Flexible LCD/Plasma TV Colour Temperature Testing

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***Abstract*—The objective of this project is to develop applications using Agilent VEE Pro or VEE Express and U2300 Series DAQ, in this case, ensuring that LCD/Plasma TVs have even brightness. One way to ensure the even brightness is to perform a colour temperature test on various points of the screen. The colour temperature test setup should have five test points, four at the corners of the screen and one at the center. The test setup should be able to adjust its position to test LCD/Plasma TVs of different sizes. It was suggested by Agilent Technologies that a 20 inch LCD monitor is sufficient for this test.**

I. Literature Reveiw

Colour temperature is determined by comparing its chromaticity with a theoretical, heated blackbody radiator[1].

Chromaticity is the quality of a colour such as hue, saturation and brightness, and is specified by the tristimulus values of the radiant power of the colour stimulus entering the eye. The tristimulus values of a colour stimulus are the amounts of the three primary colour stimuli required to give, by additive mixture, a colour match with the colour stimulus considered[2].

A blackbody is an object that absorbs all electromagnetic radiation that falls onto it. Hence, the amount and wavelength of electromagnetic radiation it emits is directly related to its temperature[3]. Blackbodies below about 700K (430 °C) produce very little radiation at visible wavelengths and appear black, hence the name. However, blackbodies above this temperature produce radiation at visible wavelengths starting from red, going through orange, yellow, and white before ending up as blue when the temperature increases.

For radiators which are not ideal blackbody radiators, the chromaticity may not be exactly equal to the chromaticity of a blackbody radiator. The correlated colour temperature is defined as the temperature of the blackbody radiator whose perceived colour most closely resembles that of the given non-ideal blackbody radiator at the same brightness[4].

A colour space is an abstract mathematical model describing the way colour can be represented as tuples of numbers, which are the tristimulus values as mentioned in section 1.2 above. The International Commission on Illumination (CIE) XYZ colour space, also known as the CIE 1931 colour space, is used as it is a mathematically defined colour space using three parameters, i.e. the tristimulus values, to define a colour sensation. It is based on direct measurements of the human eye and serves as the basis for other colour spaces[5].

II. XYZ To Correlated Colour Temperature

There is not a simple formula for computing the correlated colour temperature of an XYZ colour. Instead, an algorithm is used to inverse interpolate one data table, and then forward interpolate a second table[6]. This method was developed by A. R. Robertson.

III. Sourcing For The Sensor

Despite the previous mention that XYZ colour sensors will be used for this project, the search for the required colour sensor did not begin with looking for XYZ colour sensors immediately. In fact, the existence of such colour sensors was not even known. The first searches done before a comprehensive review of literature yielded temperature sensors which measured the degree of hotness of a body. These were obviously not what were required. The subsequent searches after an initial literature review yielded plenty of seemingly suitable colour sensors.

However, they all shared a common feature - a fairly high purchase price. Hence, even before the suitability of using such sensors was assessed, they had already failed to meet pricing requirements and could not be considered. Fortunately, a company selling colour sensors at prices within the budget was found after searching online for a quite a few days.

The company, MAZeT, is German and they subsequently diverted enquiries to their Asian subsidiary in Japan. The correspondence to ascertain the suitability of the sensors for this project took weeks, despite sending them emails almost daily. Datasheets and specifications were sent upon request; and endless questions were answered. The inconvenience of working with a company overseas became evident quickly. Processes took a longer time and unfortunately, Japan had quite a few national holidays in the midst of the correspondence. However, there was not much of a choice as their sensors fitted the allocated budget, and another company selling suitable sensors at the required prices could not be found. Furthermore, they had rejected the request for free samples and hence there was a need to ensure that the sensors to be purchased were suitable for use in the project. Else, part of the budget would have been wasted on things which are not useful.

After the correspondence had been completed, with the suitability and other technical specifications of the sensors being reasonably satisfactory, the quotation and thereafter the delivery order, was processed.

IV. Prototyping Of Sensor Circuit

The MTCSiCS XYZ colour sensor, together with the MTI04CS transimpedance amplifier, was chosen partly due to budgetary concerns. The purpose of the transimpedance amplifier was to convert the currents generated by the colour sensors into voltages that could be read and stored into the PC via a data acquisition device. The MTI04CS was chosen over the MTI04CQ due to the MTI04CS having a bigger IC footprint as it was undesirable to solder an IC with pins which are very close together. On hindsight, the MTCSiCT colour sensor will have been easier to solder as it had legs, while the MTCSiCS was a surface mounted device (SMD). However, even the MTCSiCT had been selected, a problem with the MTI04CS would still be faced as they had tiny legs which would not fit onto a breadboard for prototyping purposes.

After asking around as well as searching online, it was discovered that suitable adapters that will allow the SMDs to be prototyped on the breadboard had to be found. Prototyping on the breadboard is crucial as it allows checking to determine if the circuit actually works as desired, before doing soldering and hence, setting the circuit layout into stone. Fortunately, an American company which made adapters precisely for such purposes was found while searching online. Even better, the American company had a distributor in Singapore, which allowed tasks to be accomplished quicker.

The next step involved soldering the SMDs onto the adapters. This created yet another set of problems. The soldering irons found in the laboratories in school, as well as the common ones sold commercially, all had relatively thick tips which were not conducive for soldering SMDs, which were comparatively smaller than normal ICs. An effort was made to source for soldering tips which were thinner and meant for soldering SMDs. However, such tips, while available online, invariably involved usage with a specified soldering iron which was relatively expensive. Hence the ordinary soldering irons were used, resulting in a long and arduous soldering process. Fortunately, the laboratory technician at the Digital Electronics Laboratory in NUS chanced upon this arduous soldering process. She managed to locate a thinner tip which was compatible with the soldering iron in the laboratory. Subsequently, the soldering process became very much faster. After soldering the SMDs onto the adapters, the breadboard prototyping could finally proceed.

V. Storing Data Via Agilent DAQ

The colour sensors were connected to Agilent Technologies' U2353A Data Acquisition Device so that the data from the sensors could be stored into the PC. Agilent Measurement Manager software was used to control the input and output of the DAQ. The input data from the colour sensors were stored into an Excel spreadsheet by the software. The data from the sensors were then converted to colour temperature, according to Robertson's method of computing the correlated colour temperature of a XYZ colour,

However, it was desired to measure and display the colour temperature using only one interface, instead of combining the usage of three different programs. This would be less messy and demonstrates an integrated approach to solving the problem at hand. Agilent VEE is a graphical programming language optimized for building test and measurement applications, and programs with operator interfaces. As Agilent VEE works well with the U2353A Data Acquisition Device provided by Agilent Technologies for the purpose of this project, it was chosen.

To implement the required single interface in Agilent VEE, the manual had to be read up to learn the basics of the program. It actually allowed for a C program to be incorporated into the VEE program; however complications were faced with this particular implementation and hence other methods of implementing the C program to calculate the correlated colour temperature had to be devised.

While experimenting with the different methods to implement the C program into the VEE program, problems with the implementation of the If/Then/Else object in VEE was faced. It took days of debugging and trying various methods before the problems were rectified by storing the output values from the sensors as Global Variables in VEE. This solved the problems encountered with the If/Then/Else object and finally the processes of measuring and calculating the correlated colour temperature were integrated successfully into a single interface.

Thereafter, the entire graphical programming code was replicated four more times since there were five sensors in total. However, the replication was not as simple a process as thought to be. The window size was limited and could not display the entire code, while the code was extremely large in comparison. Instead of replicating the code box-by-box, which was what was done at the beginning, the discovery that there existed a function that could copy the entire code once was made. This speeded up the process greatly. However, extra care was taken and the names of all the Global Variables, as well as the various data values, were changed for each replication to avoid errors when running the code later.

However, after replicating the code for the fifth time, the resulting code displayed on the screen showed errors, with some of the boxes missing. The replication was repeated several times but the errors remained. After reading the manual, it was found that there is a limit on the number of boxes that can be used in each program and that the number had been exceeded, resulting in some of the boxes not being displayed. Hence, the code was streamlined by combining the boxes which performed mathematical operations on the data together by editing the formula used in the box. This reduced the number of boxes used and subsequently the replication could be completed without anymore errors.

VI. Realisation Of Actual Circuit

After ensuring that the breadboard circuit works as desired, the next step was to remove the sensors from the breadboard and solder them onto Velo boards for use in the actual implementation of the colour sensors. Care was taken that the temperature did not exceed 240 degrees Celsius while soldering, as recommended by the datasheets in order not to damage the sensors. This slowed the soldering process down somewhat since the solder did not melt immediately and made soldering more difficult. However, the temperature limit was adhered to as it was undesirable to risk damaging the sensors.

The Velo board was used as it was much lighter than the breadboard and all the wires were soldered onto the board, in contrast to being pushed into the breadboard. This offered better connectivity as soldering ensured that the wires would not come off easily.

After the sensors and amplifiers were soldered onto the Velo boards, along with the necessary capacitors and wire connections, the outputs of the amplifiers were connected to the inputs of the U2353A Data Acquisition Device. Subsequently, the Data Acquisition Device was connected to the PC and the VEE program was ran to check if everything worked fine.

VII. Building The Motor System

Low speed high torque DC motors were used to bring the sensors from the center to the edges of the LCD/Plasma screen to be tested. This decision was made based on previous experience in building motor systems while doing the EE2001 project. The motors used then were high speed ones that did not have much torque and hence they were difficult to work with as they usually stopped moving once they faced obstructions. The high speed also made them difficult to control since the distances moved by the gears attached to the motors were very large even in a short period of time. Gears of suitable size such that they would fit perfectly with the motors were also purchased.

Geared tracks to be driven by the gears attached to the motors were then purchased, with the more expensive type chosen as the quality was much better and there were no problems faced with friction.

The arrangement of the gear tracks will be in an x-shape, with a sensor at the center and four sensors on the gear tracks which can move from the center to the edges of the LCD/Plasma screen. The four motors driving the gear tracks will be placed at the ends of the x-shape.

The entire motor system was to be mounted on smooth cardboard, which was lighter than other materials, yet relatively sturdy. Holes for the wires could also be easily made through the cardboard. Smooth wood strips were used to keep the gear tracks in place. The motors were to be held in place by metal strips, which would prevent them from moving. Finally holes were cut along the gear tracks to allow the wires of the sensors placed on the gear tracks to move together with the sensors.

The user could stop the sensor anywhere along the diagonals to measure the colour temperature of the screen at that point. This will be useful particularly when the LCD/Plasma screen is large and measuring the colour temperature at the center and the 4 corners is insufficient.

After ensuring that the circuit worked as desired, the circuit was transferred onto Velo boards, as done previously. However, difficulties were faced when the sensors were attached to the gear tracks. 3M double-sided tape was purchased and used to attach the sensors to the gear tracks. However, when the gear tracks were slid along the wood strips during testing, the sensors kept detaching from the gear tracks. This was caused by the pulling force of the stiff wires which were attached to the sensors since the wires were not flexible and did not move smoothly along with the sensors as intended.

Hence, the decision to use epoxy adhesive was made as previous experience with the EE2001 project indicated that epoxy was stronger than superglue or even contact glue, and would not deform plastic surfaces, which was what the gear tracks and SMD adapters were made from. However, epoxy was extremely messy as there was a need to mix resin and hardener to form the epoxy adhesive and extra care had to be taken while applying the epoxy so that it would not flow to other parts of the gear track, which could possibly cause rough surfaces, which in turn would pose problems due to friction generated by the rough surfaces.

After epoxy was used to attach the sensors to the gear tracks, the problem with the sensors detaching themselves from the gear tracks disappeared. However, this strong bond caused new problems. As the inflexible wires were forced to move along with the sensors on the gear tracks, the wires started to break at the points just before they were soldered onto the Velo boards. This was due to the repeated movements of the wires in opposite directions when the sensors moved to the edges of the screen and back to the center. This posed a huge problem as the wires had to be resoldered often.

Hence, sliding contacts were used, instead of attaching the wires to the sensors directly. I stripped the insulation from some inflexible wires and placed the bare wires parallel to the gear tracks. Short wires soldered to the sensors were then attached to the bare wires in such a way that the soldered wires slid along the bare wires while moving along with the gear tracks. However, extra care had to be taken to ensure that the bare wires did not come into contact with each other to prevent short circuits. Thereafter, the gears attached to the motors were placed on the gear tracks and the motor circuits soldered. 3M double-sided tape was used to attach the motors to the wood strips. Metal strips were also used to secure the motors further.

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