

An Approach for Enhancing an Optical Microscope with TFT Display and AV Output

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Date of First Submission: 07/09/2017

Date Accepted: 18/10/2017

Abstract: Microscopes are used in various science and engineering laboratories/fields: in Electrical/Computer Engineering for examining microchips and nanochips; in Chemical/Petroleum Engineering for observing and monitoring the chemical reactions; in Physics for optical microscopy; in Geology for studying mineral structures of rock and soil samples; in Health Sciences for studying and analysing animal or plant cells, tissues, forensic evidence; and so on. There is a need to view specimens on a broader display with a higher resolution in cases where it is to be presented to a group of persons or in a work field. This paper presents an approach to enhancing an optical microscope with images magnification efficiency. This is with the aim of using a Thin Film Transistor (TFT) Liquid Crystal Display (LCD) display with optical microscope or alternatively displaying real-time image externally on a television via the inbuilt Audio/Visual (AV) output.

Keywords: Audio/Visual (AV), Liquid Crystal Display (LCD), microscope, optical, Thin Film Transistor (TFT).

1. INTRODUCTION

A microscope is an optical instrument having a magnifying lens or a combination of lenses for inspecting objects too small to be seen or too small to be seen distinctly and in detail by the unaided eye. Aside from lens system classification, microscopes are classified based on their area of application and performance, their cost, their versatile nature or any other aspect. Microscopes can also be classified by what interacts with the object whether it is light or electrons and these includes: optical microscope which magnifies specimens through the use of lenses and visible light, and electron microscope which scans with electrons rather than visible light, resulting in a very detailed image. Wide field electronic microscope as an example of optical microscopes and transmission electron microscopes both use the theory of lenses, optics for light microscopes and electromagnet lenses for electron microscopes, in order to magnify the image generated by the passage of a wave transmitted through the sample, or reflected by the sample. The waves used are electromagnetic, in optical microscopes or electron beams, in electron microscopes. Resolution in these microscopes is limited by the wavelength of the radiation used to image the sample, where shorter wavelengths allow for a higher resolution [1].

In optical microscope, the oldest and simplest in design, this is the microscope most likely to be used by students, hobbyists, and certain types of scientists. In electron microscope, this works because the wavelength of the electrons is much smaller than the wavelength of light from a bulb or laser, allowing for greater detail when scanning. Most other types of microscopes are less common and used by research scientists. These include: Scanning Probe Microscope which scan the sample with a physical probe. The tip of the probe raster scans (goes line by line) the specimen and generates an image with a computer. Unlike an electron microscope, this scans in normal air rather than a vacuum (or partial vacuum). But the scanning can be slow and the maximum image size is limited. Scanning Acoustic Microscope which uses a principle similar to sonar, in that they employ sound waves to measure the sample. This type of microscope, called a SAM, is used to find cracks and voids, detect counterfeit materials, test for failure and reliability, and perform quality control on physical materials. They can also provide information on the elasticity of cells for biological research.

X-ray Microscope which uses electromagnetic radiation in the form of x-rays to produce images of tiny objects. Unlike an electron microscope, it can be used to generate an image of living cells. They're useful in biological research and metallurgy, as the images are highly detailed [1-3].

The general trend in the development of observational technique is currently the transition to digital systems for recording and processing images. In modern microscopy, this problem is usually solved by combining a classical light microscope with a general-purpose video camera analog or digital and storing the resulting image in a computer so that it can subsequently be processed. The microscope in this case uses both channels—the visual ocular channel, and the digital video-camera-computer channel. However, the extensive professional use of such a solution faces two problems. First, general-purpose video cameras do not provide the colour rendition quality required in many professional areas, and, second, the unwieldy complex, consisting of a microscope, an adapter, a video camera, and an external computer, cannot always be used in practice [4]. The largest producers of

microscopes in the world, such as Carl Zeiss, Nikon, Leica, and Olympus, in 1990 developed and proposed models of devices based on classical microscopes with supplementary video cameras. At the same time, companies that specialize in the production of charge-coupled device (CCD) arrays and microprocessor engineering, such as Sony and Intel, entered into competition with them in this section of the market by marketing pilot samples of microscopes with digital image recording. The development of nano and biotechnologies, the challenges that face genetic engineers, the need to obtain quick and reliable information on the characteristics of microscopic objects in a wide spectral region, and the refitting of scientific research and school laboratories with modern equipment mean that various types of digital microscopes will be required in the coming decade. In recent years, the specialists of OAO LOMO have carried out comprehensive research and have developed a fundamentally new generation of digital microscopes that have become known as micro-viewers. The creation of micro-viewers functionally complete digital systems for the observation of objects of the micro-world, requiring no external computer for information storage and processing and likewise no ocular channel for the subjective visual monitoring of the image became possible only after solving two important problems: ensuring adequate colour rendition and creating specialized information-processing hardware [4,5].

There are challenges faced mostly in scientific research and educational sector when a lecturer teaches a large population of student in a laboratory and having to sample, observe and study a specimen using a conventional optical microscope. It is always a time consuming exercise as students are expected to view the specimen one after another from the eye piece of the microscope in cases of limited optical microscope or specimen. This paper aims at enhancing the monocular compound microscope by attaching a TFT LCD display and an Audio/Visual (AV) output where a television (TV) can be connected to display real-time image of the specimen on a larger screen. The improvised microscope is not only time efficient and versatile but magnifies and gives a higher resolution of sampled specimen thereby enabling students to view the specimen under observation at the same time from their seat. It also incorporate an inbuilt battery for deployment in field works.

This paper has been organised into three sections

- **Methods and Materials**
This section details on the materials used and the various methods and processes employed to get a monocular compound optical microscope attached with TFT LCD display and an inbuilt AV output connector.
- **Tests and Results**
In this section, the enhanced microscope was tested and performance evaluation was carried out.
- **Conclusion**

2. METHODS AND MATERIALS

2.1 Monocular Compound Optical Microscope

An optical microscope, also sometimes known as a light microscope, uses one or a series of lenses to magnify images of small samples with visible light. The lenses are placed

between the sample and the viewer's eye to magnify the image so that it can be examined in greater detail [6,7]. In this work, a Monocular Compound Microscope was used.

A compound light microscope is a microscope with more than one lens and its own light source. In this type of microscope, there are ocular lenses in the monocular eyepieces and objective lenses in a rotating nosepiece closer to the specimen. The Monocular compound light microscope only use one eyepiece when viewing the specimen as presented in Figure 1. You are restricted if you want to use a charge-couple device (CCD) camera because this would occupy the eyepiece. However, monocular microscopes are light weight and are inexpensive. The first light microscope dates back to 1595, when Zacharias Jansen created a compound microscope that used collapsing tubes and produced magnifications up to 9X.

One of the biggest benefits of owning a light microscope is its simplicity and its convenience. A compound light microscope is relatively small, therefore it's easy to use and simple to store, and it comes with its own light source. Moreover, because of their multiple lenses, compound light microscopes are able to reveal a great amount of detail in samples. Even an inexpensive one can reveal an incredible view of the world that would be impossible to explore with the naked eye [8].



Figure 1: A Compound Monocular Optical Microscope

2.2 Methodology

- (1) Disassembling the monocular compound optical microscope and inserting a camera lens and image sensor inside the microscope as presented in Figure 2.



Figure 2: Insertion of the camera lens and the image sensor inside the microscope

(2) Attaching the light illumination system which was design at the base of the microscope, to enable light ray pass through the specimen under observation as presented in Figure 3.



Figure 3: Attachment of the light control system to the microscope

(3) Removing the microscope observation tube and installing the TFT display on the microscope as presented in Figure 4, to

enable specimen captured and processed with the image sensor to be displayed on the TFT.



Figure 4: Attaching the TFT LCD display on the microscope

The following components were designed, constructed and integrated into the monocular compound optical microscope.

- Power supply unit
- Light illumination unit
- Implementation of camera lens
- AV output unit
- TFT LCD Display

2.2.1) Design of the Power Supply Unit:

It supplies power to the system at the same time stores energy/power in case of field work where power might not be available and the system needs to be used. The design of the power supply as presented in Figure 5 includes the use of step-down transformer, diodes, full wave rectifier, capacitors, transistor, battery, resistors, variable resistor, and a common voltage regulator IC (7805) [9]. Some DC power supplies use AC mains electricity as an energy source. Such power supplies will sometimes employ a transformer to convert the input voltage to a higher or lower AC voltage. In this case, the transformer steps down the 220V-240V from the main to a more usable 12V.

A rectifier is used to convert the transformer output voltage which is the 12V to a varying DC voltage, which in turn is passed through an electronic filter to convert it to an unregulated DC voltage (pulsating D.C).

The filter removes most, but not all of the AC voltage variations; the remaining AC voltage is known as ripple.

The electric load's tolerance of ripple dictates the minimum amount of filtering that must be provided by a power supply. In some applications, high ripple is tolerated and therefore no filtering is required but it is advised to use an additional capacitor which is the C2 (100uF). The given AC voltage, 12V is then sent to the LM7805 voltage regulator.

The unit was soldered on the vero board. The transformer used a 220/12V step-down transformer which operates like every other transformer. The rectifier is a bridge rectifier made up of four diodes connected to each other at their separate terminals to form a square shape.

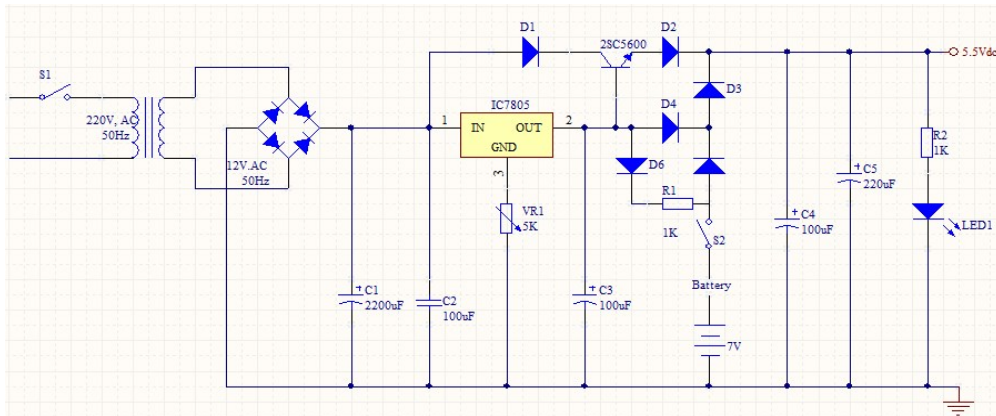


Figure 5: Circuit diagram of the Power Supply

From the circuit in Figure 5, when switch, s1, is turned on, it takes in 220/12V AC, 50Hz from the source which is stepped down to 12V AC, 50Hz by the transformer. The full wave rectifier converts the 12V AC to 12V pulsating DC, and the capacitor C1, C2 acts as a filter, it removes repulse and eliminate the AC component of the waveform and produces nearly constant DC voltage output.

The IC LM7805 is used to regulate the 12V to 5V since it can only provide 1.5amp and the rest of the current is supplied by the transistor which will supply 5V passed through a 1K resistor used to charge the battery. The diodes allow current to flow in one direction (prevents current from going back) and avoids feedback from the output to reduce over-heating.

The illumination unit controls the amount of light reaching the specimen. This light is located at the base of the microscope, the sources of the light is connected to the mains and has a regulator which controls the light brightness. In other models, a mirror is used as the light source. It is fixed to the base by a binnacle, through which it can be rotated, to converge light on the object. The mirror is plane on one side and concave on the other.

The design of the illumination system as presented in Figure 6 includes the use of LM317 voltage regulator, diodes, capacitors, resistors and a potentiometer [10]. The LM317 device is an adjustable three-terminal positive-voltage regulator capable of supplying up to 1.5A over an output-voltage range of 1.25V to 37 V. Capacitor C1, C2 and C3 are used as filters.

2.2.2) Design of Illumination Unit:

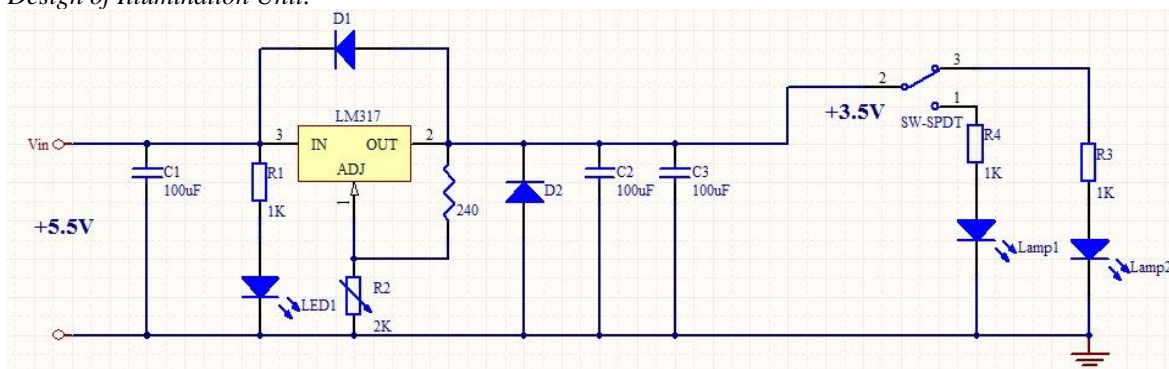


Figure 6: Circuit diagram of the illumination system

The light control circuit takes in 5.5V from the power supply, the capacitor C1 improve ripple rejection, R1 reduce the amount of current going through the LED1 and the 2K variable resistor regulates this 5.5V between 2V to 3.5V that

the lamps (light) can take, the lamps use a 2-way switch which enables one lamp to be used at a time. The Single Pole Double Throw (SPDT) switch is a switch that only has a single input and can connect to and switch between 2 outputs, in the circuit

our outputs are Lamp 1 and Lamp 2. This means it has one input terminal and two output terminals. It connects circuits to any two various paths that a circuit may need to function in, therefore in the circuit given above, SPDT can be wired up to put a circuit in either one of two modes. When the switch is connected one way, Lamp1 will turn on, while the Lamp 2 is off. When connected the other way, Lamp 2 then turns on, and the Lamp 1 shuts off.

2.2.3) Integration of Camera Lens:

This also called photographic lens of photographic objective, is an optical lens or assembly of lenses used in conjunction with a camera body/microscope and mechanism to make image of object either on photographic film or on other media capable of storing image chemically/electronically. This camera lens is engineer and fabricate using CAD facility, form the image objective lens, light is gathers from the specimen eyepiece, transmits and magnifies the image from the objective lens to your eye nosepiece rotating mount that holds many objective lenses tube and holds the eyepiece at the proper distance from the objective lens and blocks out stray light.

This is the most sensitive part of the project. Its where the specimen under observation is captured and sent to the AV output and to the TFT display. The block diagram shown in Figure 7 illustrates the system level operation of a camera system. The image sensor captures an image, allowing the image processor to analyze the image to evaluate focus score and the AF algorithm commands the driver circuit to move or modify the lens to a next focus position. This cycle repeats until an optimum focus position is determined. The lens position or shape must then return to the same value it had when the best focus score was achieved [11].

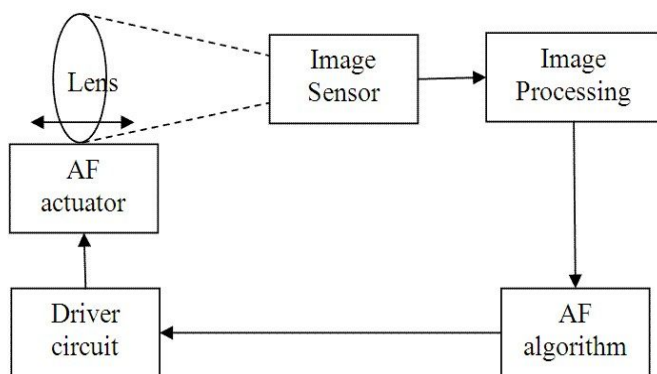


Figure 7: Block diagram of Camera

This requires the actuator to have good repeatability and low hysteresis. Furthermore, to avoid user frustration over the missed photo opportunities associated with latency, the actuator must respond quickly to the commands from the AF algorithm. Finally, in video mode, the AF algorithm is continuously active, so power consumption becomes an additional concern.

2.2.4) Design of The AV Output Unit:

AV output is a common label on a connector to receive (AV) audio/visual signals from electronic equipment that generates AV signals (AV output). These terminals are commonly found on such equipment as a television, DVD recorder or VHS recorder, and typically take input from a DVD player, a TV tuner, VHS recorder or camcorder.

The design of the AV output unit as presented in Figure 9 consists of capacitors, diodes, resistors and amplifier (that uses op-amp). The circuit has 3 major stags, which are as follows; Video signal to voltage converter, pre-amplification, amplifier, C1 to R2 converts input video signal to voltage signal. Capacitors shunt any unwanted signal to ground while the R4 regulates the amount of current shunt to ground[12]. The construction of this circuit is divided into 3 main stages:

- The video signal to voltage conversion stage
 - Pre-Amplification stage
 - Amplification stage.
- The video signal to voltage conversion stage:

This occurs at the beginning of the circuit, the incoming video signal is being converted to voltage signal. This conversion is done with the aid of Varactor diode, capacitor C1 which filters incoming ripples, Resistors R1 and R2 all connected in series with each other and C2, C3, C4 and R3 all connected as shunt, whose main aim is to prevent excessive or unwanted signals/voltage at low loads thereby sending these signals to ground. R4 regulates the amount of current shunting to ground.

The varactor diode or varicap diode consists of a standard PN junction, although it is obviously optimized for its function as a variable capacitor. In fact ordinary PN junction diodes can be used as varactor diodes, even if their performance is not to the same standard as specially manufactured varactors. The basis of operation of the varactor diode is quite simple. The diode is operated under reverse bias conditions and this gives rise to three regions. At either end of the diode are the P and N regions where current can be conducted. However around the junction is the depletion region where no current carriers are available. As a result, current can be carried in the P and N regions, but the depletion region is an insulator.

This is exactly the same construction as a capacitor. It has conductive plates separated by an insulating dielectric. The capacitance of a capacitor is dependent on a number of factors including the plate area, the dielectric constant of the insulator between the plates and the distance between the two plates. In the case of the varactor diode, it is possible to increase and decrease the width of the depletion region by changing the level of the reverse bias. This has the effect of changing the distance between the plates of the capacitor.

- Pre-amplification stage:

In this stage, a special component called the operational amplifier, Op-Amp, is being used. Op-Amp is a DC-coupled high-gain electronic amplifier with a differential input and,

usually, a single-ended output. In this configuration, an op-amp produces an output potential (relative to circuit ground) that is typically hundreds of thousands of times larger than the potential difference between its input terminals.

The amplifier's differential inputs consist of a non-inverting input (+) with voltage V_+ and an inverting input (-) with voltage V_- ; ideally the op-amp amplifies only the difference in voltage between the two, which is called the differential input voltage. The output voltage of the op-amp V_{out} is given as:

$$V_{out} = A_{OL} (V_+ - V_-) \quad (1)$$

Where A_{OL} is the open-loop gain of the amplifier (the term "open-loop" refers to the absence of a feedback loop from the output to the input).

In the Pre-Amplification stage, the Operational amplifier acts as an Integrator, that is we can cause the output to respond to changes in the input voltage over time as the op-amp integrator produces an output voltage which is proportional to the integral of the input voltage. In other words the magnitude of the output signal is determined by the length of time a voltage is present at its input as the current through the feedback loop charges or discharges the capacitor

as the required negative feedback occurs through the capacitor, $C7$ and diode $D2$ respectively.

- Amplification stage:

At this stage, the amplifier acts as a comparator. The magnitude of A_{OL} is typically very large, and therefore even a quite small difference between V_+ and V_- drives the amplifier output nearly to the supply voltage. Situations in which the output voltage is equal to or greater than the supply voltage are referred to as saturation of the amplifier. The magnitude of A_{OL} is not well controlled by the manufacturing process, and so it is impractical to use an open-loop amplifier as a stand-alone amplifier. Without negative feedback, and perhaps with positive feedback for regeneration, an op-amp acts as a comparator. If the inverting input is held at ground (0 V) directly or by a resistor R_g , and the input voltage V_{in} applied to the non-inverting input is positive, the output will be maximum positive; if V_{in} is negative, the output will be maximum negative. Since there is no feedback from the output to either input, this is an open-loop circuit acting as a comparator.

The capacitors $C5$, $C9$, $C11$ are connected in shunt in this stage; its purpose is to send unwanted signals to ground.

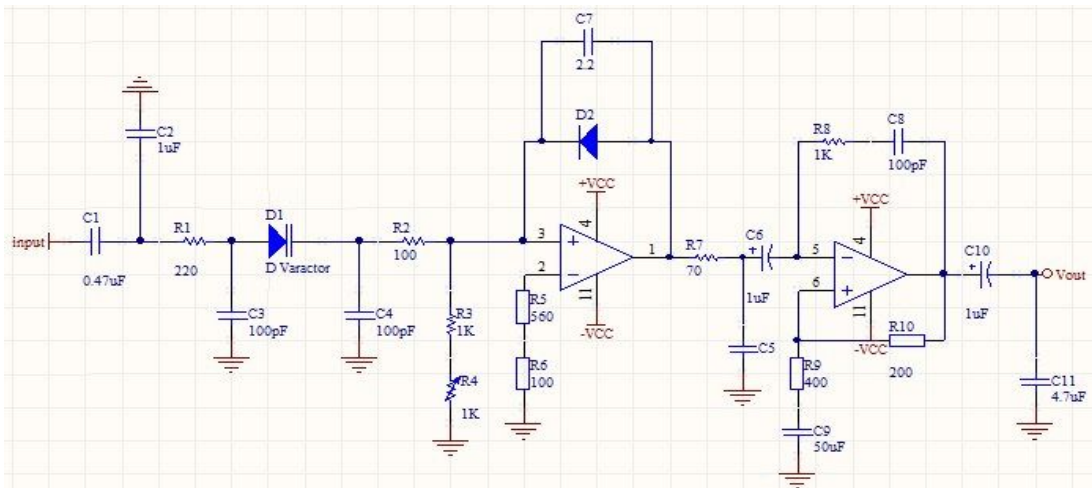


Figure 8: Circuit diagram of the AV output unit.

The circuit in Figure 8 is a simple video amplifier circuit that use an op-amp IC number: LM395, which can work in high frequency such as LM3900 series. Gain bandwidth of the LM359 is approximately 10-100 times at frequency 30MHz range, and can use up to 400MHz but lower gain.

2.2.5) TFT LCD Display:

A thin-film transistor (TFT) is a special kind of field-effect transistor made by depositing thin films of an active semiconductor layer as well as the dielectric layer and metallic contacts over a supporting (but non-conducting) substrate. A common substrate is glass, because the primary application of TFTs is in liquid-crystal displays. Thin film transistor is a type of LCD flat-panel display screen, in which each pixel is controlled by from one to

four transistors. The TFT technology provides the best resolution of all the flatpanel techniques. TFT screens are sometimes called active-matrix LCDs. TFT is used to improve the image of a regular LCD screen by attaching a transistor to each pixel, which provides more control over the color and images it can render. This where specimen under observation on the microscope will be displayed instead of viewing from the smaller lens with our eye. The TMDS-Rx reference design is a high-speed serial video interface to connect a remote automotive TFT LCD display with DVP (LVCMOS) Interface to a video processing system [13]. As presented in Figure 9, it uses TIs FPD-Link II SerDes technology to transmit uncompressed video data over shielded twisted pair cable.

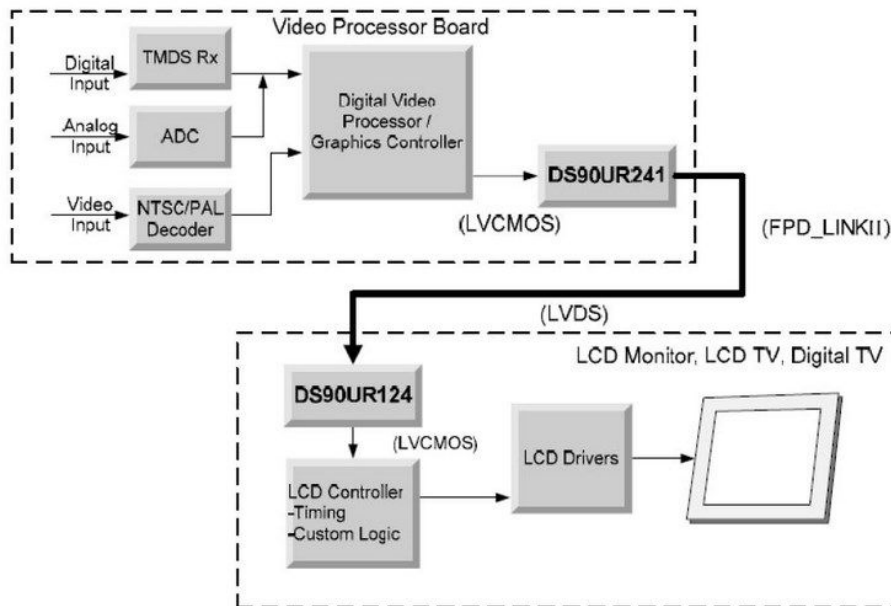


Figure 9: TFT LCD block diagram

The TFT LCD display is where the specimen after being captured and processed by the camera lens and image

sensor is being displayed and sends to the output source. The overall block diagram is shown in Figure 10.

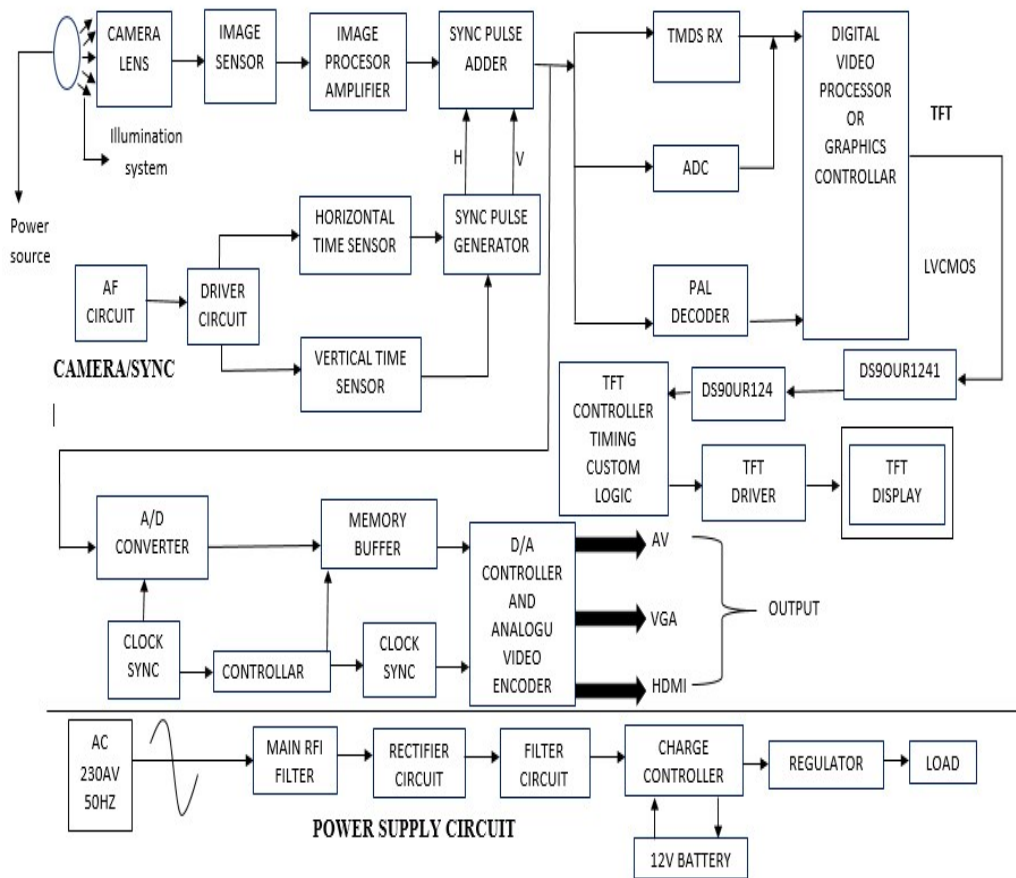


Figure 10: Block Diagram of Monocular Compound Optical Microscope enhanced with TFT display and AV output

2.2.6) Packaging:

All the circuits (power supply, light and AV) are all soldered on the Vero board as shown in Figure 11. The light control and AV system are all connected to the power supply unit/system, in other to get power that can be used by each of them. The circuits are powered by 220/12V from the source stepped down to 12V by the transformer. The full wave rectifier converts the 12V AC to 12V pulsating DC, the LM7805 together with the transistor, is used to regulate this 12V to 5.5V output to the other circuits. The light control circuit take in 5.5V from the power supply, LM317 together with the 2K variable resistor regulates this 5.5V between 2V to 3.5V that the lamps (lamp1 and lamp2) can take, the lamps uses a 2-way switch which enables one lamp to be used at a time. The AC circuit take in an input voltage of 0.5V from the power supply and gives out 1.5V output. The specimen under observation is captured by the image sensor, processed and sent to TFT LCD display to be viewed and to the AV output source to be projected on a TV screen. Figure 13 shows the instrument powered and fully functional with a specimen (leaf) viewed.

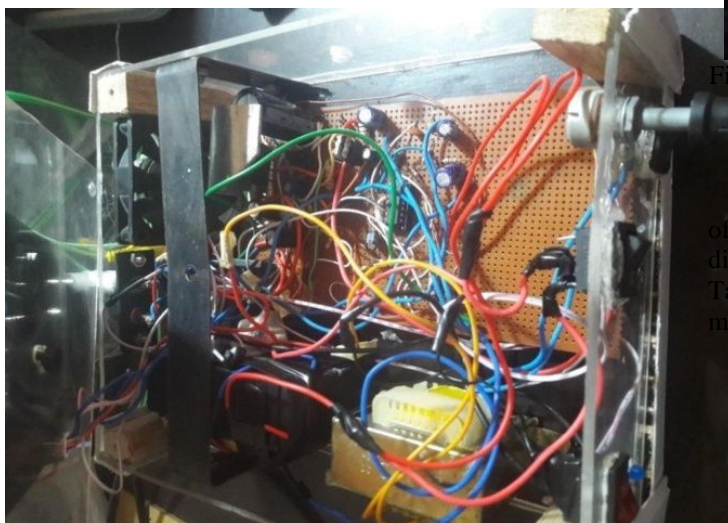


Figure 11: The complete circuit soldered on the Vero board placed in the plastic case

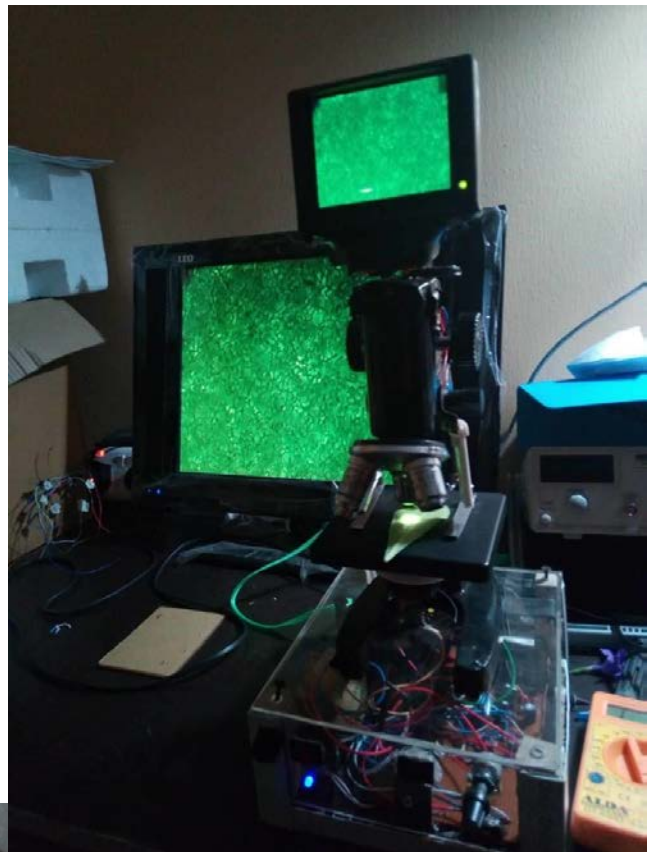


Figure 12: Complete package projected both on the TFT LCD display and externally on a TV via the inbuilt AV output

3. TESTS AND RESULTS

Figure 13 and Figure 14 show the front view and back view of the monocular compound optical microscope with TFT display respectively. To carry out the tests in Table 1 and Table 2, the following steps are taken to safely operate the monocular compound optical microscope.

- (1) Turn on the mains power supply and switch on the microscope using the power switch on the base of the microscope.
- (2) Turn on the illuminator by using the lamp switch in the base, choosing either lamp one or two depending on the intensity of the sample.
- (3) Place a slide or specimen on the stage with the sample directly above the aperture and, if possible, fasten it to the stage with the stage clips.
- (4) Rotate the nosepiece so that the objective lens with the lowest level of magnification is directly above the sample. Using lower magnifications first helps to select the part of the specimen of interest and then adjust further depending on the view preferred.
- (5) Look at the TFT LCD display screen until the amount of light satisfactory for the sample is obtained. (more light is better than less light).
- (6) Turn the coarse adjustment knob until the specimen comes into broad focus.

Caution: you should not use the coarse focus with a high magnification objective for fear of the objective making contact with the slide or even breaking the slide.

(7) Turn the fine adjustment knob until the specimen comes into sharp focus.

Caution: it should not take a long time to find focus due to high resolution of the system; otherwise the high magnification objective could also hit the slide. If you are having a difficult time to find focus then restart with the lower magnification objective.

(8) The viewer should then be able rotate the nosepiece to higher settings and bring the sample into more and more detail with a minimal amount of refocusing.

(9) External view can be enabled by connecting the AV output of the microscope to a wider screen.

For viewing objects with very thick layers, lamp two should be turned ON which is beside object lens.

In order to move your microscope safely, one hand should be under its base for support and the other at its arm. Be sure to only switch off the microscope when the dimmer is set to the lowest intensity and always turn off the lamp before moving the microscope.

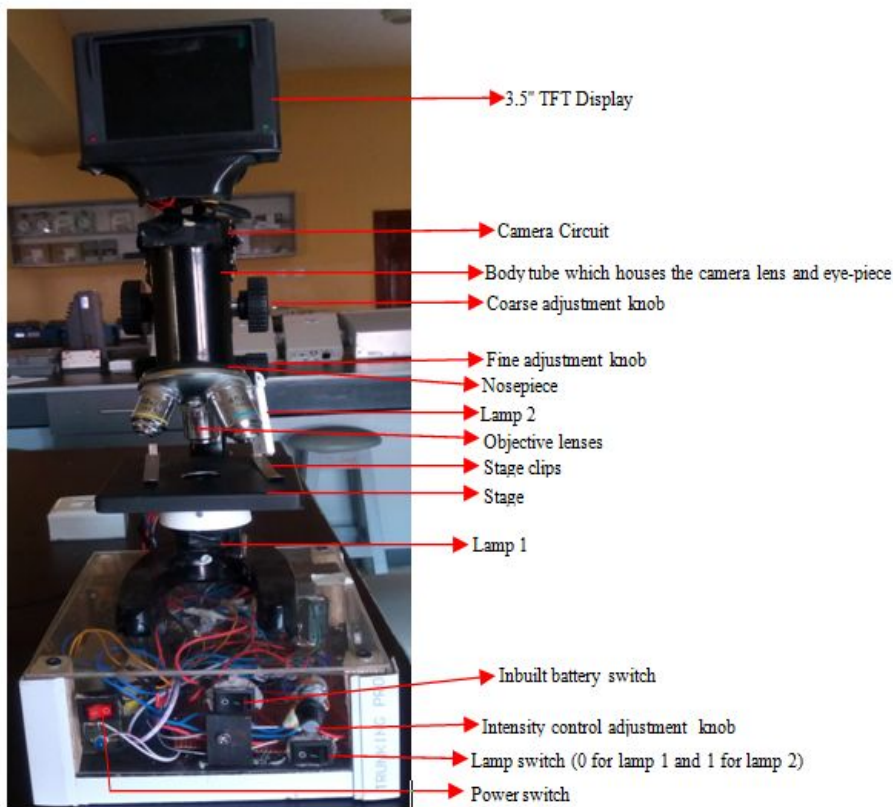


Figure 13: Front view of the monocular compound optical microscope

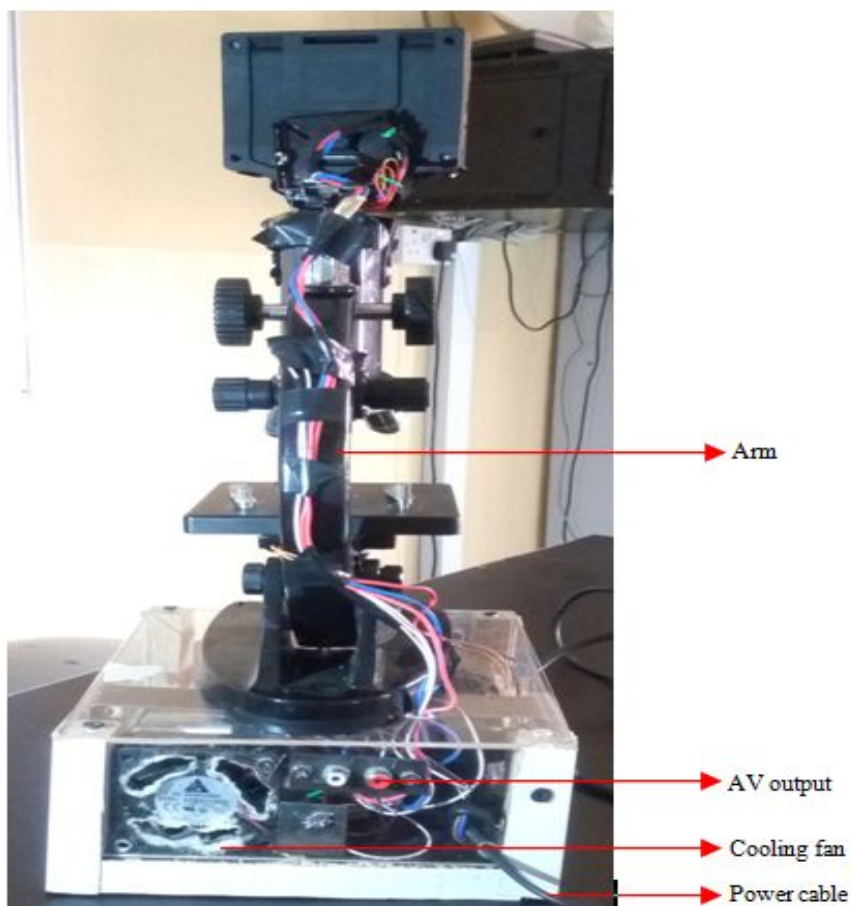


Figure 14: Back view of the monocular compound optical microscope

Table 1: Test and Result Analysis

Test	Result
Clarity	The TFT has a better and clearly display than the external TV output because the TFT has its own rectifier, processor and filters.
Object illumination	Lamp1 is better for transparent objects because it illuminates a specific spot on the specimen while lamp2 is better for opaque objects because the object reflects.
AC power sources	The resolution and colour is good and last longer if there is constant power supply.
Battery	The resolution and colour is better than that of the AC power source but has low life span.
System Reliability	Under power source the system has proven to be stable without any component malfunctioning and its supported by the cooling fan.

Table 2: Test for Transparency and Opaque

Tests Narrow Lens	Results Transparent Specimen	Results Opaque Specimen
5 x 0.10	8mm far from the specimen	7mm far from the specimen
10 x 0.25	6mm far from the specimen	5mm far from the specimen
4.5 x 0.65	0.9mm far from the specimen	0.5mm far from the specimen

3.1 Performance Evaluation

In other to test the performance of this system, the power section of the system operated as desired and the required approximation of 5.5V is supplied to the entire system. The light system takes this 5.5V and regulates it to about 3.5V that the LED's lamps can take. The AV circuit has an input voltage of 0.5V and an output voltage of 1.5V.

The major test which was carried out to determine the overall performance of the system after construction and casing with the transparent plastic was the system start-up time which was recorded to be 3 secs maximum.

The start-up time of the electronic microscope is the time it takes for the TFT LCD to display the information about the specimen. The time it takes from when the AC power (220v) is supplied from the mains to the transformer and stepped down to 12V, then the rectifier, voltage regulators and capacitors which helps in stepping this 12V to 5.5V used by the light control system, Camera, AV output source, and the TFT LCD display.

Immediately the circuit is powered and there is a specimen to be observed with the required amount of light passing through it, in nanoseconds, the TFT LCD displays the information seen from the specimen, which is in turn sent to the output source.

4. CONCLUSIONS

In the process of improving learning process in our educational systems as well as in various areas of research, an optical microscope attached with TFT LCD display and an inbuilt AV output has been developed. This enhanced scientific instrument outperforms the existing optical microscope by projecting the images in a higher resolution on a TFT LCD display and also externally via the inbuilt AV output where a TV is connected for the audience to view the specimen being sampled at same time thereby conserving time that would have been used by each person to individually view the specimen using the eyepiece. Also the enhanced microscope has the ability to increase/decrease the intensity of the light using six (6) white LEDs which is not possible in the existing optical microscope. It also has an additional advantage of an inbuilt battery for deployment in field works as well as having a better zooming and auto focusing capability than the existing optical microscope. However, further can be done to improve this work which includes implementing a HDMI Port and VGA output sources; having the ability to save and print specimens; also a more enhanced

battery should be implemented to increase the time duration the microscope will function in the absence of power supply.

ACKNOWLEDGMENT

The authors wish to thank Okorie Emmanuel and Nwaneke Emmanuel who were undergraduate students of the institution we work. They were a part of the success of this work and also special thanks to the Department of Electrical/Electronics and Computer Engineering, College of Engineering, Afe Babalola University Ado-Ekiti for their support.

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