

M-Learning Based Remote Laboratory for Electronics Experiments

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Abstract—The paper goals on the implementation of Mobile learning (M-learning) based Remote Laboratory to maximize the available resource as well as to improve self-learning ability. The developed system provides practical experience to the learners in the field of analog electronics. This laboratory permits the learners to conduct experiments on real time with the internet facility using developed android mobile application. A characteristic of Junction Field Effect Transistors (JFET's) related to analog electronics has been considered for remote laboratory experimentation. The designed system can be expanded by adding new experiments without any complexity. This M-learning based remote laboratory approach enables the sharing of resource between the institutions for the minimization of expense and also encourages learners by enhancing engineering education.

Keywords—M-learning, Remote Laboratory, Analog Electronics, Junction Field Effect Transistors (JFET's)

1 Introduction

There are a number of Remote Laboratories available worldwide for the engineering education platform. But the focus is to complements those remote laboratories with M-learning facilities. M-learning offers better learning engagement and has a capability to offer anytime-anywhere learning on the go. M-learning platform has evolved technologically and has grown popularly, this has replaced the need for desktop or laptop computer to access internet. In M-learning, use of a tablet or other mobile device is a crucial part of the educational programs.

M-learning based remote laboratories are used to deliver distance education and is proliferating exponentially in various learning programs. Extensive research has been carried out and the importance of remote laboratory in undergraduate engineering

education has been presented [1]. Literature has also witnessed the conduction of experiment in laboratory by complimenting with web-based [2] in the last few decades.

In general, laboratories are divided into three categories viz., Physical, Virtual & Remote. Physical laboratories provide investigations of experiments inside campus, Virtual laboratories provide interactive environment for conducting experiments and Remote laboratories provide real experiments to be conducted over the internet. Many comparative case studies have been carried out for all the three categories of laboratory [3]. Different fields of signal processing and electronics device characterization with web-based remote-control laboratory is also developed [4], [5].

The flexibility of the mobile learning in education provides the new way to learn the content, combining remote laboratory with a mobile device benefits many learners and tutors [6] - [8]. Mobile learning plays an important role in different fields of engineering where biotechnology and other experimental mobile learning or web-based learning provides lot of opportunities [9]-[15]. The focus of the proposed work lies in creating a conducive environment for conducting electronic experiments remotely and accessing the same via mobile learning platform.

The proposed remote laboratory is cost effective and is integrated with android mobile application. Remote users with mobile application can control and monitor the experimental results in real-time. This M-learning provides an opportunity for the remote users to perform their experiment individually and they can relate the theoretical knowledge with practical experience.

The paper is organized as follows; section 2 describes the proposed architecture of M-learning and presents the working of JFET experiments in an undergraduate analog electronics course. Section 3 discusses the way to access the remote laboratory with the android mobile application. Section 4 explicates the obtained experimental results and section V concludes the paper.

2 Proposed Architecture and Working

In general, Remote laboratory requires three main platforms called physical laboratory, embedded systems and Internet. The proposed architectures present the M-learning based experimentation for the characteristics of N-channel and P-channel JFET Common Source (CS) configuration. M-learning based remote laboratory provides flexibility to expand by adding new experiments in the analog electronics field. Fig 1. shows the proposed architecture of M-learning based remote laboratory setup.

The physical laboratory consists of N-channel JFET and P-channel JFET experimental circuits for the conduction with M-learning. Basically, JFET uses the voltage that is applied to their input terminal, called the gate to control the current flowing through them resulting in the output current being proportional to the input voltage, the gate to source junction of the FET is always reversed biased. Fig 2. (a) and (b) shows the physical laboratory experimental circuit of N-channel JFET and P-channel JFET CS configuration.

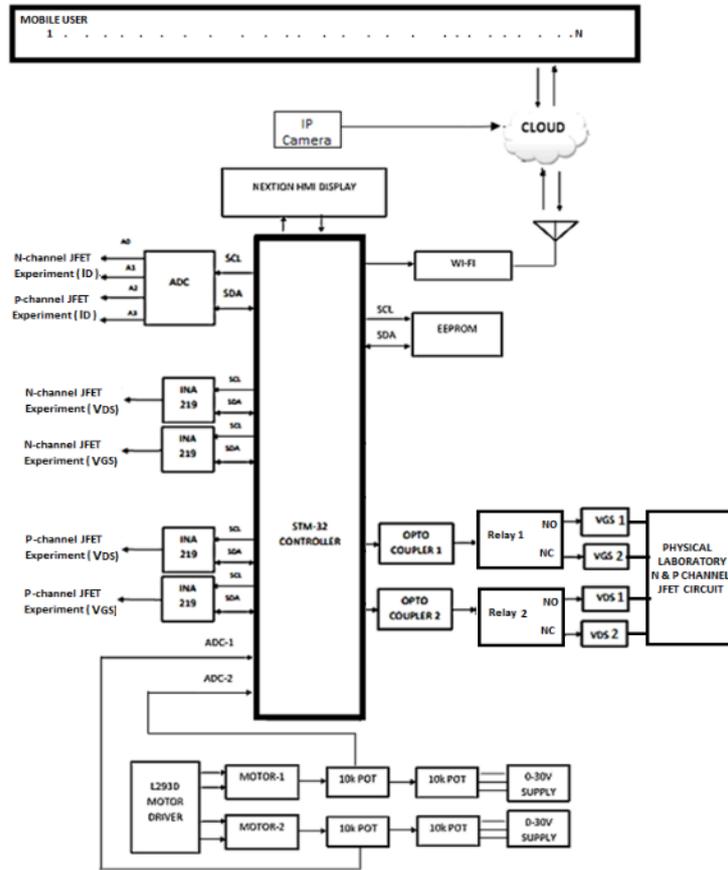


Fig. 1. Architecture of M-learning based remote laboratory setup

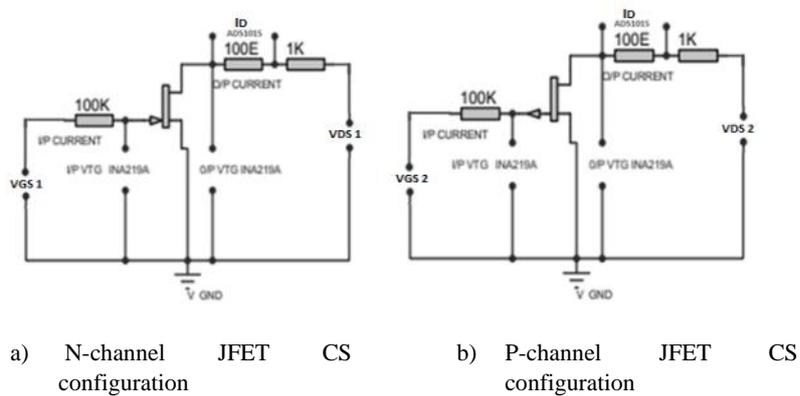


Fig. 2. Physical laboratory experimental circuit

An embedded system bridges the physical laboratory and internet, ARM STM-32 controller is used to perform all major tasks in the M-learning based remote laboratory setup. Dual Regulated Power Supply (RPS) is required to conduct the experiments present in the physical laboratory. To vary the RPS input voltages, DC Motorized pots are used which move $0^\circ - 270^\circ$ for 0 - 30V full scale voltage. Motorized pot uses L293D H-bridge motor driver circuit to increment and decrement the RPS input voltage. Opto-coupler and Relay unit connect the dual RPS input voltages of 0-30V to N-channel JFET and P-channel JFET circuits. These are also used to provide input/ output isolation for the STM-32 controller units. The relay's, when Normally Open (NO) connect the dual RPS to N-channel JFET experiment and when Normally Closed (NC) connect the dual RPS to P-channel JFET experiment.

To measure the input/output voltages and output current, voltage monitoring IC INA219 and current monitoring IC ADS1015 are used. IC INA219 is a digital-output IC that measures the input voltage across JFET's Gate to Source terminals (V_{GS}) and output voltage across the JFET's Drain to Source terminals (V_{DS}). The two channels of IC ADS1015 are used to monitor Drain currents (I_D) of N-channel and P-channel JFET configuration. Both voltage and current monitoring IC communicates to ARM STM-32 with the Inter-Integrated Circuit (I^2C) protocol. I^2C protocol consists of serial clock (SCL) and serial data (SDA) lines for communication.

To enable M-learning, the setup requires the ESP12E Wi-Fi Module. The Wi-Fi module is configured by providing the SSID (Service Set Identifier) and network key of the internet. The EEPROM stores the SSID, Network security password of the Wi-Fi module and communicate to ARM STM-32 with the I^2C protocol.

The Obtained output parameters from the experiments of the physical laboratory are displayed on Nextion HMI display and IP camera captures the HMI display, which provides live-streaming of the physical laboratory to remote user.

Message Queuing Telemetry Transport (MQTT) protocol and Real Time Streaming Protocol (RTSP) are used to connect the cloud by the Wi-Fi module and IP camera, respectively. By entering the Wi-Fi module MQTT endpoint address in the mobile application of remote user connects the physical laboratory. RTO's programming is used to carry out multiple tasks on ARM STM-32 controllers which are developed using arduino IDE.

3 Accessing the Remote Laboratory

Accessing the physical laboratory from a remote place is possible by installing the android mobile application specifically developed for our remote laboratory setup. By selecting the N-channel JFET or P-channel JFET experiment from the main screen of android mobile application, this setup will automatically reconfigure and connect the selected experiment in physical laboratory to the remote user mobile application. The development of android mobile application is carried with the Android studio software with Java language supported.

When N-channel JFET or P-channel JFET experiment selected by the remote user, the physical laboratory setup takes up the flow explained with the Fig 3. The ARM

STM-32 controller initializes the UART communication between the HMI display and Wi-Fi module and I²C protocols between the EEPROM, voltage and current monitoring IC's. If any data received by the Wi-Fi, the ARM STM-32 connects the selected experiment and executes the N-channel or P-channel JFET experiment and send the obtained output values to Wi-Fi module. The mobile application records all the obtained output values from the physical laboratory, with recorded values the graph can be generated any time and calculation of drain resistance and trans-conductance are also obtained. If required, all the obtained output data, graph and calculation can be exported in the form of PDF by the remote user in their mobile.

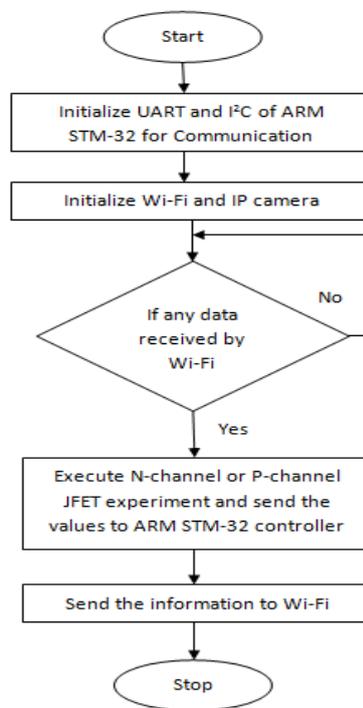


Fig. 3. Flow chart at the Physical laboratory

4 Experimental Results

JFET CS configuration is probably the most widely used of all the FET circuit configurations for many applications. The following obtained results are discussed with respect to N-channel JFET CS configuration; similarly, the results for P-channel JFET CS configuration can be obtained.

Selecting the N-channel JFET CS configuration experiment from the main screen of android mobile application, the setup will automatically reconfigure and connect the selected experiment in the physical laboratory. The live video streaming captured from

the HMI display will be continuously streaming in mobile application screen. Fig 4. shows the android mobile application screen when JFET CS configuration selected.

The followings steps are carried to conduct Drain and Transfer characteristics of JFET CS configuration using android mobile application:

1. To obtain drain characteristics, Set V_{GS} constant by increasing block '+' or by decreasing block '-' of mobile application.
2. Vary Drain Source voltage ' V_{DS} ' in regular interval of steps and record the corresponding ' I_D ' value.
3. Repeat the steps 1 and 2 for different values of ' V_{GS} '.
4. Generate the graph and calculate the drain resistance from the drain characteristics.
5. To obtain transfer characteristics, set ' V_{DS} ' constant by increasing block '+' or by decreasing block '-' of mobile application.
6. Vary Gate Source voltage ' V_{GS} ' in regular interval of steps and record the corresponding ' I_D ' value.
7. Repeat the steps 5 and 6 for different values of ' V_{DS} '.
8. Generate the graph and calculate the trans-conductance from the transfer characteristics.

To record the output parameter values, click on the 'New Tabulate' column which creates new table and the output values will be recorded by selecting the 'Tabulate' column. From the tabulated values graph can be generated and also the calculation is obtained from the recorded output values.

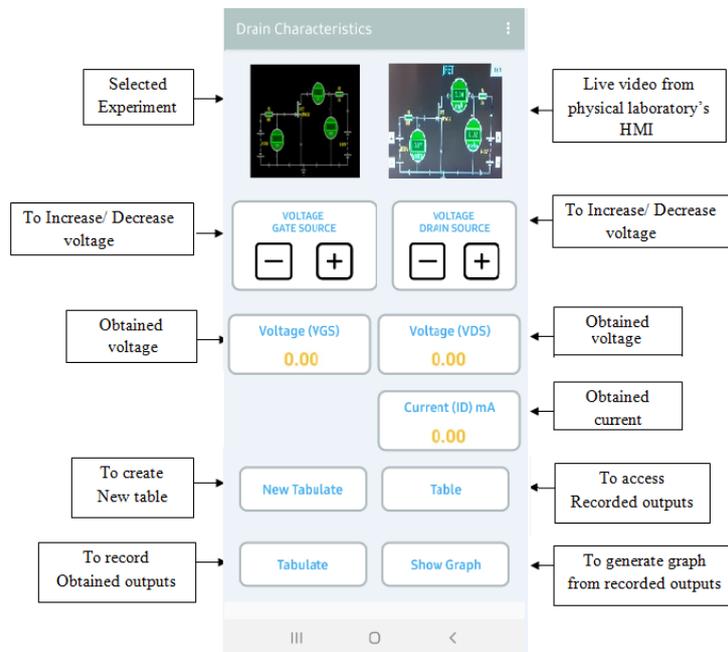
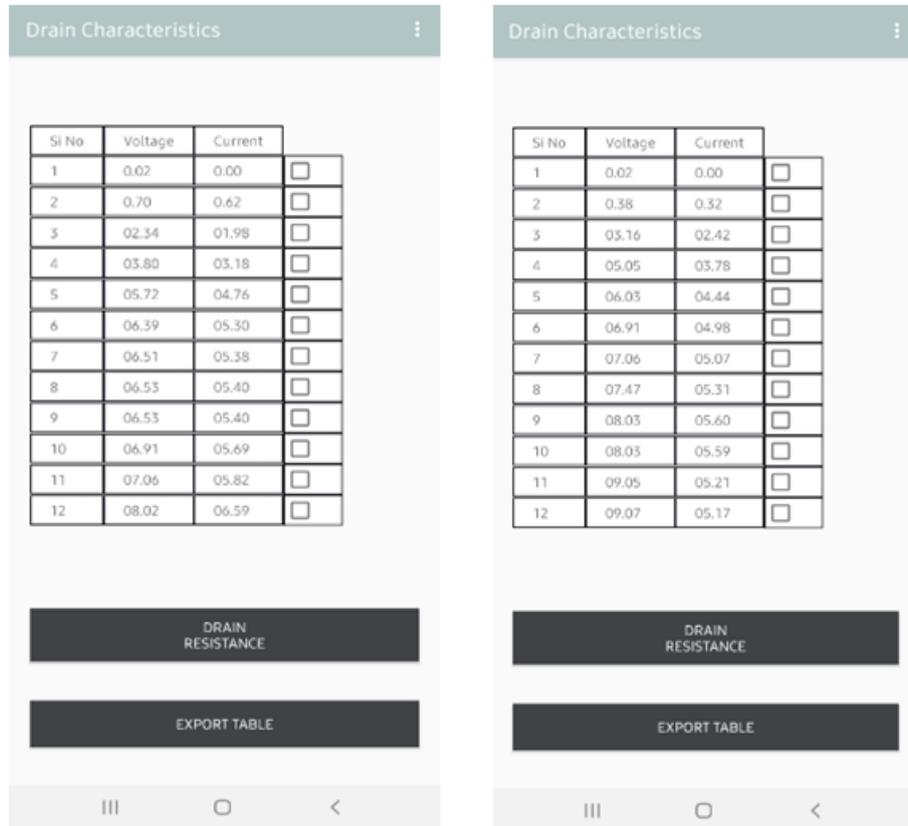


Fig. 4. Android mobile application screen for JFET CS configuration

The drain characteristics are obtained by keeping V_{GS} constant and recording the values of V_{DS} Vs I_D . Fig 5. (a) and (b) shows the recorded values of the V_{DS} Vs I_D for constant of $V_{GS}= 0V$ and $V_{GS}= -2V$. The distant user can record V_{DS} and I_D for any values of V_{GS} .

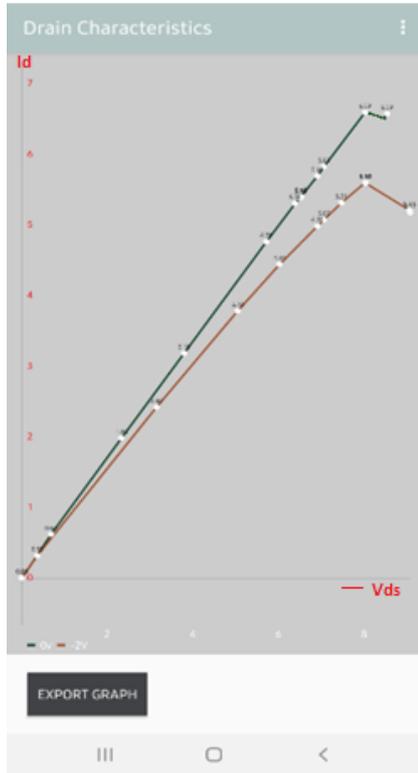


a) Drain Characteristics keeping $V_{GS}=0V$

b) Input Characteristics keeping $V_{GS}=-2V$

Fig. 5. JFET CS drain characteristics readings

The graph can be generated for the recorded readings in Tabulate column; Fig 6. (a) shows the drain characteristics curve of V_{DS} Vs I_D by keeping V_{GS} constant for $0V$ & $-2V$. Fig 6 (b). shows the calculation of the drain resistance of JFET CS configuration.



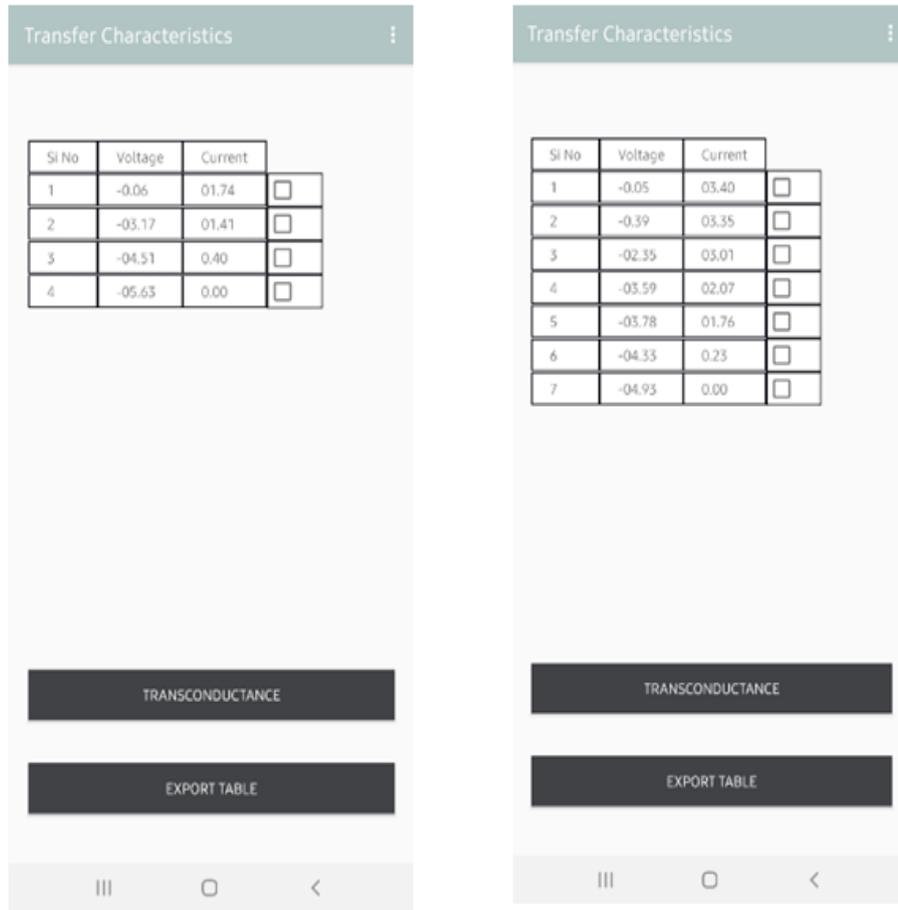
a) Drain Characteristics keeping $V_{GS}=0V$ & $-2V$



b) Calculation

Fig. 6. JFET CS Drain characteristics graph and calculation

The transfer characteristics are obtained by keeping V_{DS} constant and recording the values of V_{GS} Vs I_D . Fig 7. (a) and (b) shows the recorded values of the V_{GS} Vs I_D for constant V_{DS} of 2V and 4V. The distant user can record V_{GS} Vs I_D for any values of V_{DS} .

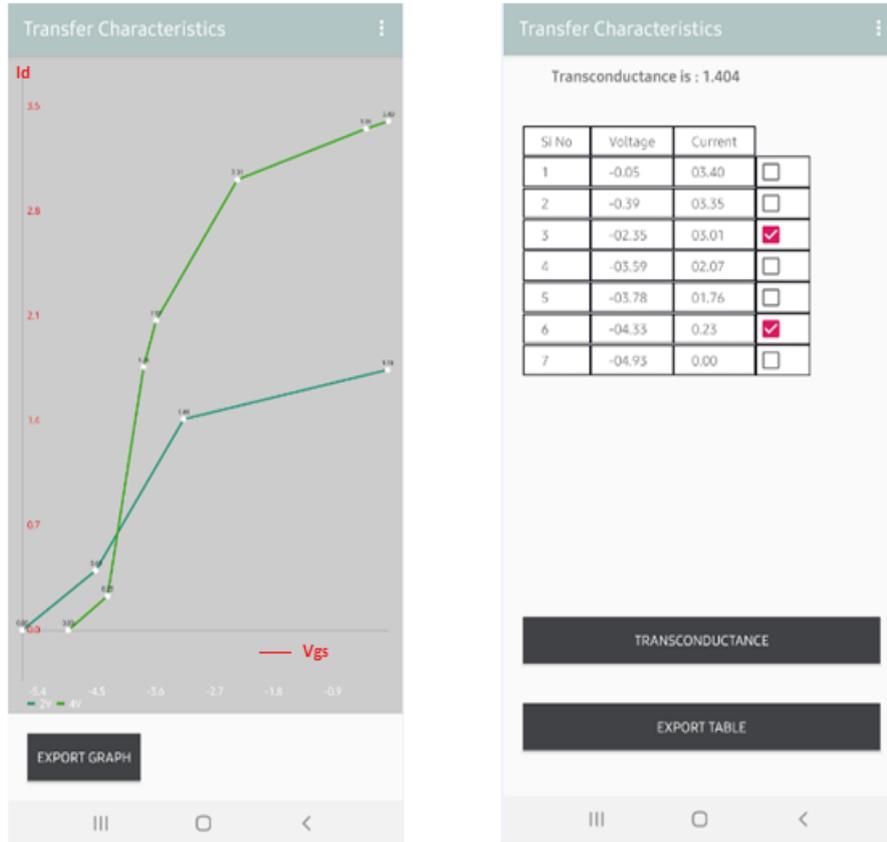


a) Transfer Characteristics keeping $V_{DS}=2V$

b) Transfer Characteristics keeping $V_{DS}=4V$

Fig. 7. JFET CS Transfer characteristics readings

The graph can be generated for the recorded readings in Tabulate column; Fig 8. (a) shows the transfer characteristics curve of V_{GS} Vs I_D by keeping V_{DS} constant for 2V & 4V. Fig 8. (b) shows the calculation of the trans-conductance of JFET CS configuration.



a) Transfer Characteristics keeping $V_{DS} = 2V$ & $4V$

b) Calculation

Fig. 8. JFET CS transfer characteristics graph and calculation

5 Conclusion

Remote laboratories are not substituting the physical laboratory rather it complements the traditional hands-on conduction. Here the control and measurement of the experiment is carried with the M-learning, which provides add-on advantage to remote laboratories. Use of an android mobile device along with the internet facility is the crucial part of M-learning.

The remote user can conduct widely used JFET CS configuration of analog electronics experiments with M-learning. With mobile application, the conduction of N-channel or P-channel JFET experiment is carried to obtain the drain and transfer characteristics from anywhere and anytime without any restrictions. The recorded output values are

stored in the mobile device, which are used to generate graph and to complete the required calculation by remote user.

The designed Mobile learning based remote laboratory system can be expanded by adding new experiments as per the requirements without any complexity. Hence, it enables the sharing of resource between the institutions and provides a feasible platform to the learners.

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