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Microprocessor Controller in Closed Loop Angular Position Servo System

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ABSTRACT

Integrated command, control and communication systems are based on the use of computers for digital data processing. The weapon system platforms like missile launchers are given input command for accurate and quick positioning in azimuth and elevation. The technologies of sensors, signal conditioning and associated solidstate electronics have moved from analog to digital. Therefore, a position controller has to be designed around a microprocessor in embedded form for usage in such servo control systems. This paper highlights the basic approach for such design and problems which need to be tackled during actual implementation.

1. INTRODUCTION

Integrated command, control and communication (IC^3) systems are entirely based on extensive use of computer for digital data processing of target information in weapon systems. The weapon system platforms like missile launcher have to respond automatically to the angular position command in azimuth and elevation. Closed loop angular position servo systemsutilised in the launcher platforms are designed around a reliable microprocessor to produce very accurate position control output.

2. MICROPROCESSOR CONTROL SYSTEM

Figure 1 shows functional elements of a digital closed loop system. It may be seen that for any stable and accurate closed loop servo system, the position information and velocity component feedback are essential. In a classical system, the implementation was more by way of hardware, but in the case of systems where microprocessor is used, it is more by way of software. A typical microprocessor-based closed loop control system is shown in Fig. 2.

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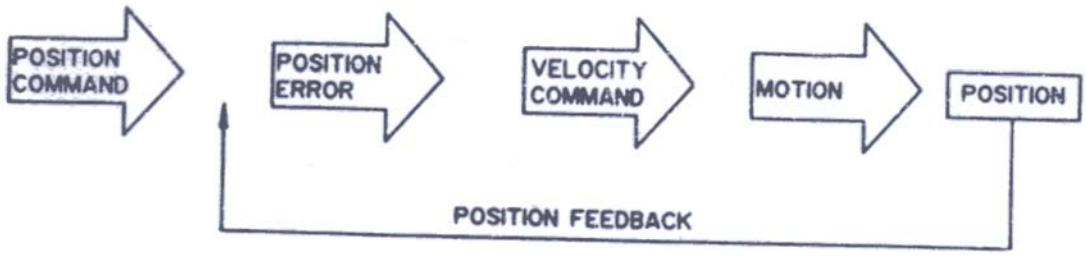

Figure 1. Functional elements of a digital closed loop system.

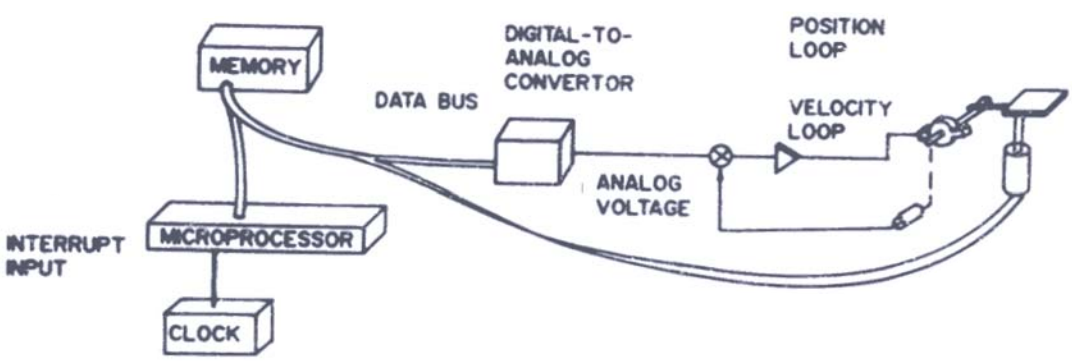

Figure 2. Microprocessor-based closed loop control system.

It can be seen that the command is received by the system periodically in certain time increments. These signals tell the drive to move through some angular rotation. The position measuring transducer indicates the position of the load and this information is subtracted from the digital word representing the command. The information from the transducer is in the form of a negative feedback so that subtracting the position information from the digital command yields the difference between drive position and the position command. The digital position difference is called FOLLOWING ERROR. This can be held in an accumulator. The digital number held in the accumulator is then converted by a digital-to-analog convertor (DAC) to an analog voltage proportional to the position difference. This voltage generates motion in a motor or drive mechanism, generating a new load position which attempts to reduce the FOLLOWING ERROR.

Many types of position transducers can be used in the system. Common transducers include optical encoders, resolvers and synchros. Although synchro has been a favourite in the military equipment, absolute optical encoders which give direct digital information corresponding to the angle position, seems to be used in the recent past, because it is easy to interface with digital computers.

The velocity feedback comes from a tachometer attached to the motor. In the velocity loop, the voltage from DAC is combined with the voltage produced by the tachometer. The tachometer voltage indicates the motor speed and is a form of negative feedback. Subtracting this feedback from DAC voltage yields a voltage proportional to the difference between achieved and commanded velocity. An amplified form of this voltage drives the positioning motor directly. DAC output voltage amplifier and motor/tachometer are called velocity loop. In the recent past, it has become possible to obtain velocity feedback from position feedback information by using certain electronics circuit configurations where mechanical problems as well as signal-noise problems associated with tachometers can be avoided.

2.1 Flow Chart for Software Development

The microprocessor hardware needs software support, since the position loop servo system using microprocessor would be based on software. A typical flow chart for a position loop execution is given in Fig. 3. The loop can execute once every few milliseconds based on the sampling time set for the system. It is a usual practice to write such a software in the machine language by using relevant set of instructions provided for the chosen microprocessor.

2.2 Choosing a Sampling Rate, Gain and Bandwidth

In a closed loop system, the control accuracy is dependent on the position loop gain. The higher the position loop gain, the lower the FOLLOWING ERROR for a given velocity command. In a position servo, the FOLLOWING ERROR produces an actual error in the position, so the gain must be as high as possible to keep the FOLLOWING ERROR to a minimum. For any rotation, quickly from one position to another, maximum speed and minimum travelling time are very important. At high velocities, position loop gain may be reduced at the expense of position accuracy. so that the positioning motor drive accelerate limits are not exceeded.

Velocity loop gain imposes an upper limit of permissible position loop gains. Position loop gain is proportional to the position loop bandwidth. From feedback control theory, to be stable, a system must have velocity loop bandwidth at least 3 to 4 times higher than the position loop bandwidth. The velocity loop bandwidth is determined by the motor drive combination and the presence or the absence of system mechanical resonances near the bandwidth of the motor drive. However, the servo designer must pick a position loop gain, that is high enough to give a low FOLLOWING ERROR for accurate positioning and low enough to avoid the system unstability. The position loop bandwidth must be calculated from the position loop gain to determine how often a position command must be sent to the motor. This helps in choosing appropriate sampling rate.

It has been determined empirically that the sampling frequency should be at least 7 times greater than the position loop bandwidth to maintain stability.

2.3 Self Checking of Operation of the Loop

Often several checks of the computer operation are made within a servo position software loop to verify that the computer itself is operating correctly. Checking the computer before sending the position command reduces the chance for errors. Error detecting devices are generally kept as simple as possible so that their reliability is greater than that of a computer. One such error detecting device is called a 'watch dog timer', which monitors and acknowledges the computer clock signal. This device detects such general error conditions as the computer not responding to a clock signal or doing nothing but responding to the clock. The latter condition might occur if

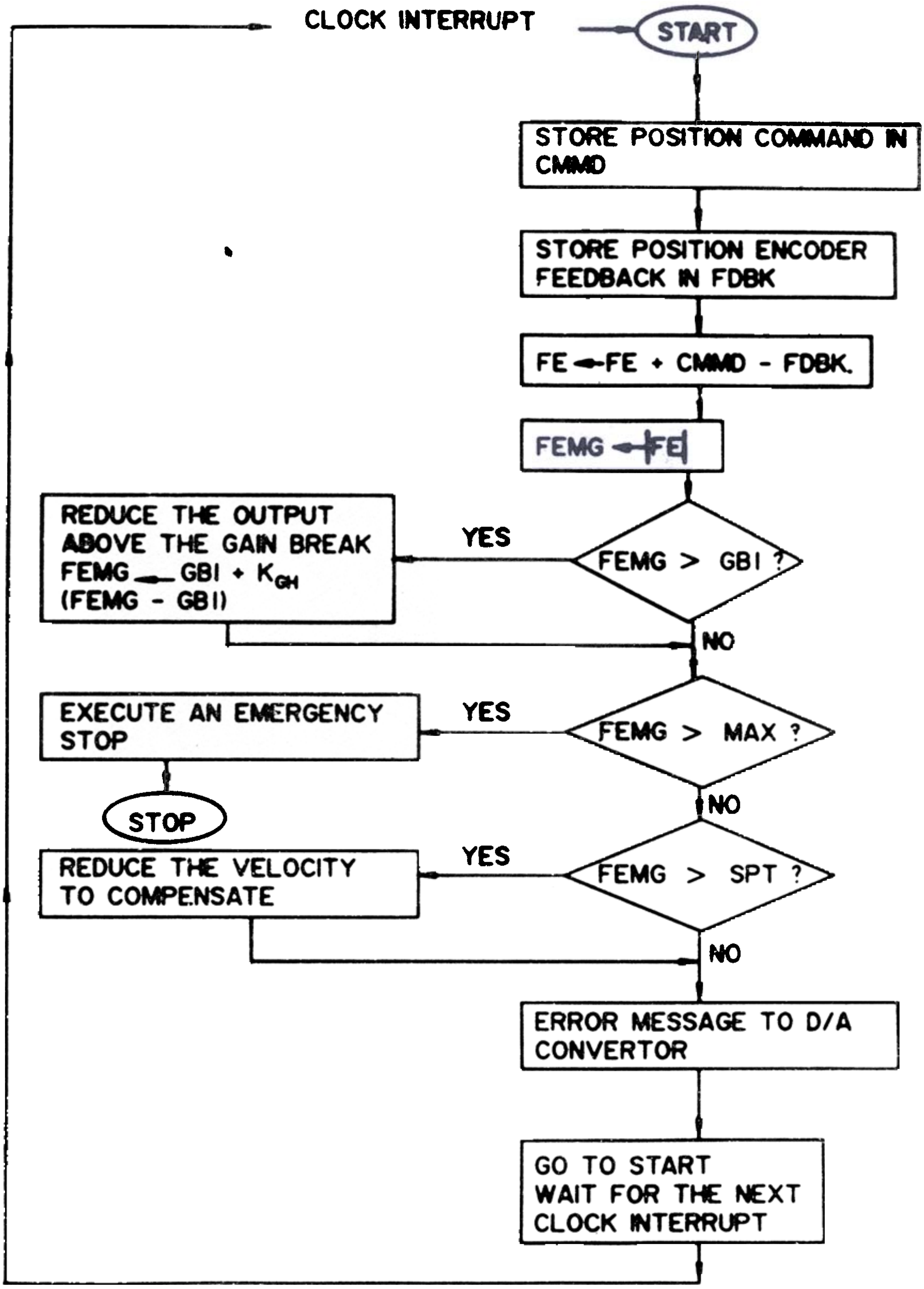

Figure 3. Flow chart for a position loop execution.

Key to abbreviations :

CMMD - Memory location containing the most recent position command; D/A - Digital-to-analog convertor voltage that drives the motor; FDBK - Memory location containing position encoder feed back; FE - Memory location containing the most recent following error; FEMG - Memory location containing following error magnitude; GB1 - Following error at the gain break point; K_{GH} - Reduced gain above the gain break; MAX - Default following error limit that stops the system; SPT - Following error limit that slows velocity commands programme memory is changed or faulted by electrical noise so that the microprocessor sends only clock pulses out on the data lines.

The position loop software can be written so that the first task in the loop is to acknowledge the watch dog timer signal. If the timer sees no response from the computer within the preset time frame after a clock signal, it would produce an error signal and perhaps stop the programme execution. Schematic diagram of a typical watch dog timer is shown in Fig. 4.

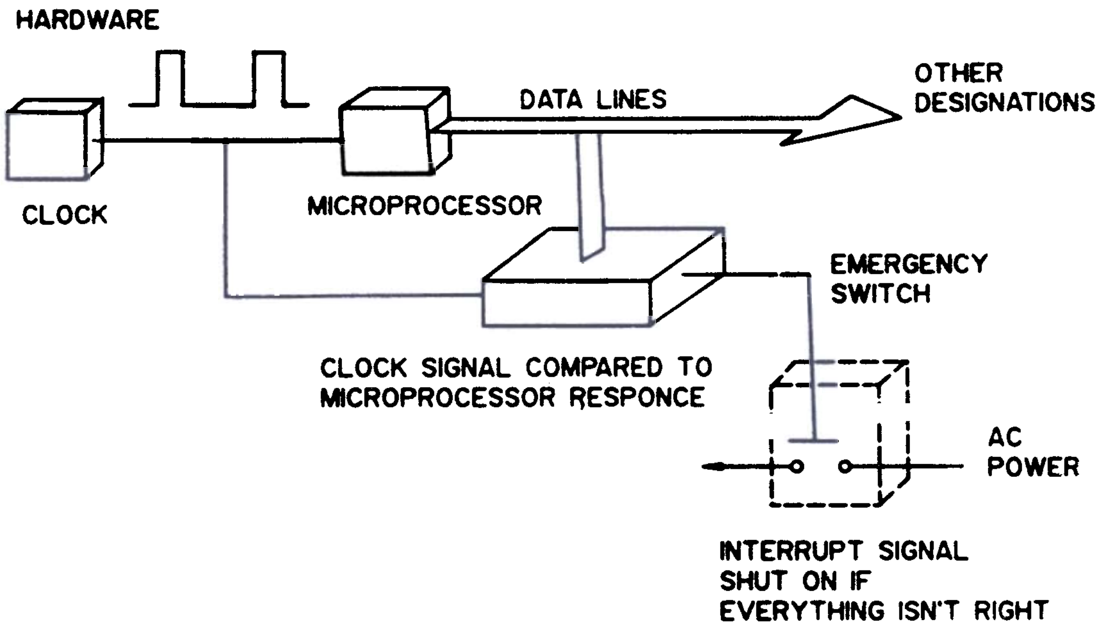

Figure 4. Schematic diagram of a watch dog timer.

3. TECHNICAL SPECIFICATIONS

The system consists of a contιυι console comprising of front panel displays and controls, the microprocessor controller and power supply integrated into a standard rack, position feedback (digital signal in serial mode) from optical encoders which withstands military environment of large vibrations/shocks and extreme temperature, dust and humidity, etc., pressure feedback from pressure transducers for stability purposes, and other inputs like vehicle offset angle, horizontality error angle, etc., for local error corrections. A feedback GO type signal is also required for use as interlock element at a remote point. The schematic diagram of the proposed system is shown in Fig. 5.

The relevant characteristics of the various inputs, outputs and processing are given in the following sections.

3.1 Inputs

(i) Input angle information, 16-bit serial natural binary in twos compliment, TTL compatible with MSB signed, secant corrections for accurate tracking of the target at the radar end;

(ii) Vehicle axis offset angle through manual (thumb-wheel or key pad) input of angle of north direction with respect to vehicle axis as reference;

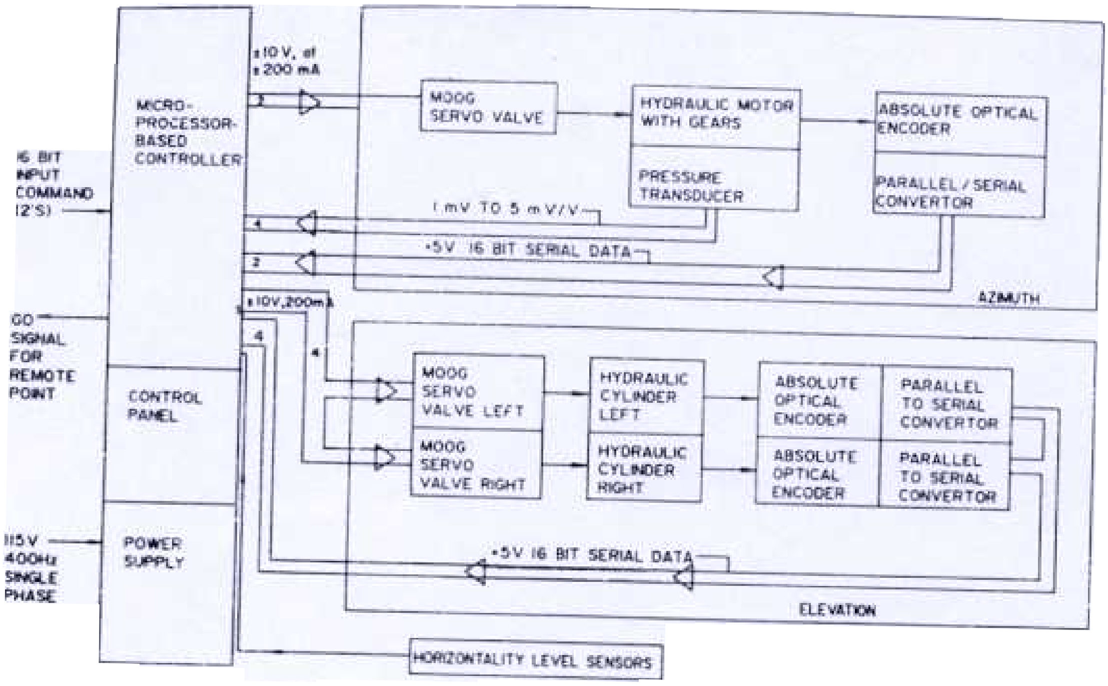

Figure 5. Schematic diagram of a microprocessor-based closed loop control system.

(iii) Horizontality error angle, either automatic or manual (thumb-wheel or key pad) from the horizontality sensor;

(iv) Debarred angles (interlocks) manually by or through a set of limit switches to bar certain sectors of angles for safety;

(v) Load position angle — automatic input from optical encoder in serial digital format, TTL compatible, mounted on load rotation axis (two speed synchros may be used as alternative);

(vi) Hydraulic pressure (azimuth only), automatically from hydraulic pressure transducer mounted near the hydraulic motor (requires excitation voltage and signal conditioning at transducer end or in the control console); and

(vii) Limit switches, etc. as required.

3.2 Outputs

(i) Three analog ± 10 V DC outputs for current-driven electro-hydraulic servo valves from 0-200 mA, which may consist of step signal for slewing and controlled signal for tracking;

(ii) Automatic store command to bring platform at azimuth and elevation in azimuth (0°) for transportation mode;

(iii) Displays of load position angles and error angles of load position on control console; and

(iv) GO condition seen as error angle within 10 minutes of an arc.

3.3 Processing

(i) Digital processing of error command from various input angles, feedback angles and local angles, providing GO condition angle accuracy of positioning (10 minutes of an arc);

(ii) Signal conditioning of all inputs;

(iii) Other in-house functions like routine self test, transducer function tests, indicator function checks and taking care of safety interlocks, etc.;

(iv) Driving displays on front panel;

(v) Total processing cycle time within 100 ms, i.e., less than command input rate;

(vi) Flexible software amenable to easy changes based on failures/faults noticed during hardware/software evaluation of the prototypes and user-friendly as far as possible; and

(vii) Hardware based on proven devices used in rugged environments of temperature, dust, humidity and mechanical hazards like vibrations, bumps, etc., (JSS : 55555 as guideline) protection from unwanted EMI.

3.4 Control Panel

The control panel has

(i) Provision for operating the platform in different modes such as 'manual' (usually locally), 'auto' (usually remotely), 'stow' (for bringing the system in transportation mode, i.e., azimuth angle 0° and elevation angle 0°);

(ii) Provision for display of load azimuth and elevation angles (degree and minutes), load azimuth and elevation error achieved (within 10 minutes in track mode), state of horizontality, limits of debars angle, fault indication, etc.;

(iii) Ergonomical design for rugged handling by soldiers with gloves in cold areas; and

(iv) Easy access to modules/sub-systems for repair/maintenance/testing/fault findings, etc.

3.5 Primary Power

The system requires single phase power of 115 V AC at 400 Hz.

4. ADVANTAGES

There are a number of advantages in using a microprocessor in the closed loop servo system which include

(i) Extensive computing capability of software;

(ii) Use of a number of sub-routines between two updates of command signal to do in-house functions;

(iii) Use of digital and analog integrated circuits for easy implementation of design and reduction of hardware;

(iv) Reduction of slip-ring connections by resorting to serial bit communication of data;

(v) Flexibility to change design based on experience gained through prototype evaluations;

(vi) Repeated diagnostic/specification testing while the system is in actual use;

(vii) Addition/deletion of safety interlocks/logical interlocks possible after prototype evaluation; and

(viii) Processing of various angle informations and their digital display on control consoles.

The technology would be moving towards customised large scale integrated chip design and extensive use of digital circuit ideas. The sensors produce suitably conditioned digital outputs for direct use in microprocessor-based systems. Therefore, hardware/software implementation of design concepts would be simplified.

5. CONCLUSION

Use of microprocessor-controlled systems in the weapon systems of the future is a logical and imminent conclusion. This is mainly because of the possible simplicity in the design concept implementation and easy/quick possibility of updating of the system. The experience gained from stages of development to the actual in the field, etc. can thus be used in improving the system capabilities in shorter turn-round time.

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