.

Sometimes it is necessary to obtain a different relationship between the input and output of the converter. Reversing the connections to S1 and S3 produces the relationship shown in Fig. 6-19. Reversing the reference connections produces the relationship shown in Fig. 6-20.

Sometimes it is required that the output of the converter is 0 to 10 volts representing 0 to 360 degrees. This can be done with the circuit shown in Fig. 6-21.

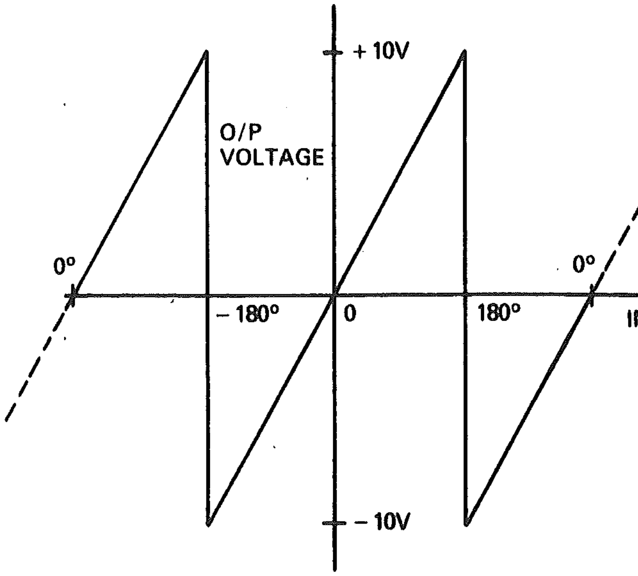

Fig. 6-18 Relationship between input and output of SAC 1763.

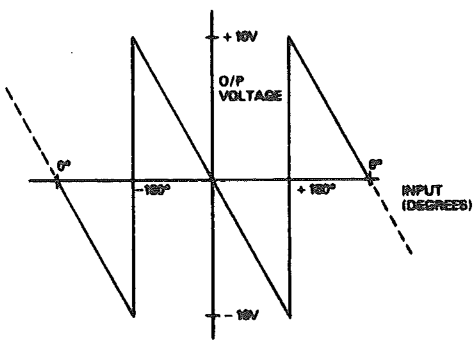

Fig. 6-19 Relationship between input and output with S1 and S3 reversed.

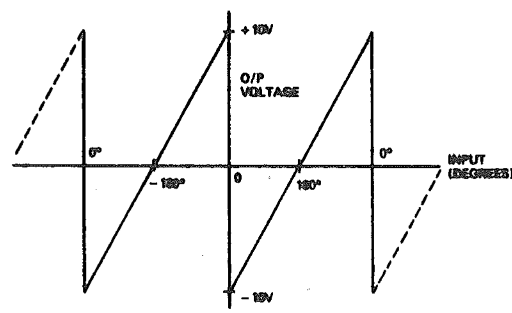

Fig. 6-20 Relationship between input and output with reference reversed.

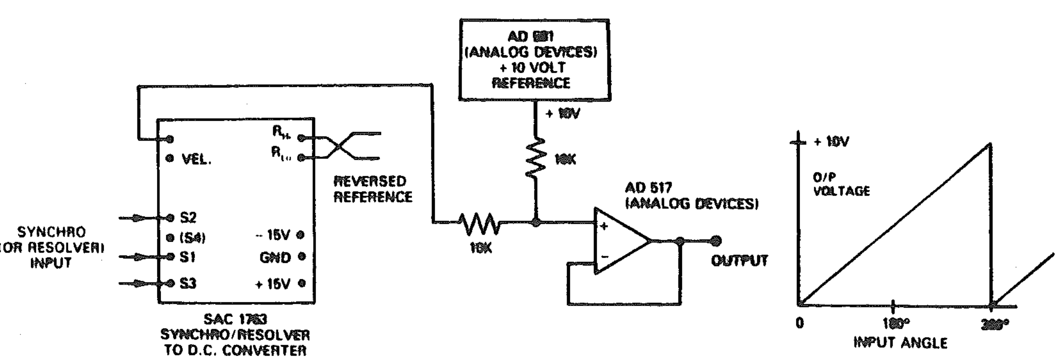

Fig. 6-21 Circuit for converting output of SAC 1763 to 0 to 10 volts for 0 to 360 degrees.

Applications of the SAC 1763

Recording of synchro or resolver information

One use for the SAC 1763 is for recording angular information on X-Y plotters or FM tape recorders. This information could typically have originated from navigational equipment such as a gyrocompass. This is illustrated in Fig. 6-22.

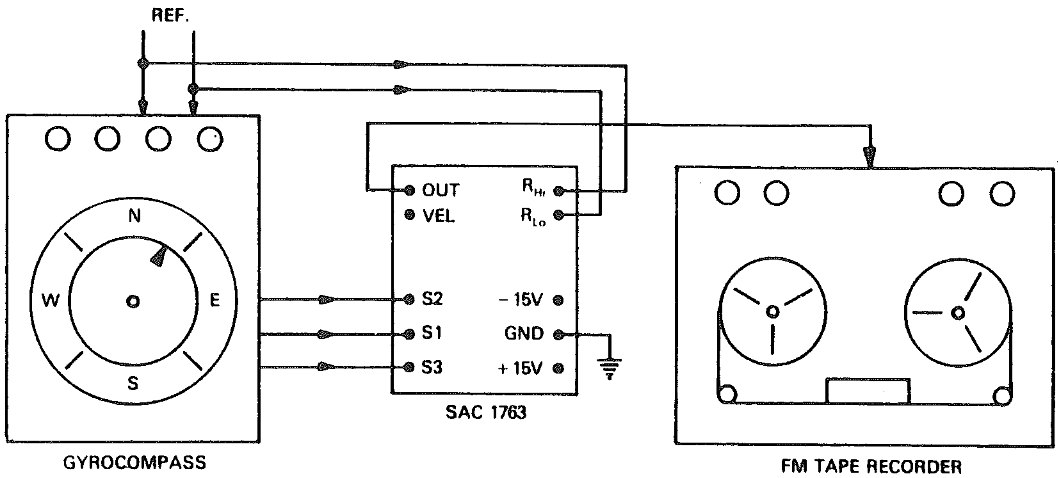

Fig. 6-22 Recording the output of a gyrocompass using the SAC 1763.

Using the DC voltage output of the SAC 1763 in a Servo system

A common use for the synchro to DC converter is for producing a DC voltage from a synchro or resolver transmitter which is already in the system as part of a control loop. It is a simple matter to connect the three synchro wires and reference to the SAC 1763 in order to get a DC voltage which is proportional to angle. This voltage can then be used for a variety of purposes; it can be fed to analog comparators for limit detection or mixed with other analog voltages to give simple analog operations as functions of the angular motion. See Fig. 6-23.

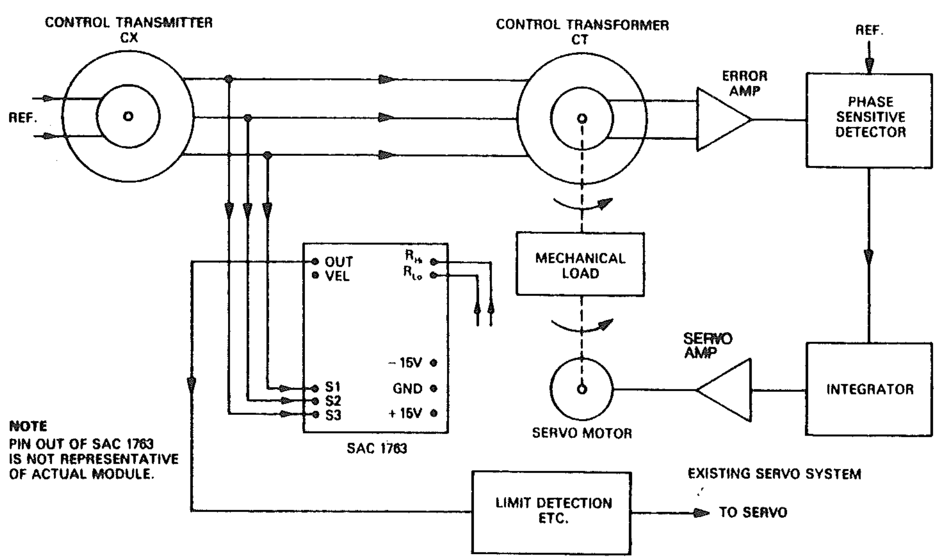

Fig. 6-23 The conversion of synchro data to DC voltage in a servo system.

Using the SAC 1763 in a servo where the input is analog

The SAC 1763 can be used in a servo system where the input is a DC voltage representing the angle. See Fig. 6-24. Note that the availability of the velocity voltage output from the

SAC 1763 eliminates the need for an electromechanical tachometer to make the system more stable.

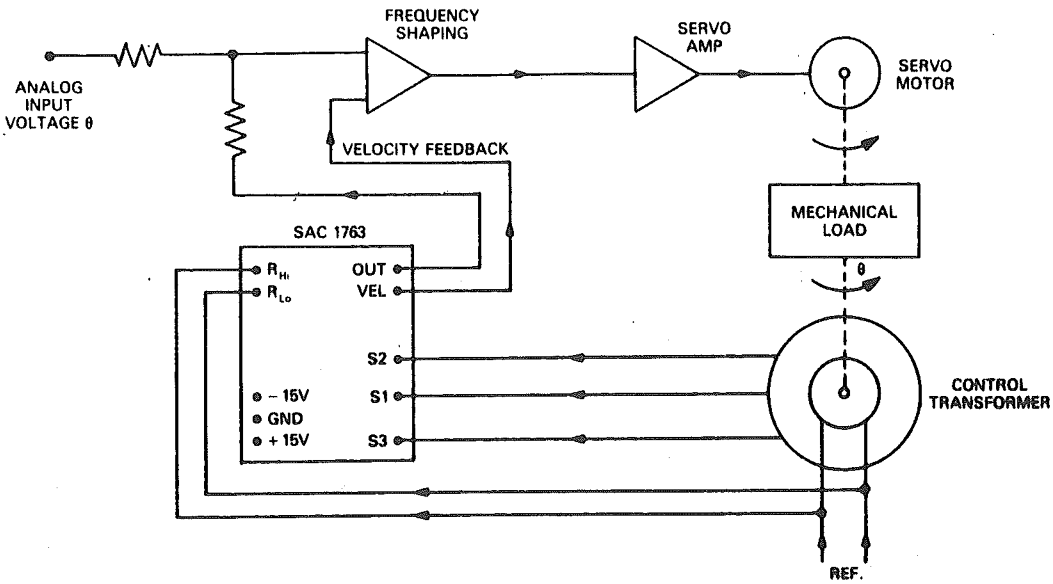

Fig. 6-24 An analog input servo system using the SAC 1763.

SOLID STATE DUMMY DIRECTOR DDU1714

What is a "Dummy Director"?

The term "Dummy Director" is naval in origin and refers to a piece of test equipment which is used for setting up and checking mechanical servo mechanisms. Although primarily designed for naval use, Dummy Directors are used in many other instances where it is necessary to investigate some of the characteristics of mechanical servo systems.

How did the peculiar term "Dummy Director" originate? In order to understand this fully, let us examine the simplest possible naval fire control system such as that shown in Fig. 6-25.

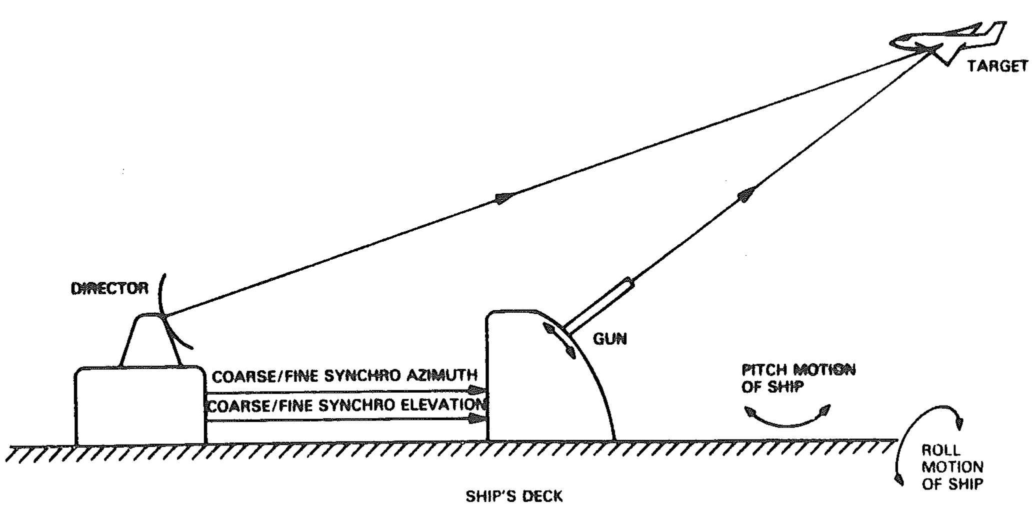

Fig. 6-25 A simple naval fire control system.

In the system shown above, the "Director", which is the device used to track or lock on to the target, transmits the target's azimuth and elevation angles to the gun mounting servos by means of synchro signals. This enables the gun to automatically align itself with the Director and consequently keep trained on the target.

The Director, which is usually mounted on top of the ship's superstructure, can take various forms. On larger vessels, the Director is normally a tracking radar mounted on top of the superstructure but on smaller vessels, such as Fast Patrol Boats, an optical, optronic or television system may be used.

Let us consider the case where the Director is locked on to the target. The pitch and roll motion of the boat, which is sinusoidal in nature, will cause the synchro inputs to the azimuth and elevation servos on the gun mounting to be modulated sinusoidally in order to keep the gun aligned with the director. This means that it is very important for the gun servos to respond accurately to sinusoidally modulated inputs. Because the gun servos are normally set up when the ship is not at sea and consequently not undergoing pitch and roll motion, a piece of test equipment is needed which can generate the sinusoidally modulated synchro signals normally supplied by the Director. This piece of test equipment, not unnaturally, became known as a Dummy Director. Its use in the case of the simplified fire control system is illustrated in Fig. 6-26.

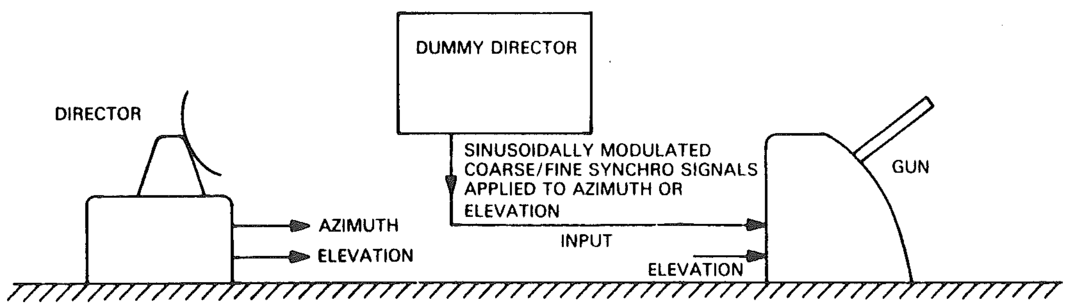

Fig. 6-26 Using a Dummy Director in place of a Director to test naval Gun servos.

The Fire Control System described above is far too basic to ever be a practical proposition; even the earliest Fire Control Systems had some form of ballistics computer interposed between the director and the gun. However, the example does illustrate the fundamental requirement for a Dummy Director which still exists even on the most sophisticated naval weapons systems.

Electromechanical Dummy Directors

The original Dummy Directors were purely electromechanical in operation and were constructed from cams, gear wheels and mechanical servo loops driving synchro transmitters. The output of the unit, which was taken directly from a synchro transmitter, could be modulated sinusoidally, rotate at constant velocity or go to an angular position demanded by the handwheel control.

These electromechanical Dummy Directors, of which thousands are still in use today, suffer from disadvantages which cause them to lose votes in the most popular piece of naval test equipment competition!

Disadvantages of electromechanical Dummy Directors

1) The units, by virtue of their electromechanical construction, are extremely heavy and are not easy to move around the confines of a warship.

2) In order to change some of the parameters, it is necessary to adjust cams and levers and in fact with some of the two speed output units, gear wheels need to be changed in order to alter the coarse/fine ratio.

3) It is difficult to set up the parameters with any degree of repeatability. For example an indicated constant velocity rotation of 10°/sec may vary by 1 or 2% between repeated settings.

4) The dynamic range of the selectable parameters is limited.

5) The electromechanical nature of the units require them to undergo constant maintenance.

6) It is difficult to use the unit to check for backlash in a servo system when the unit itself exhibits backlash.

In view of the foregoing, the introduction of a versatile solid state Dummy Director is long overdue.

The solid state Dummy Director

The solid state Dummy Director, type DDU1714, is a microprocessor controlled instrument and all of the parameters are selected from the keyboard on the front panel which is shown in Fig. 6-27.

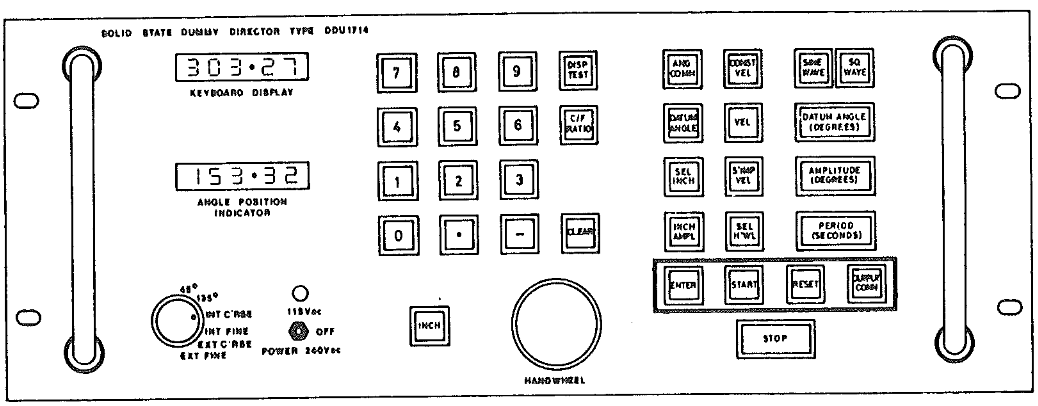

Fig. 6-27 The front panel of the Solid State Dummy Director type DDU1714.

The DDU1714 has coarse/fine two speed synchro or resolver as well as opto-isolated digital outputs with any ratio selectable from between 2:1 and 63:1.

The internal timing of the unit is crystal controlled and consequently the velocity and Simple Harmonic Motion modes exhibit a very high degree of accuracy and repeatability.

There are seven modes which are user selectable from the front panel. These are:

1) *Angular Command*
The output can be commanded to go to any angle selected on the keyboard.

2) *Constant velocity*
The output can be made to 'rotate' with a velocity selected on the keyboard.

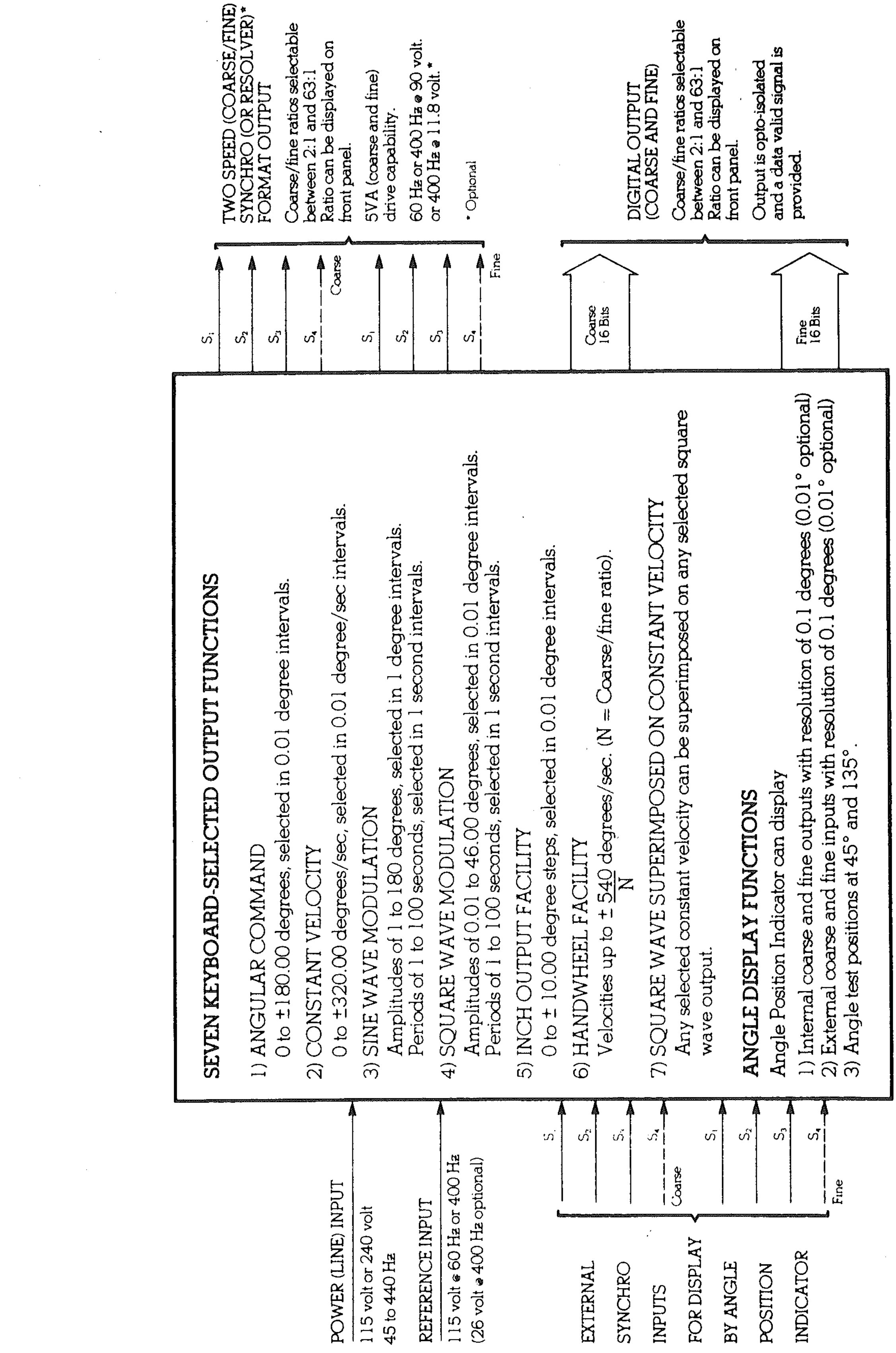

Fig. 6-28 Summary of inputs, outputs and available modes of the DDU1714.

3) *Sine Wave modulation (Simple Harmonic Motion)*
The output can be made to change sinusoidally with an amplitude and period selected on the front panel.

4) *Square Wave modulation*
The output can be modulated with a square wave of which the period and amplitude are selected on the front panel.

5) *Inch Facility*
The output can be made to change by a fixed angle selected on the keyboard.

6) *Handwheel Facility*
The handwheel can be used to cause the outputs to change at varying velocities. The more the handwheel is turned, the greater the output velocity.

7) *Superimpose velocity on square wave*
Any selected square wave can be superimposed on any selected velocity.

All of the above facilities as well as the inputs and outputs of the DDU1714 are listed in the table in Fig. 6-28.

Applications of the Solid State Dummy Director Type DDU1714

Testing large naval servo systems
The fire control system shown in Fig. 6-25 is too simplified to be used in actual practice. A computer, called the predictor, is usually at the heart of the fire control system and the arrangement might be as shown in Fig. 6-29.

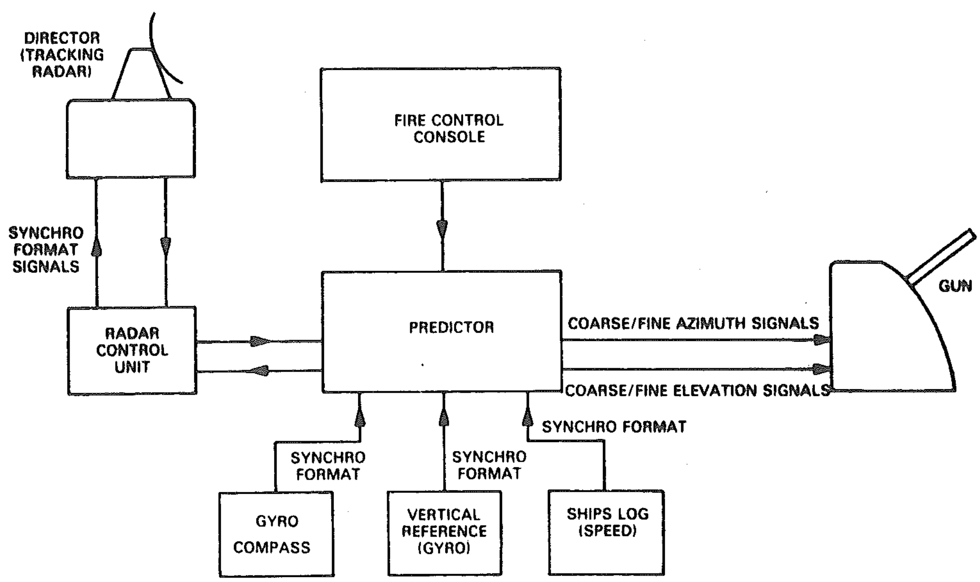

Fig. 6-29 A naval fire control system.

In a system such as that shown in Fig. 6-29, it is necessary to "tune" the gun servo system to suit the roll and pitch characteristics of the ship. This means inputting synchro information into the gun mounting servo and modulating it sinusoidally with a period and amplitude which are as near as possible to the ship's natural roll and pitch motion. The internal servo loop error can then be taken from the output of the servo's phase sensitive detector and displayed on a chart recorder. The resultant trace will indicate how well the gun mounting is following the input demand and consequently how well it would follow the target in the presence of the pitch and roll motion of the ship. Adjustments can then be made to the servo loop circuitry in order to achieve the best possible accuracy at that particular period and amplitude. The method of carrying this test is to use the DDU1714 in the "Sine wave" mode in order to provide the stimulus for the servo system. Mountings of this type usually operate on a coarse/fine synchro principle and when responding to a sine wave stimulus such as this, the mounting usually remains under control of the fine channel (see the section on "Coarse/fine synchro and geared systems" in chapter I). Therefore it is important to measure the error signal with respect to the fine channel when performing tests such as these. The DDU1714 can provide for any coarse/fine ratio between 2:1 and 63:1, the change being effected by means of a thumbwheel switch. The method of performing these tests and the resultant chart recorder trace is illustrated in Fig. 6-30.

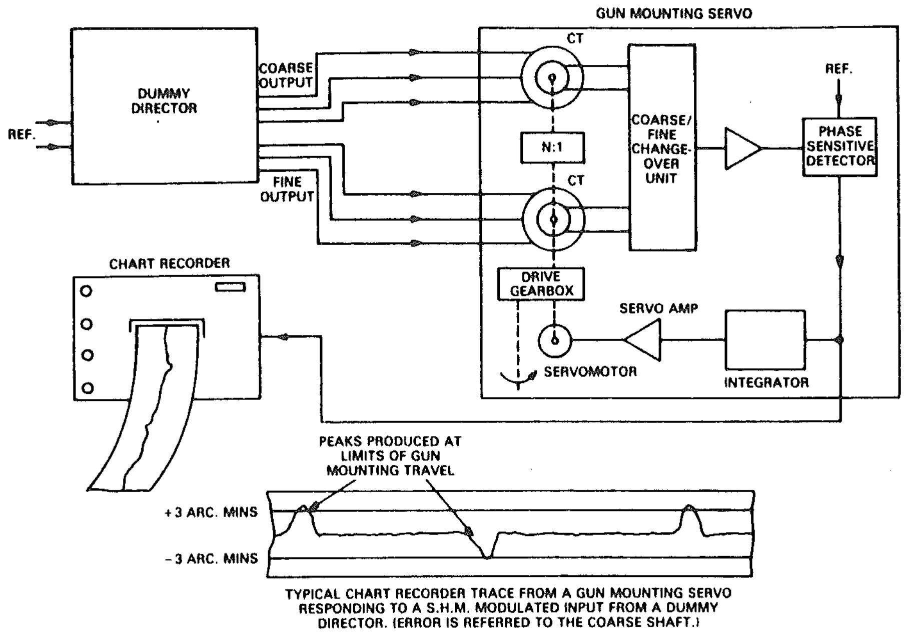

Fig. 6-30 Using the DDU1714 to provide sinusoidal inputs to a gun mounting.

Other tests which the DDU1714 can perform on the mounting using the same test set up as shown in Fig. 6-30 are as follows:

1) Response of the servo to a constant velocity input:
Servo systems which work on a type 1 principle will exhibit a velocity lag error which can be measured using the Dummy Director in the "Constant Velocity" mode and the same configuration shown in Fig. 6-30. The resultant chart recorder trace is shown in Fig. 6-31.

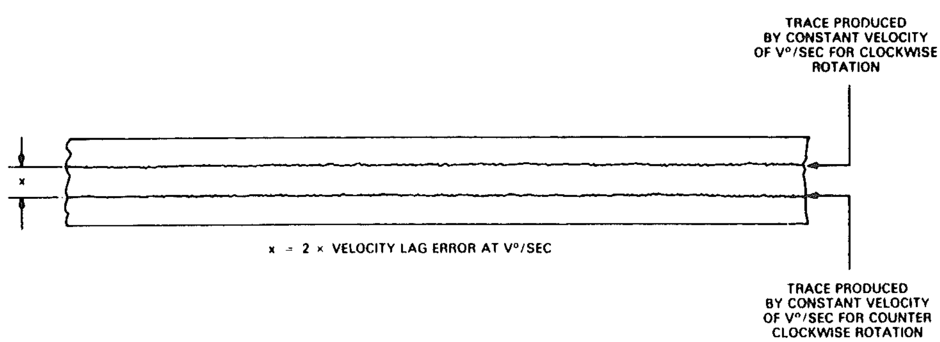

Fig. 6-31 Chart recorder trace showing velocity lag error for a constant velocity input.

Another use of the constant velocity input provided by the "Constant velocity" mode of the DDU1714 is for examining any errors which may exist in the mechanical part of the servo mechanism. For example, cyclic errors in any of the gear wheels or specks of dirt or swarf in a gear box. Fig. 6-32 shows a good constant velocity trace produced by the chart recorder compared with that of a system in which an error is present every 360° in the fine gearing of a 9:1 ratio system.

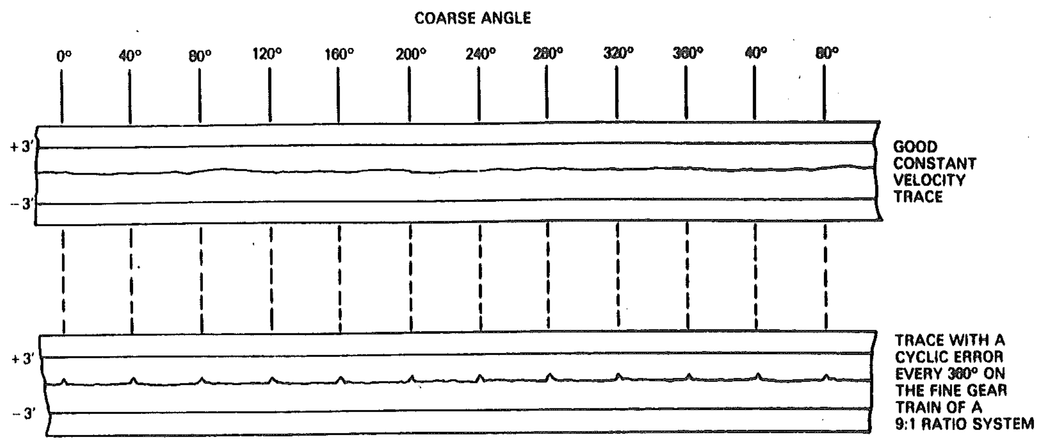

Fig. 6-32 Using the constant velocity mode of the DDU1714 to check for errors in the mechanical part of a servo system.

2) Run-in time:
A step input of say 60° is applied to the synchro inputs of the mounting and the time taken for the error to reduce to zero (i.e. the time taken for the mounting to reposition itself to the new angle) is measured. This facility is easily accomplished using the "Angular Command", "Inch" or "Square wave" mode and the test gives an indication of how quickly the gun can track from one target to the next.

3) Response to a step input:
The synchro input to the mounting is modulated by a square waveform of very low amplitude (e.g. 0.2°). The resultant chart recorder output will then provide information on how well the servo responds to step inputs. This test can be performed with the Dummy Director in the "square wave" mode.

4) Response to a step input superimposed on a constant velocity:
The "Superimpose square wave on constant velocity" mode of the DDU1714 means that the response of the gun to step inputs of small amplitude superimposed on the constant velocity can be determined.

The type of fire control system shown in Fig. 6-29 is generally used for the control of the smaller calibre guns with relatively high rates of fire. For the larger guns the system shown in Fig. 6-33 is often used.

As can be seen in this system, the servo loop is closed through the predictor itself by means of coarse/fine synchro transmitters on the gun mounting and synchro to digital converters in the predictor. The Dummy Director can be used in this instance to simulate the director inputs into the predictor. The error present during tracking with sine wave or constant velocity inputs can be recorded at various points in the servo system as before. See Fig. 6-34.

Checking the performance of a Director
The director itself, when tracking a target, also requires a servo system which can respond satisfactorily in the presence of the pitch and roll motion of the ship. The DDU1714 can be used to provide the sine wave modulated synchro stimulus and the response of the director can be monitored in a similar fashion to that of the gun mounting tests.

Testing naval retransmission units
Much of the synchro information generated in ships is distributed by means of retransmission systems. These are often electromechanical and their function is to provide a number of channels of the same information from one synchro input. For example, a retransmission system is used to distribute the synchro format stabilisation data from the gyro to the many stations requiring it around the ship. A retransmission system used for this purpose is illustrated in Fig. 6-35.

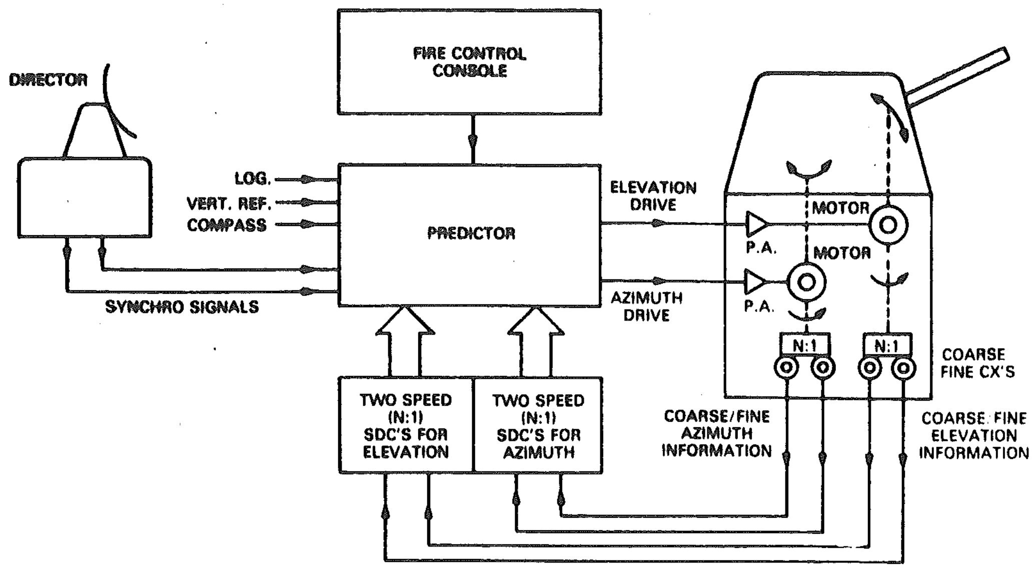

Fig. 6-33 A fire control system where the servo loop is made through the predictor.

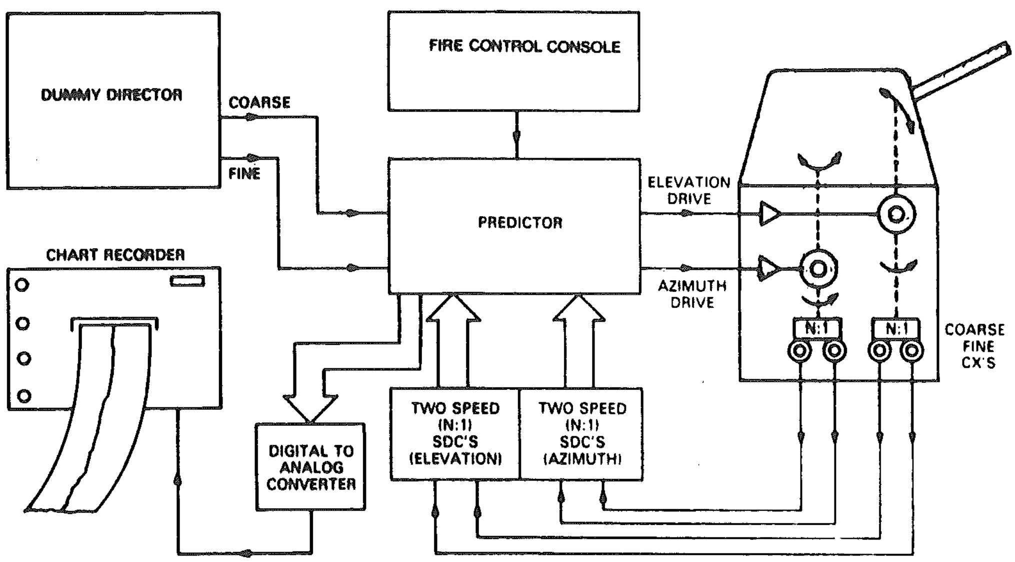

Fig. 6-34 Using the DDU1714 Dummy Director in a fire control system where the servo loop is closed through the predictor to check the elevation servo.

Because the gyro in Fig. 6-35 is fixed in space and the ship is rolling and pitching in a sinusoidal fashion, the retransmission unit servo mechanisms will need to respond satisfactorily to sinusoidally modulated inputs in much the same way as the gun mounting. The DDU1714 used in the "Sine wave" mode can therefore be used to check the response of these servos. This is illustrated in Fig. 6-36.

Checking the backlash in servo system gearboxes

The DDU1714 provides an extremely accurate angular reference and by the very nature of its solid state construction is backlash free. It can therefore be used to ascertain the backlash present in servo system gearboxes. A good example of this type of application is its use with gun mountings.

The gun barrel is positioned at a fixed angle and the DDU1714 handwheel control is used to increase the demand angle very slowly until movement in the gun barrel is detected by using say a laser beam. At this point the input demand is stopped and the existing angle, as

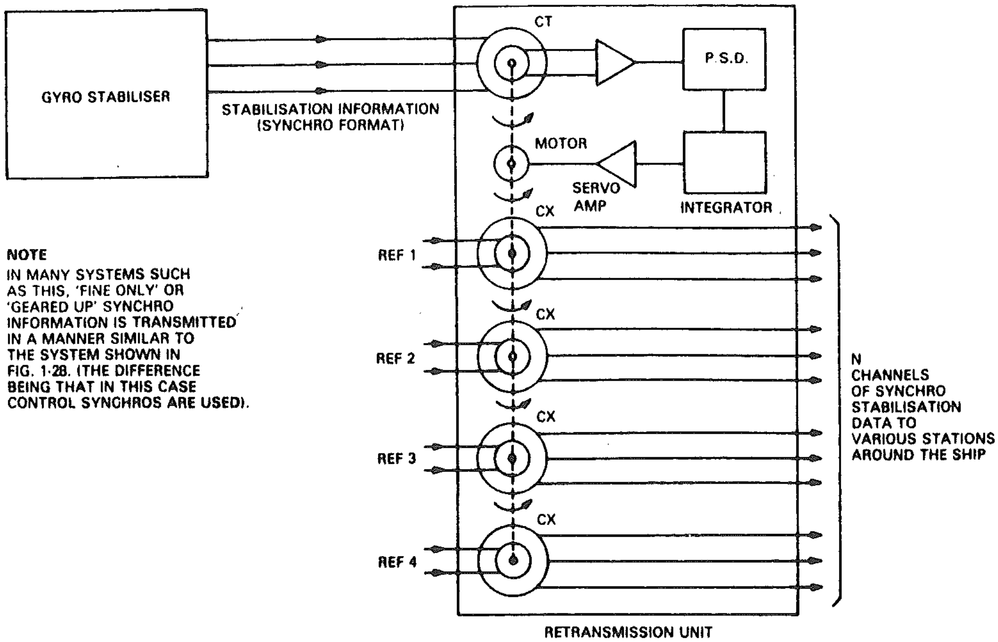

Fig. 6-35 A retransmission system distributing stabilisation information.

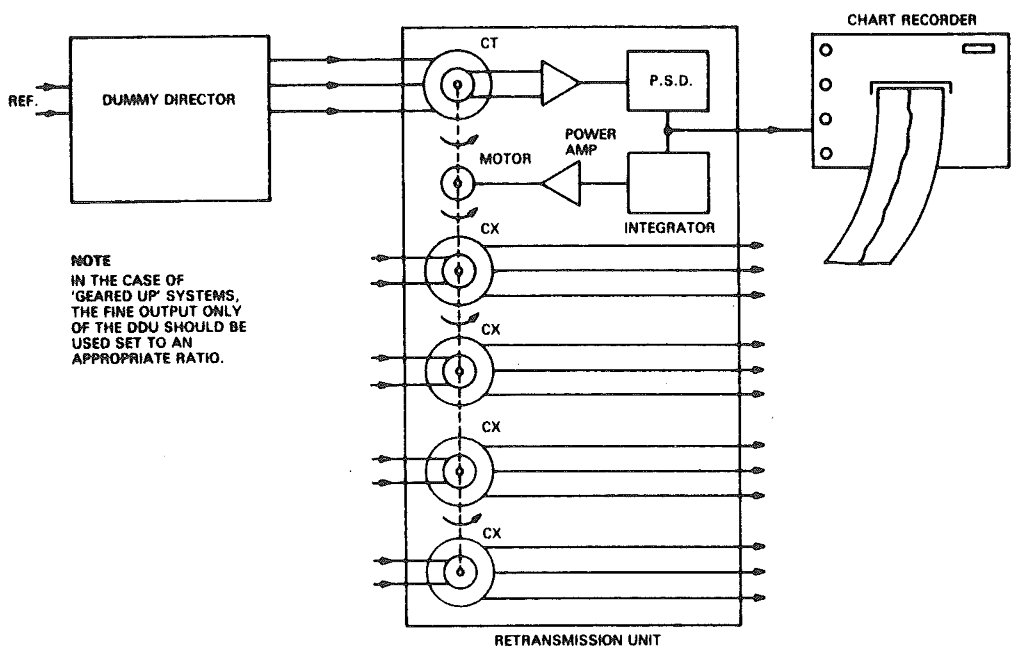

Fig. 6-36 Checking the response of retransmission unit servo mechanisms.

indicated on the Angle Position Indicator of the DDU1714, is compared with the original angle. The difference will be an indication of the backlash in the gear train. This is illustrated in Fig. 6-37.

Non-naval servo systems
So far we have dealt mainly with naval systems, the reason for this being that Dummy Directors were originally designed for naval use. However as can be seen from the above applications, there is no reason why the DDU1714 should not be used with any servo system where the inputs are in synchro, resolver or digital form. A few examples of other applications would be in aircraft systems, steel mills, machine tool and robot control and ground radar.

Testing Digitally controlled machines
The digital output of the DDU1714 means that the unit is not only limited to synchro input

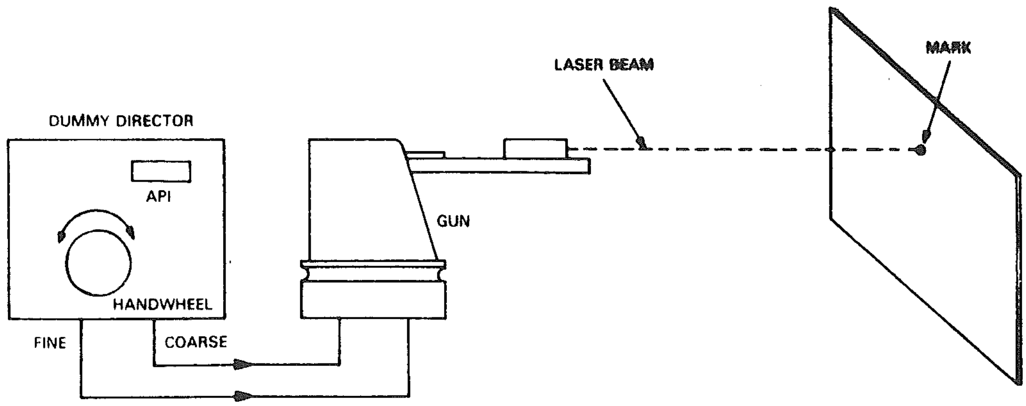

Fig. 6-37 Using the DDU1714 to check for backlash in a gear train.

servo systems. The unit can be used very successfully to provide the stimulus for digitally controlled servos such as those sometimes encountered in machine tool control.

The digital outputs from the DDU1714 are 16 bits wide and opto-isolated on both the fine and the coarse channels and although the maximum velocity referred to the coarse channel of 320 degrees per second may not be sufficient in some cases, the effective speed of 320 × 63 or 56 Revs per second provided by the fine channel when used at a ratio of 63:1 should be suitable for most purposes. See Fig. 6-38.

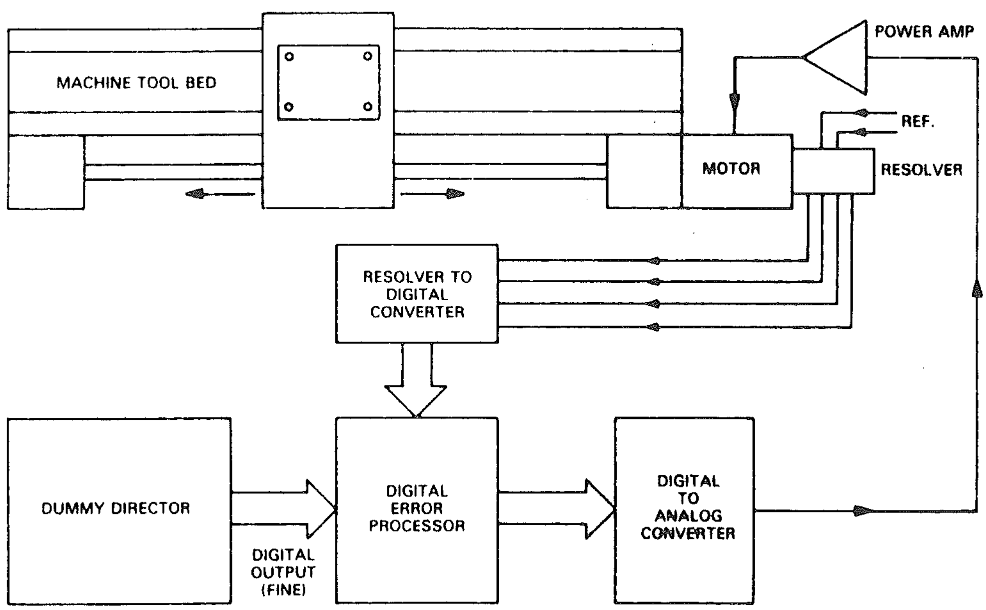

Fig. 6-38 Using the DDU1714 with a digitally controlled machine tool system.