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SHORT COMMUNICATION

Microcontroller-based Ground Weapon Control System

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ABSTRACT

Armoured vehicles and tanks generally consist of high resolution optical (both infrared and visible) and display systems for recognition and identification of the targets. Different weapons/articles to engage the targets may be present. A fire control system (FCS) controls all the above systems, monitors the status of the articles present and passes the information to the display system. Depending upon the health and availability of the articles, the FCS selects and fires the articles. Design and development of ground control unit which is the heart of the FCS, both in hardware and software, has been emphasised. The system has been developed using microcontroller and software developed in ASM 51 language. The system also has a facility to test all the systems and articles as initial power on condition. From the safety point of view, software and hardware interlocks have been provided in the critical operations, like firing sequence.

Keywords: Fire control system, ground control unit, target identification, target recognition, handing over electronics, image processing

1. INTRODUCTION

A ground control unit (GCU) monitors the status of the articles present on the vehicle and passes the information to operator/gunner/commander. Depending upon the health/availability of the articles, the GCU selects/fires the articles. In the present system, four articles are present on an elevated platform of a modified BMP vehicle. In general, a fire control system (FCS) consists of a sighting system for recognising and identifying the target, handing over electronics (HOE) for generating the reference image, control panels, a laser range finder (LRF) for finding the range of the target, and display panels. The GCU is the heart of the system. The configuration and their interconnections are shown in the Fig. 1.

The ambient temperature and operational altitude are required for optimum trajectory performance of the articles. These data can be available on standard ARINC-429 bus or 1553-Mil STD bus. In the present system, these parameters are fed manually through a set of potentiometers. The GCU checks the health of the articles at regular intervals and informs the commander/operator. It also gives the fire command as per the sequence of operations after satisfying the interlock conditions. All the control switches are provided on the control panels and the status/warnings/error messages are displayed on display panels.

2. ACQUISITION/RECOGNITION OF TARGET

2.1 Handing over Electronics

The articles have the capability of tracking the target of interest. A target of interest has to be

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assigned to the article before it is launched. Acquisition and recognition of the target depends on the field-of-view (FOV), target size, optics size, sensor resolution, etc. With the article system constraints, a typical target at maximum range may occupy only a few pixels in the image plane. As per the Johnson's criteria, at least six to seven lines through target (LTT) are required for recognition[1]. Hence, target recognition is not possible through the article and there is a requirement of a high resolution sensor - CCD/IR sight, with narrow FOV satisfying the LTT requirement. After recognising the target through sight and pressing a button, the scene around the centre of FOV is converted to make it compatible (in spatial resolution) with the image acquired by the article. The converted image is used as the reference image. This reference image is used for locating its position in article FOV through image correlation techniques. Once the reference is located in the image seen by the article, the article is automatically trained to bring the located area to the centre of FOV. Image correlation tracker continues updating the reference at faster rates and thus, the article keeps tracking the target area. The sensors onboard the article and the sight image from which the reference is generated, have different spatial resolutions. To accomplish a correlation between them, the two images are made similar (in spatial resolution) by applying an image preprocessing technique[2].

Handing over electronics gets the target video from the sighting system in CCIR format and it digitises in real-time using flash A/D and stored in memory. After receiving the command from GCU, applies the image-preprocessing algorithm[3,4] on the target image and generates the reference image. The reference image is transmitted to the GCU through a serial link.

2.2 Sighting System

The sighting system consists of a thermal sight and a CCD camera. Since the thermal/CCD sight is a ground-based system, it can have bigger optics with both wide and narrow FOVs and high resolution sensors. It has an IR/CCD visible camera with facilities like zooming, focus, etc. to aid the operator during the daytime operation.

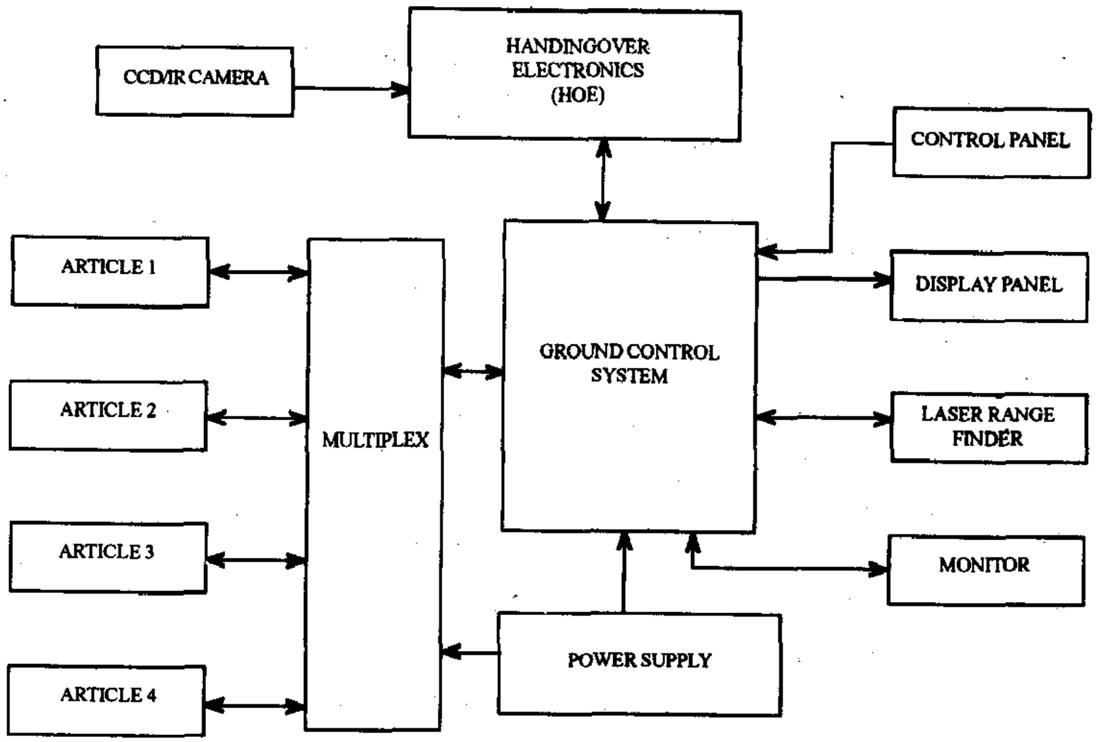

Figure 1. Interface block diagram

3. HARDWARE SYSTEM DESIGN

The hardware has been designed around 8751-FA microcontroller operating at 16 MHz and some of the design aspects are described here.

3.1 Loading of Application Software

A facility is provided for loading the application software after closing the unit. Thus, software and hardware development can be progressed independently and at the end, software can be ported into the system externally. By sensing the bit P1.0, the monitor program residing on the microcontroller jumps to the routine for reading/ receiving the code from the serial port and storing in flash EPROM. If the bit is not set, it executes the earlier stored code on the external flash EPROM. For this function, 28C010 flash 128K × 8 is provided with ACT-257 for selection control signals. To reduce the code fetching time, (that is to reduce the execution time), it is planned to download the application code into the SRAM area on booting and execution from the SRAM.

3.2 Generation of RESET Signal

The system needs to be reset either by remotely pressing the reset button on the control panel or on the unit. Power ON reset is generated using Max-691. All the three resets combine and generate a reset signal to the controller.

3.3 Design of Built-in Test Facility

The system is having built-in test facility (BITF). On power ON reset, the GCU invokes the individual subsystems by sending a code through a serial link and the corresponding health status is monitored and displayed on a display panel. In this mode, tests activate most of the hardware modules and clear the hardware.

3.4 Signals to Articles

Each article requires power lines, pyro lines, two RS-422 serial links and reset lines. One set of these signals is generated and multiplexed/ de-multiplexed using ACT-253/ACT-138 and given to four articles. Using the article selection bits, multiplexer connects the signals to the corresponding article. The article power goes through the relay and the relays are switched by the GCU depending on the section of the article. For resetting the article, open collector signal line is provided and made active high for 250 ms (say). Depending on the article requirement, this signal can be pulled to 28 V/5 V. All the input and output ports from control panel are taken through buffers and connected to the data bus. The output status/error messages are also buffered and given to display panel for display.

For the ground subsystems, like handing over electronics and GCU, a common reset signal is provided to have synchronisation between the two and which is generated by pressing a reset button provided on control panel. For resetting the selected article, separate reset button is provided on the control panel as article bite switch.

3.5 Serial Communication Ports

In the system, five serial communication links are provided, one each for the monitor, handing over electronics and LRF and two for articles. The serial port present on the microcontroller chip is used for development/ testing/debugging (monitor) of the application software. Remaining serial ports are designed using two 8274 dual USARTs. All serial ports are configured in asynchronous communication mode. It receives the data on R × D line serially and converts into parallel and puts on the data bus. Similarly, it takes the parallel data from the data bus and sends serially on T × D line. The required bad rate clock is generated using 8254 programmable timer. Only one RS-232 serial link is provided for the monitor and other four serial ports are designed for RS-422 format. All the RS-422 serial links receiving lines are taken through opto-couplers 6N140, and the transmitted lines are connected through the drivers 26C31. Since each article needs two serial links, two serial links are multiplexed to cater for all four articles. Depending on the article selection, corresponding serial link will become active.

4. SOFTWARE DESIGN

The application software is developed in ASM 51 language. The software is developed in modular format. The system can be reset on power ON and/or by pressing an external switch provided on a control panel. The CPU initialises all the peripherals USARTs, timers and the I/O ports. The GCU scans the commands invoked from the control panel at regular intervals and takes necessary action.

The system has two levels of self-test, the first level is brief and the next level is elaborate. On power ON reset, it performs only first level of testing. In this level, after clearing the on-chip RAM, it checks all serial ports. Once they are proper, it checks the health of the other subsystems by sending and receiving a specified code in a specified time. Depending on the status/health of the subsystem, message is displayed on the display panel. The switch activates the next level of self-test.

After passing the preliminary self-test, the GCU checks for the operational modes. It has three modes of operation like monitor mode, application mode and self-test mode. Depending upon the switch position (mode selection), corresponding procedures are called.

4.1 Application Mode

Once the article is powered ON, the GCU checks the control functional switches like article bite, LRF fire, target designate and article fire. If none is active, the GCU checks the health of the selected article. The above conditions/status are monitored at regular intervals and the status is displayed on the display panel. Application mode flow chart is shown in Fig. 2. The main functions/commands are article select, health check, LRF fire, target designate and fire command.

4.1.1 *Article Select & Health Check*

The GCU automatically selects the articles (1 and 4 or 2 and 3) depending on the health and availability. If all the articles are present and healthy, then as predefined, articles 1 and 4 (refer Fig. 1) are selected first. Once the power is ON to the article, weapon system controller (WSC) residing in the article, checks all the active elements and responds to the GCU command. The GCU checks the health of the article as per the protocol by sending 0CCH and receiving 0DDH in a specified time. Monitoring the health of the selected articles is carried out at regular intervals.

4.1.2 *Article Health Check Command*

The GCU monitors the status of the selected articles and displays the status on the monitor in case of an error. At any point of time, operator/commander can find the health of the selected (automatic) article, by pressing the health check (press button) switch. The GCU checks the health of the selected article and displays on the control panel for a specified time.

4.1.3 *LRF Fire Command*

On giving the LRF fire command, range information is available in the LRF subsystem. Once the range data is ready, DT_AV line becomes active, indicating GCU that data is ready. The GCU receives range data from LRF and temperature and altitude through potentiometers. All these values are transmitted to the selected article's WSC using predefined protocols.

The GCU first sends range-low and range-high bytes, then waits for range-low byte echo within 60 ms and compares with the transmitted one. If it fails, then GCU sends 0EEH to WSC indicating that error has occurred and sends once again range-low and range-high bytes, which is repeated maximum three times. Otherwise, GCU sends Y to WSC to confirm the correctness. Once range-low check completes, the GCU waits for range-high byte echo within 60 ms. The received byte is compared with the transmitted one. If it finds any mismatch, then after informing WSC about the error by sending 0EEH, the GCU repeats sending range-low and range-high bytes to WSC maximum three times. If still error is present, then GCU declares the article is bad and displays on display panel and selects next/other article. Otherwise, GCU sends Y to WSC to confirm the correctness of data. Same procedure/

protocol is repeated for sending/receiving altitude and temperature data.

After completion of data transfer to WSC, the GCU sets a flag (LRF_F). The flag LRF_F is checked in the fire mode to confirm that all the parameters have been passed to WSC.

4.1.4 *Target Designate Command*

The GCU after receiving target designate (TAR_DES) command, checks for the sighting system's narrow FOV status, since it is one of the parameters used in generating the reference image. The GCU gets the status of the narrow FOV. If it is not present, the GCU waits for fixed time (say 300 ms) and returns to the main routine. The GCU gives the signal to handing over electronics for generating the reference image. Once the reference data is ready, handing over electronics transmits the data to the GCU which transmits it to the WSC using a predefined protocol.

The GCU gets the lock-on code from the WSC within the specified time (say 4 s/200 ms). The WSC sends lock-on byte followed by a confidence byte (which gives qualitative measure of

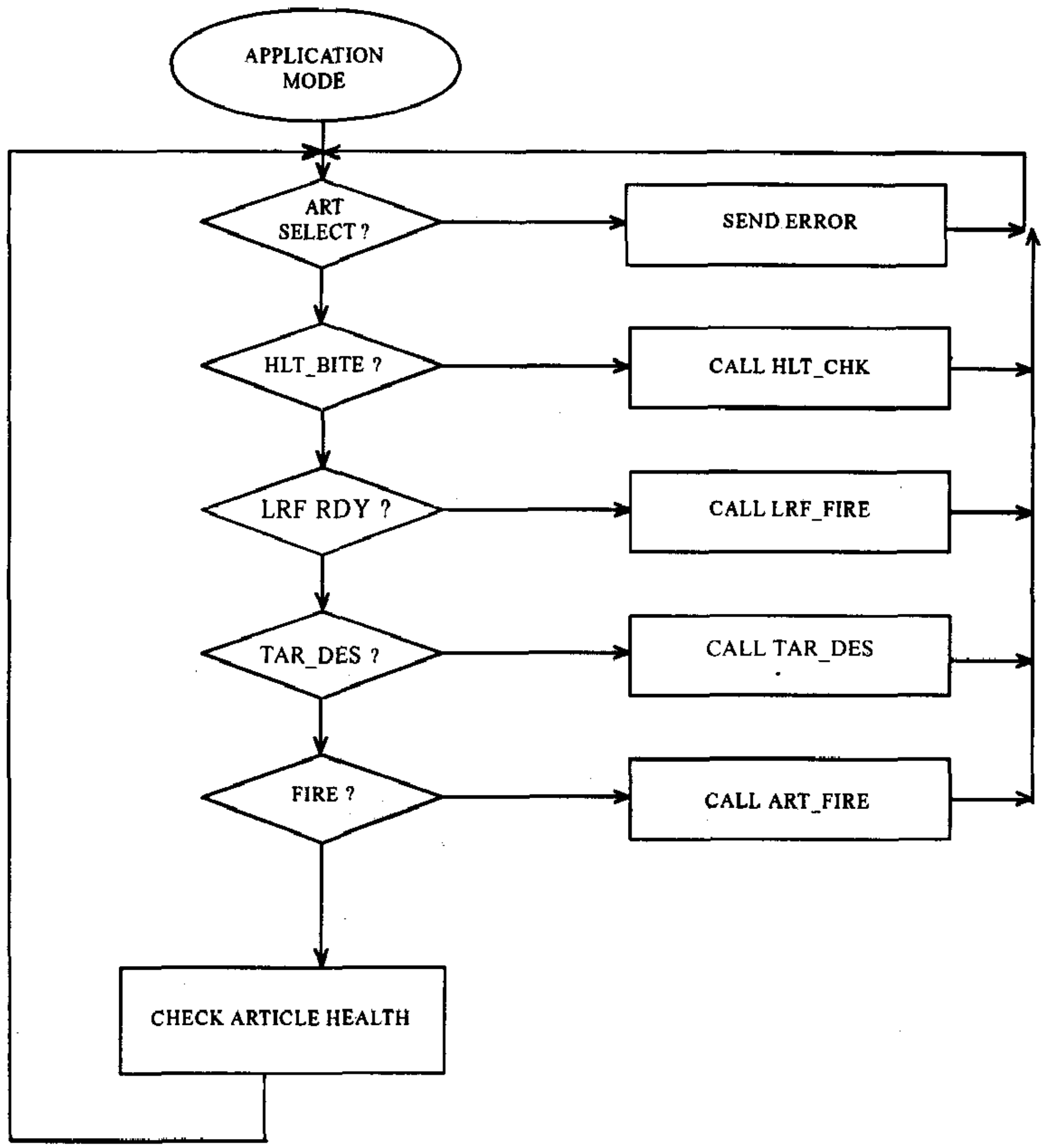

Figure 2. Application routine software flow chart

registration-confidence) to the GCU which is displayed on display panel as a lock-on confidence. LOCKP status flag is set to indicate that the WSC is tracking the specified target. This flag is sensed during the fire command.

4.1.5 *Article Fire Command*

Pressing FIRE button on the control panel generates article fire command. The GCU checks for the test/fire switch status. Test/fire is one of the interlocks for firing. If it is in test mode, no action is taken and it returns to main routine. Otherwise, it enables the interlocks to the selected article and confirms the health. If it is bad, selects next article, disables the interlocks and unlatches the fire command. The GCU checks and confirms that all the parameters required by the WSC have been passed by checking the status flags. Once the health of the article is good and all parameters have been sent, only then GCU gives the fire command to the article. This finishes the firing part and waits for article takes off. The GCU resets the flags, if still the article is present then it is declared as hang fire and it is displayed on display panel. Otherwise, article status is updated and it selects the next article and disables the interlocks.

4.2 Monitor Mode

In this mode, system can be connected to external system like PC-based emulators for debugging/developing the software. Through the terminal port (serial port) emulator receives/sends commands to the system. This mode is for testing the system for future applications/developments. Monitor mode can be selected by putting the external switch in monitor mode position and giving the reset command.

4.3 Self-Test Mode

This mode can be invoked by putting the switch in BITF mode and giving a reset command or after putting the switch in this mode and powering the system. Here the self-test is very elaborate and it tests all the modules of the hardware and the results are displayed on the terminal. For this purpose, the system initialises the terminal (serial) port.

4.3.1 *SRAM Test*

In this test, system does four types of tests to clear both internal and external static RAM memory. The GCU fills the memory with fixed values 0H and while reading, system checks with the 0H. If it finds mismatches, then number of mismatches are displayed, otherwise TEST PASSED message is displayed on the terminal. In the second stage, a fixed value FF is written into the memory and while reading, it is compared with the same fixed value. If any mismatch occurs then the number of mismatches are displayed on the terminal, otherwise not. Third stage writes incremental pattern throughout the memory space. While reading, the same procedure is followed for displaying the mismatches (if any). Fourth stage writes random pattern on the memory. While reading, it compares with the same random numbers and displays mismatches (if any) on the terminal as explained above. Thus, complete SRAM can be cleared/tested.

4.3.2. *Testing of Serial Ports*

In this mode, all the five serial communication links are checked. Initially, ASCII A is transmitted to all the serial ports and at each port, system waits (say 10 ms approx.) for a character. If the character is present, it is displayed/transmitted to all the ports, otherwise old/earlier character is displayed/transmitted. In this process transmission/reception of all the serial ports can be checked. System comes out of this loop only if the received character is at the rate from any port.

4.3.3 *Input/Output Lines*

In this test, all the 32 I/O ports are tested by outputing and inputing the values. One test LED panel is made to test all the input and output ports and it is each used along with the patch cards. During each test, type of the test is displayed on the terminal. Once the test is activated, the display can be observed on the panel for its performance. Switching ON/OFF with some delay is to test all the 32 output ports and it can be seen that all output lines are active. Next, system outputs high only on one output line and it is shifted to all other output lines with fixed delay so that it can be viewed. Thus, all outputs can be checked and cleared. The test panel is made in such a way that buffered output value can be read through input ports and it can be compared with the output values. The input values are complemented and output on to the test panel. This process is repeated 10 times. The complete I/O testing can be repeated by responding to a prompt on the terminal. Thus all the modules present in the hardware can be tested using BITF.

5. CONCLUSIONS

As a stepping stone towards fire control system (FCS), the GCU is realised and integrated in the launch vehicle. It has met all the specifications. At present, all interlinks between the subsystems are either RS-232/RS-422 serial links or I/O lines. These links have to the converted into 1553B-Mil STD so that different articles can be integrated easily without changing the GCU/FCS.

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REFERENCES

1. Johnson, J. Analysis of image systems. Paper presented at Image Intensifiers Symposium. US Army Engineering Research Development Laboratory, Fort Belvoir, 1958.
2. Boland, J.S.; Pinson, L.J.; Kane, G.R.; Honnell, M.A. & Peters, E.G. Automatic targets hand-off using correlation techniques. Auburn University, Alabama, 1977. Technical Report, 57-63.
3. Sankar Kishore, M. Image preprocessing system. Paper presented at the SPIE International Technical Symposium on Optics and Optical Electronics, Applied Science and Engineering, 6-11 August 1989, San Diego, USA, 140-45.
4. Sankar Kishore, M. Automatic target handing over system. *Def. Sci. J.*, 1994, **44** (1), 69-80.

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