EMBEDDED SYSTEM FOR AUTOMATION VISUAL TESTING OF ELECTRONIC MODULES

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Abstract: The subsystem of a visual functional test is an embedded system, which is an integral part of testing equipment for functional testing of electronic modules of dash-boards of vehicles after their installation. The flexible solution of structure of measuring an information subsystem chain with a CCD camera and its interconnection with a controlling PC of testing equipment enables measurement and also analysis, in a long term time horizon, the functional characteristics of electro-optical parts installed generally in electronic modules produced. The solution is proposed with respect to reliability, the flexibility of re-installation also for other type of the electronic module measured, removal of the human factor from the process of visual functional tests and harmonization of the testing period with the period of production line.

Keywords: Visual, Functional test, Measuring, Embedded system, Cameras

1. INTRODUCTION

The project of the development and realization of a measuring embedded system with a CCD camera was initiated by the company SIEMENS VDO Automotive s.r.o. from Frenstat p.R. in the year 2002. The goal was to develop and realize a subsystem of measuring a CD camera with an interconnection with a PC serving completely the testing equipment of the companies TERADYNE or AGILENT in functional tests of installed DPS devices of dash-boards for vehicles (Eckerl, K. 2004). The measuring equipment designed in this way will enable the elimination of the human factor from visual functional tests of DPS after their installation. It is possible to extend the original purely functional visual test including the attributes of the state and colour by further attributes of intensity quantification and a calorimeter connected to the batch check of delivery of the electro-optical elements being installed (Ott, E. 2003).

2. DESCRIPTION OF THE EMBEDDED SYSTEM STRUCTURE

The proposal of the embedded system was based on the requirement of system minimization as to the technical and program aspects. Due to its simple character and long-term reliability the operation system MS-DOS was preferred by the ordering subject. The application realization itself is broken down into two technical subsystems. The scanning subsystem with the module of a CCD camera and module of image digitalization installed in the control PC slot. Both subsystems are possible to realize as an embedded system with embedded PC, which communicate with higher control level (Fig. 1).

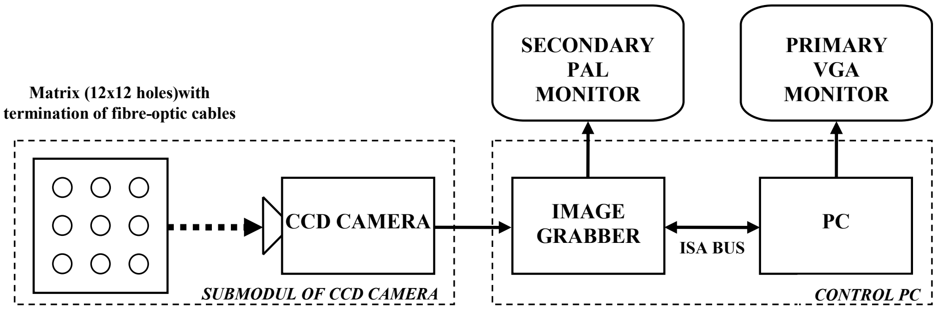

Fig. 1: Block diagram of subsystem for visual functional test.

2.1 Scanning subsystem

The first part is represented by the CCD camera placed inside the testing machine in a special cover. The second part is represented by a ZOB08 digitalization card installed in the slot connected to the ISA bus-bar of the original control computer of the testing application. The blocks are interconnected mutually with a cable of the CCD camera video signal. In the beginning of the proposal/design the placing of the CCD camera from the outside was considered - accordingly to the person's point of view in servicing the testing machine. The fact that it is necessary to identify the areas of interest together with the changing light conditions in the scene scanned, requiring a measuring chain on a technically higher level as to the resolution and sensitivity of the CCD camera, the speed of image information transfer into the control computer memory and the evaluation of such information containing a substantial redundancy.

For the removal of redundant visual information and a limitation of the solution of the problems connected to the program means, the solution with a full encasing of the CCD camera in the cover of testing machine and leading the optical information into the field of view of CCD camera from the areas of interest with the help of optical fibres was used. The proposal of a subsystem for measuring electro-optical elements characteristics was included homogeneously into the conception of testing process. The optical fibres are arranged in the CCD camera field of view into the matrix of 12x12 points (ending of optical fibres) and fixed with the help of special manually moveable terminals.

The optical system of the CCD camera is created by a lens with great field of view; it is supplemented with the possibility of the manual limitation of the CCD camera sensitivity with the help of a grey filter. This limitation enables eliminating the optical signals causing a choking up of the CCD sensing element and the „transfer of choking up" between columns and rows. The disadvantage of the solution was the possibility only of a jump set up dependent on filter damping. The other set up of damping then required another grey filter. The purchase of a set of such filters was not economical. The solution enabling the continuous manual setting up of optical signals blackout in the field of view of the CCD camera was subsequently enabled by the installation of a pair of anti-parallel set polarization filters. In this system the blackout is achieved by mutual rotation of polarization filters. Geometrical distortions of an image connected with the great field of view of the lens are not corrected and do not influence the measuring of the state, intensity of optical signal, its colour and deviations of colour (Krueger, U., Schmidt, F. 2003).

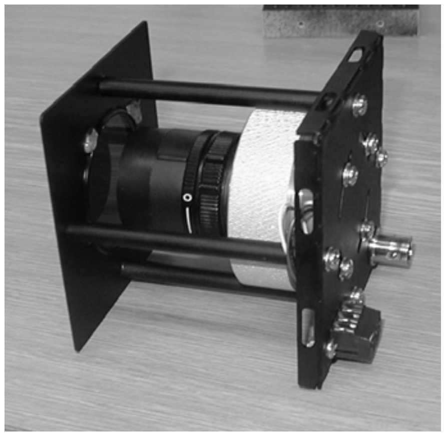

Fig.2. Assembly of optic system of CCD camera module.

The embedded system of colour PAL CCD camera with the resolution of 768x640 pixels is embedded into the divided duralumin casing. The casing is composed of a basic (Fig. 2) and covering part (Fig. 3). The CCD camera module itself is in the position in the basic part, fixed with four screws. On the periphery of the basic part the external thread is spun enabling the screwing of the covering part. This solution ensures the extension of the possibility of setting lens optics by rotating the basic and covering part mutually. In the covering part the lens of the CCD camera are fixed.

Fig.3. Embedded system with CCD camera prepared for installation in TERADYNE test machine.

The assembly unit of the CCD camera is fixed on the back face of the metal sheet casing with the help of four screws with counter nuts. The fixing screws, thanks to their lengths, fix the basic as well as the covering part by their mutual bracing against rotation caused by machine vibrations during operation. The camera cables, on the back face, are terminated by a BNC video connector and by a terminal board for the connection of feeding. The changing of poles of the CCD camera feeding is protected by an embedded diode on the printed connection of the terminal board.

The holders of polarization filters are connected to the back face by brackets. The whole optical systems with the CCD camera and back face is inserted into the casing created by „U“ metal sheets with assembly and fitting holes. This casing divided horizontally enables the single fixing of a matrix with the terminations of optical fibres and its own simple construction inside the testing machine.

2.2 Subsystem of image digitalization

The second part is represented by a module of image digitalization interconnected with the CCD camera set (Fig.4). The image digitalization ZOB08 has 2 inputs and three outputs. In the application the wide input with the connector „cinch“ and the output „cinch“ (television standard PAL) are used. The signal from a video camera is led to the input with a metallic coaxial cable. The output is led on to a secondary graphical monitor. Before installation of the digitalization module into the ISA slot of control computer, it is possible to enter the port address and the memory segment address of the module. The module is set at the manufacturer at the addresses 240H-24FH and 260H-264H. In case of occupation of this address space in the control computer, it is possible to change them on 340H-34FH and 360H-364H using the interface unit (at the same time the change of parameter of the initialization routine *z8InitCard* on 0x0340 in application software is necessary). The setting of memory segment in the range of C8000H-C8FFFH, CC000H-CCFFFH, D0000H-D0FFFH is possible with moveable interface units, The standard setting D4000H-D4FFFH is made without interface units.

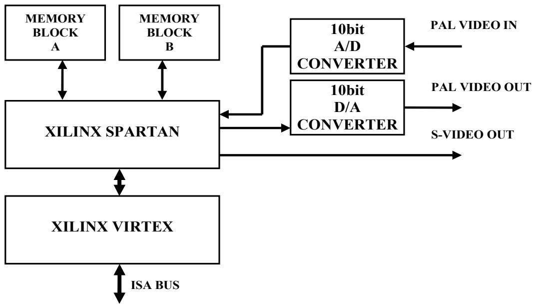

Fig.4. Block diagram of Image Grabber module

3. SOFTWARE

3.1. Configuration of the MS-DOS system

It is necessary so that the controller of the extended EMS memory was implemented. The controller EMM386.EXE which is an integral part of MS-DOS operation system installation is the best. The command line of the file CONFIG.SYS looks as follows: DEVICE=C:\DOS\EMM386.EXE NOEMS X=D400-DFFF RAM

The obligatory parameter is highlighted, which enables the exchange of image data between the module of image digitalization and control program.

3.2 Configuration of control program

The control program consists of several subprograms (see below) which must be included into the whole project of tester software. The important presupposition for the correct function of controller is the memory model used in compilation of application software.
In the environment Borland C++ it is necessary, in the menu Options – Compiler – Code generation, to select the memory model HUGE). In the following table 1 the files are given which are necessary for the correct function of application program.

3.3 Description of testing program

The testing program contains several routines and global constants. In the following table 2 all global constants are given.

Table 1 Application program files

ZB080002.RBT	file for chip configuration on grabbing card
ZB080002.I2C	file for chip configuration of grabbing card
BCLIB.LIB	Library
BCOVRLIB.LIB	Library
I2CFILE.H	Head file of controller
I2CWDM.H	Head file of controller
WIN.H	Head file of controller (compatibility with Windows 9x)
ZOB6WDM.H	Head file of controller
NETFILE.HPP	Head file of controller
I2CFILE.CPP	Program file of controller
I2CWDM.CPP	Program file of controller
NETFILE.CPP	Program file of controller
ZOB6WDM.CPP	Program file of controller
DIODY.H	Head file of tester (in details see *Description of testing program*)
DIODY.CPP	Program file of tester

An important part of the tester is the structure MyRGB. This structure serves for handing over information about colours of single optical cables terminations. The structure includes 4 compounds: R – red, G – green, B – blue, Y – brightness compound

Table 2 List of global constants

LEDnumX	Columns number of terminations of optical cables (ZOK) on matrix
LEDnumY	Lines number (ZOK) on matrix
LEDRMAX	Maximum admissible radius ZOK (in image's pixels)
LEDRMIN	Minimum admissible radius ZOK (in image's pixels)
LEDXMAX	Maximum admissible X position ZOK (in image's pixels)
LEDXMIN	Minimum X position ZOK (in image's pixels)
LEDYMAX	Maximum admissible Y position ZOK (in image's pixels)
LEDYMIN	Minimum Y position ZOK (in image's pixels)
ImagesMAX	Maximum number of calibration images
LEDToleration	Maximum admissible measuring toleration (see z8ReadColors)
PositionFile	File of single ZOK positions on matrix (see z8InitCard)
KalibrationFilePrefix	Prefix of colors calibration files (see z8KalibColors)

Routine *BOOL z8InitCard(UINT32 Port)* carried out the initialization of card. It records the configuration files into the chip of the card; it initializes the display, etc. The input parameter is the port on which the card is set (as standard 0x0240). It is not necessary to set up the memory segment; it is automatically read from registers of the grabbing card.

It returns the TRUE value if the correct initialization occurred. It also reads the file of single diodes positions from the disc (*PositionFile*). If this file does not find it the single positions are calculated automatically. The positions are also checked in the case that it comes to the file damaged, so that some diode outside the image scanned will not occur. The routine also reads the calibration files of colours, if these files are not on the disk, the calibration images are automatically set to the values (R,G,B,Y)=(0,0,0,0). Routine *void z8SaveImage* (LPSTR filename) carries out the saving of the whole field into the file of the BMP type (Windows BitMap 24 bit). However, it is not important for the correct function of the program, it provides only supplementary information. The file name is handed over by the parameter.

Routine void *z8PositionKalib* (BOOL TextInfo) switches on the function for setting up of ZOK positions. The setting up is done manually. If the input parameter is TRUE, the supplementary information is written on the text screen. However, the single ZOK are always displayed in the output image (secondary monitor) which can be moved and setup in the correct position. The movement and setting up is done with the help of keys, which are in Table 3. After ending the setting up, the new positions and diodes sizes will be saved automatically into the configuration file (*PositionFile*). In the setting of diodes, the maximum and minimum positions in all directions and also the maximum and minimum size of ZOK are watched naturally.

Routine *BOOL z8KalibColors* (BYTE ID) carries out colour calibration. In a substance, it will read the single ZOK colours and will save them in the memory as the calibration image (each ZOK is represented by the only structure *MyRGB*). It will automatically come also to be saved into the file *KalibrationFilePrefix.ID* (ID serves as the file's suffix). The input parameter ID which serves as the number of calibration image must be less than *ImagesMAX* (numbering from 0). If all is OK (corrects ID, trouble-free reading of ZOK colours, saving the calibration file on disk) the routine will return the TRUE value, otherwise FALSE.

Routine *BOOL z8ReadColors* (BYTE ID, BYTE *VectorBool, DWORD VBoolLength, BYTE *VectorRGBY, DWORD VRGBYLength, BYTE TextInfo, LPSTR FileName, BOOL Details) is a question of the main program routine which carries out the image testing itself. If all diodes light correctly, it returns the TRUE value, if at least one diode lights incorrectly, it returns the FALSE value.

Table 3 Key functions

TAB	Next ZOK
SHIFT + TAB	Previous ZOK
ESC	End of positions setting up and saving of actual positions into the file
+	Extension of radius ZOK +1
-	Diminution of radius ZOK -1
key K	Change of motion step ZOK (in cycles 1,5,20)
Arrow ↑	Shift ZOK upwards by a step (1, 5 or 20 pixels)
Arrow ↓	Shift ZOK downwards (1, 5 or 20 pixels)
Arrow ←	Shift ZOK to the left (1, 5 or 20 pixels)
Arrow →	Shift ZOK to the right (1, 5 or 20 pixels)

ZOK is evaluated as incorrect lightning in case that the difference of at least one colour or brightness compound measured on ZOK, from calibration image for given ZOK is greater than *LEDToleration*.

The first parameter is ID of calibration image (same as ID at z8KalibColors). So, it is possible to test more kinds of ZOK lightening in one program.

The second parameter is VectorBool which determines the indicator on output space, the Dan7 vector determines whether ZOK lights correctly or incorrectly. With the third parameter (VBoolLength) the size of this vector is transferred over (the calling program must have this vector allocated in memory).

The data format is as follows: Each ZOK is presented by one byte (8 bits). If ZOK lights correctly, on its place the TRUE (1) value appears, if it lights incorrectly, then the value FALSE (0) can be found on its place. The ZOK is ordered in lines, so for the case 6 ZOK (2 lines, 3 columns) numbered from 0 the sequence is as follows: (0,0) , (0,1) , (0,2) , (1,0) , (1,1) , (1,2).

The fourth parameter is the indicator on the vector of the luminance for a single ZOK (VectorRGBY). Its maximum length is determined by the fifth parameter (VRGBYLength). The ordering of ZOK in this vector is the same as in the previous vector (VectorBool). The difference consists in the fact that the logic information is not handed over here but directly the values of RGB and Y (brightness). Each ZOK is presented by a 4 byte structure (vector size should be 4x greater than VectorBool). The byte ordering for each ZOK is as follows: R , G , B , Y.

The parameter TextInfo informs the routine about whether it is to write the information on the primary (text) screen. 0 means that nothing is written. 1 will write the differences of colour compounds of all ZOK from the calibration image given. The statement is well-arranged and colour, exceeding the limit given (LEDToleration) is identified by the brightness of single colours. The incorrect lighting ZOK is also identified by a yellow stripe over its values of colour compounds. **2** is the same kind of statement as in case of **1**, but the differences are not written but the values actually measured - RGB and Y (always the exceeding of limits is identified).

The further parameter is the indicator on the NULL-TERMINATED chain which contains the file name for detailed statement (*FileName*). If this parameters is NULL, the statement is not carried out. The file format was proposed to be done as well-arranged as possible. The detailed format of head is in table 4.

Table 4. Detailed format of head

#	Indication of line on which the remarks are given (it does not bear the measured information)
[LEDnumX]	Number of ZOK columns (it corresponds to LEDnumX)
[LEDnumY]	Number of ZOK lines (it corresponds to LEDnumY)
[Kalibration]	Number of calibration image (it corresponds to ID parameter in routine z8ReadColors)
[ErrorBorder]	Maximum admissible error (it corresponds to LEDToleration)

Table 5. Format specification

YY	Line of ZOK (numbered from 0)
XX	Column of ZOK (number from 0)
Num	Order of ZOK (numbered from 1), *Num=YY*LEDnumX+XX+1*
Calibration	Calibration values of colors and brightness for given ZOK
Measured	Actually measured values of colors and brightness for given ZOK
Error	Deviation of measured value from the calibration one (also RGB and Y)
*****	It is only on this line when to exceeding **LEDToleration** occurred

The data from measuring have the following format, which is specified in table 5: [YY,XX;Num] Calibration - Measured = Error *

The values of calibration, values measured and deviations have the following format (R,G,B,Y):
R-Red colour value, **G-**Green colour value, **B-**Blue colour value **Y-**Brightness value. The resulting line then looks as follows (an example with concrete values, without exceeding the limit allowed): [07,02;087] (046,029,018,024) - (048,025,020,023) = (-2, 4, -2, 1)

The last parameter of the routine *z8ReadColors* is *Details*. If this parameter is TRUE, the routine will carry out the detailed statement for each ZOK into the separate file. Each ZOK is separately exported into the bitmap file BMP (Windows BitMap 24bit) and also the statement of colour compounds for each point ZOK on the screen in text format is exported to it. The graphical file has the name D_????.BMP and the text one D_????.TXT. In fact, instead of question-marks the ZOK number is given. For instance, for 16 ZOK the names are as follows: D_0016.BMP and D_0016.TXT. The format of the text file is also well-arranged. On each line, the quaternion of RGBY values is given one after another for the whole graphical line of the BMP file. The points (res. quaternion) are separated by a space. In this way, all lines are exported. The last two lines have a special format: RGBY: (?,?,?,?)- Average value of RGBY from all measured points XYR: (?,?,?) - Actual positions on the screen (X,Y and radius)

Because of the fact that ZOK is in the shape of a circuit on the screen, the environs of the circuit in the BMP file is black and, in the text file, the quaternion filled with the values 0 are given.

4. CONCLUSION

The implemented system to be deployed is composed of three elements: a module of encased CCD camera, module of image digitalization with cable and application software for the analysis of image information.
The realization of the camera module enables its arbitrary placing in the framework of its testing application in the place without the humidity effect and aggressive gases. The solution of a fully encased CCD camera with a matrix of optical cables termination enables the very flexible reaction to a change of up to 144 measuring points. The number of measuring points monitored could be increased up to 400. The further extension is limited by the matrix area and the resolution capability of the CCD scanning element. This solution enabled the utilization of the existing Low-Cost sensing and digitalization technique, existing control computer with MS-DOS operation system with verified responsibility and the composition of an application with a great impact on the process period of production and testing connected, on increasing the production quality by removing the human factor from the process of a visual functional test, quantification of optical characteristics of the electronic parts being installed and the possibility of the long-term analyses of characteristics of their batches delivered from subcontractors. The camera module enables, in external feeding, also the function of an outside testing machine and its functions can be utilized also within general applications.

Thanks to the cooperation of the company SIEMENS VDO, s.r.o. and VSB – Technical University of Ostrava the technicians were successful in developing and immediately applying the subsystem of an electronic visual functional check utilizing a colour CCD camera for measuring. With the embedding into the testing equipment (TERADYNE, AGILENT) the possibilities of an electro-optical component were extended, installed during production into the electronic modules measured. With the utilization of the measuring information chain for the electronic visual functional test the human factor was removed from this part of the testing process. At the same time, the testing process was extended by the possibilities of the measuring, quantification and long-term analysis of electro-optical elements analysis (radiation intensity, colour deviations) in single batches from suppliers. Up to the year 2004 10 subsystems have already been produced and handed over to the ordering subject. Cooperation between both institutions is developed now also in further spheres of research, development and support of the manufacturing process.

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