International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

# Design and Evaluation of a–120Watt DC – DC Amplifier for Solar Cell Module Applications.

**Michael Olusope Alade**
Department of Pure and Applied Physics,
Ladoke Akintola University of Technology,
P.M.B.4000, Ogbomoso, Oyo State, Nigeria.
Email ID : aladey2008@yahoo.com

***Abstract* – The design, implementation and evaluation of 120Watt dc – dc amplifier for solar cell module applications are presented. The aim of this study is to amplify a low output dc voltage from a 80-Watt, 12V solar cell module, and use the operation principle of chopper amplifier to achieve a high dc voltage that is enough to charge two - 12V, 60AH batteries. A 16 pin dual-in-line SG3524 IC is employed in the design of the system which comprises of astable square wave oscillator that converts the output dc of photovoltaic module to square wave ac, and a class B push – pull employing IRFP 250 MOSFET power driver to amplifier the output of the oscillator and use it to drive the power transformer in the system. With the help of bridge rectifier, RC filter, and switching regulator, a stabilized dc output is obtained to charge the required battery size. Design calculations were done with the aid of MATLAB R2007a software. The results of practical laboratory test carried out show that the oscillator and power amplifier output voltages of 4.5V and 26.0V were achieved respectively. The efficiency of the oscillator stage is ~51.6% in agreement with the calculated design efficiency. Also, the measured efficiency of the amplifier is ~50.0%. The measured output power is ~120.0Watt.**

***Keywords* – Design, Implementation, dc–dc amplifier, Solar cell module.**

## I. INTRODUCTION

Generation of electricity from solar energy using photovoltaic device has remain the only alternative source of electricity in recent time. However the cost of solar electricity generation is very high, because large solar cell modules and batteries are required to store very large quantity of electricity [1]. For instance to charge two 12V 60AH batteries require two 80Watt, 12V size solar cell modules. One 80Watt, 12V size solar cell module can not charge two 12V, 60AH batteries. If an amplifier unit is employed to increase the voltage and the power output of the solar cell module to the level that can charge enough size of batteries, the cost of solar electricity generation can be reduced.

An amplifier is a circuit that can increase the peak-to-peak voltage, current, or power of an electrical signal. Generally speaking, it is has been difficult or almost impossible to build direct current (dc) power amplifier. Amplifiers are conventionally alternating current (ac) type [2], [3]. Scientists and engineers have provided one possible way of producing dc amplifiers by leaving out the coupling and bypass capacitors of the conventional ac amplifiers. In this way, dc voltages are coupled as are ac voltages. The major drawback of direct coupling of dc is drift, a slow shift in the final dc output voltage produced by minor changes in supply voltage, transistor parameters, and temperature variations. Chopper amplifier has been reported as one way to overcome the drift problem of direct coupling. Instead of using direct coupling, JFET chopper is used to convert the input dc voltage to a square wave (which is ac signal) that can be amplified by ac power amplifier and then be peak-detected by a transformer to recover the original dc input signal [4].

Various possible dc-dc amplifier designs have been reported in the literatures: relaxation oscillator, IC square wave oscillator and Op-amps in astable mode whose frequencies are set by the feedback resistors and capacitors and connected to class B push-pull or class C using JFET or MOSFET, and the output square wave is used to drive the primary winding of transformer [4] – [9].

The primary aim of this study is to amplify a low dc voltage (charge) from the solar (photovoltaic) cell module using a chopper amplifier to achieve a high dc voltage that is enough to charge a required size of batteries. The objectives, as a case study, are to design, construct and evaluate the performance of 120Watt dc-dc amplifier system using 16 pin dual-in-line SG3524 IC to amplifier the output of 12V, 80Watt size solar cell module and use the amplified output to charge two 12V, 60AH batteries.

## II. DESIGN AND IMPLEMENTATION

The design of the dc-dc amplifier system in this work is basically illustrated in the schematics shown in Figure 1.

International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

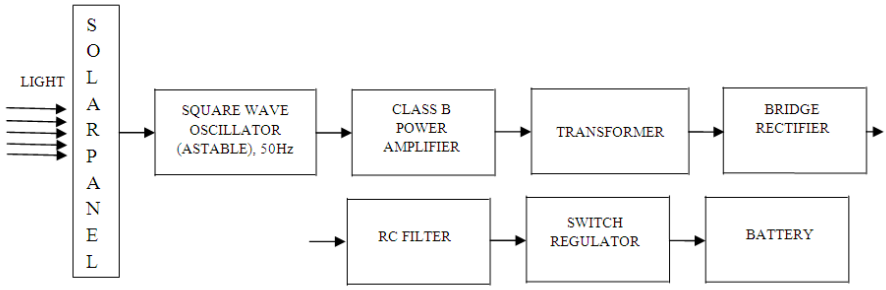


Fig.1. Schematics showing design of dc-dc amplifier system for solar cell module applications.

The output dc voltage from the solar panel is applied into the input of the SG3524 (shown in Figure 2) is operated as astable square wave oscillator employing pulse width modulation scheme at frequency 50Hz set by RC time constant circuit to convert the dc output of the solar panel to ac voltage. This ac voltage is then input into class B push-pull power amplifier using IRFP250 MOSFET. The output of the power amplifier is connected to the transformer to peak detect the ac voltage. A bridge rectifier is employed to convert the ac voltage back to dc voltage. LC filter is also employed to remove the remaining unwanted ac. Finally SG3524 is also employed as switching regulator after smoothing of the dc voltage before very low resistance loads (batteries) are connected.
The design goals of this system are efficiency, simplicity, reliability and the use of replaceable components. The system is design in such a way that whatever comes into the system (charge or voltage) is supplied out (linear amplified) but higher gain energy is achieved to sufficient battery size. The configurations of the photovoltaic module (solar panel) employed in this design are shown in the Table 1. The specifications for design are tabulated in the Table 2.

Table 1: The photovoltaic cell module configurations

| |
|---|
| Peak voltage ($P_{max}$) = 80Watts |
| Open circuit voltage ($V_{cc}$) = 22.1V |
| Warranted minimum $P_{max}$ = 76Watts |
| Short circuit current ($I_{ec}$)= 4.8A |
| Voltage ($V_{mp}$) = 17.6V |
| Minimum Bypass Diode = 8A |
| Current ($A_{mp}$)= 4.5A |
| Maximum series fuse=20A |

Table 2: Design Specifications

| **Parameter** | **Ratings** |
|---|---|
| Input power | 80W |
| Input Current | 4.6A |
| Input Voltage | 12 - 17.5V |
| Input waveform | Dc |
| Oscillator frequency | 50Hz |
| Output waveform | Dc |
| Output Voltage | $24V_{min}$ |
| Load resistance ($R_L$) | ~0.01 – 0.05Ω |

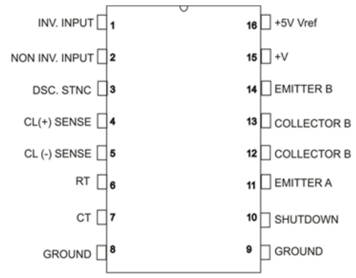


Fig.2. SG3524 IC

Where;

- Pin 1 – Inverting input for error amplifier
- Pin 2 – Non-inverting for error amplifier
- Pin 3 – Output pin for oscillator section
- Pin 4 – This pin is related to amplifier section
- Pin 5 – This pin is related to amplifier section
- Pin 6 – This pin is related to amplifier section
- Pin 7 – Oscillator section time constant capacitor input pin
- Pin 8 – Ground
- Pin 9 – Pulse width control input
- Pin 10 – Shutdown input
- Pin 11 – Oscillator section output
- Pin 12 – Positive supply for Oscillator section
- Pin 13 - Positive supply for Oscillator section
- Pin 14 – Oscillator section output
- Pin 15 - Positive Supply for IC
- Pin 16 – Output of Voltage regulator

*Description of SG3524 IC*

The SG3524 IC employed in this design is an active device that is incorporated on a single monolithic chip whose functions are required for the construction of regulating power supplies inverters or switching regulators. Its configuration is shown in Table 3. The SG3524 family is designed for switching regulators of other polarity, transformer -coupled dc-dc converters, transformers of less voltage doublers and polarity converter application. The SG3524 is a fixed frequency pulse width modulation voltage regulator control circuit that are used as controlling element for high power- output applications. The regulator operates at a frequency that is programmed by one timing resistor ($R_T$) and one timing capacitor ($C_T$). $R_T$ established a constant charging current for $C_T$. This results in a linear voltage ramp at $C_T$ which is fed to the comparator providing linear control of the

International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

output pulse width by the error amplifier. The SG3524 contains an on-board 5V regulator that serves as a reference as well as powering the SG3524's internal control circuitry and is also useful in supplying external support functions.

Table 3: SG23524 IC configurations

| Symbol | Parameter | Test Condition | Minimum | Maximum | Unit |
|---|---|---|---|---|---|
| $F_{MAX}$ | Maximum frequency | G=0.001μF, $R_T$ =2kΩ | 10 | 500k | Hz |
| | Initial Accuracy | $R_T$ and G constant | 5 | 5 | % |
| | Voltage Stability | $V_{IN}$ = 8 to 40V, $T_i$=25$^0$C | 1 | 1 | % |
| Δf/ΔT | Temperature stability | Over operating Temperature use range | 2 | 2 | % |
| | Output Amplitude | Pin 3, $T_j$=25$^o$C | 3.5 | 3.5 | V |
| | Period | G=0.001μf, $T_j$=25$^o$C | 0.5 | 5 | Ms |
| $V_{IN}$ | Input voltage | Input voltage | 8 | 40 | V |
| Output Section | Output Voltage | Collector-emitter Voltage | 20 | 40 | V |
| | Saturation Voltage | $I_C$=50Ma | 0 | 2 | V |
| | Saturation Leakage Current | $V_{CE}$=40V | 0 | 50 | μA |
| | Emitter Output Voltage | $V_{IN}$=12V | 17 | 24 | V |
| | Total Standby Current | $V_{IN}$=12V | 3 | 5.4 | A |

(Retrieved from http://www.audiodesignguide.com/powerfollows/index.html on 16 Dec, 2010 at 13:00)

*Design of oscillator and amplifier stages*

The reference voltage is lowered externally by a resistor divider to provide a reference within the common mode range the error amplifier or in external reference may be used. The power supply output is sensed by a second resistor divider network to generate a feedback signal to error amplifier. The amplifier output voltage is then compared to the linear voltage ramp at $C_T$. The comparator is then steered to the appropriate output pass transistor by the pulse steering flip-flop which is synchronously toppled by the oscillator output. The IC (SG 3524) requires some components in order to give an astable signal (Oscillation) at the output. The oscillator employed is operating at a frequency 50Hz with the aid of RC time constant circuit.

The power amplifier stage employed MOSFET circuit that uses the low voltage or low current signal produced by the oscillator circuit stage for the buffer circuit to drive a very high current voltage for the transformer. Four IRFP250 MOSFETs are employed as class B push-pull power amplifier. The configurations of IRFP250 MOSFET are shown in the Table 4. The design is carried out with the aid of computer programme implemented by MATLAB R2007a software as follows:

```
>> F = 50;
>> C = [0.001 0.01 0.1 1 10 100 1000];
>> R = 0.72./(C*F)
R =
  14.4000    1.4400    0.1440    0.0144    0.0014    0.0001
0.0000
>> Ro = [14400 1440 144 14.4 1.4 1 0.1];
>> R2 = 15;
>> C1 = 1;
>> R1 = 1;
>> T1 = 0.7*C1*(R1 + R2)
T1 =
  11.2000
>> T2 = 0.7*C1*R2
T2 =
  10.5000
>> T = T1 + T2
T =
  21.7000
>> E = 100*(T1/T)
E =
  51.6129
>>
```

Where R1 and R2 are the timing resistors in kilo ohm (kΩ), and also employed as potential divider resistors for the driver stage. C1 is the timing capacitor in micro-farad. E is the efficiency expressed in %.

Table 4: IRFP 250 MOSFET configurations

| | | |
|---|---|---|
| $V_{GS}$ | Gate –Source Voltage | 20V |
| $I_D$ | Continuous Drain Current ($V_{GS}$=0, $T_{case}$=25$^0$C) | 30A |
| $I_D$ | Continuous Drain Current ($V_{GS}$=0, $T_{case}$=100$^0$C) | 19A |
| $I_{DM}$ | Pulsed Drain Current | 120mA |
| $P_D$ | Power Dissipation @ $T_{case}$=25$^0$C | 150W |
| $E_{AS}$ | Linear Derating Factor | 1.2W/$^0$C |
| $I_{AR}$ | Single Pulse Avalanche Energy$^2$ | 200mJ |
| $E_{AR}$ | Repetitive Avalanche Energy$^2$ | 15mJ |
| $I_{AR}$ | Avalanche Current$^2$ | 30A |
| $^{dv}/_{dt}$ | Peak Diode Recovery$^2$ | 5V/ns |
| $T_J$, $T_{stg}$ | Operating and Storage Temperature Range | -55 +150$^0$ C |
| $T_L$ | Lead Temperature 1.6mm(0.63$^0$) from case for 10sec | 300$^0$C |
| $R_{DS}$ | Resistance Drain Source | 0.083Ω |

(Retrieved from http://www.audiodesignguide.com/powerfollows/index.html on 16 Dec, 2010 at 13:00)

*Implementation of the device*

International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

The dc-dc amplifier device designed was constructed and displayed in Figure 3. The system acts as an ON/OFF switch for our solar cell module to prevent it from over charging the batteries when they reach full charge. The system can measure the voltage in the battery and short off when fully charge and turn ON when the battery voltage drops.

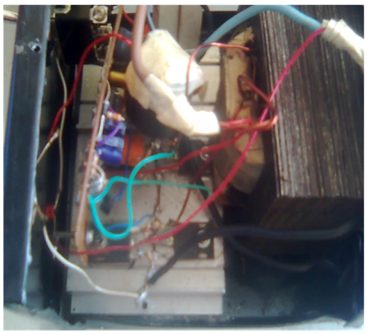

Fig.3. Device Implementation.

## III. Results & Discussion

In this work, a dc-dc amplifier device is designed and implemented using 16 pin dual-in-line SG3524 IC and IRFP250 MOSFET to amplifier the output of 80Watt, 12V size solar cell module. The design calculations were carried out using MATLAB R2007a software. The optimized values of R1, R2, and C1 that achieved 50Hz frequency of oscillation of the astable square wave oscillator employed and also provided voltage for the driver stage are 1kΩ, 15kΩ and 1μF respectively. The implemented system was analyzed practically in the laboratory. The results obtained as displayed in Figure 4a show that the widths of positive and negative half cycle of oscillation are respectively 0.011s and 0.0105s which are in agreement with the design calculations results. The measured output voltage of the oscillator is 4.5V. Figure 4b shows the output of power amplifier stage of the device. The measured output voltage of the amplifier is 26.0V. The efficiencies of the oscillator and amplifier stages are 51.6% and 50.0% respectively. The device was used to charge two 12V, 60AH as shown in Figure 5.

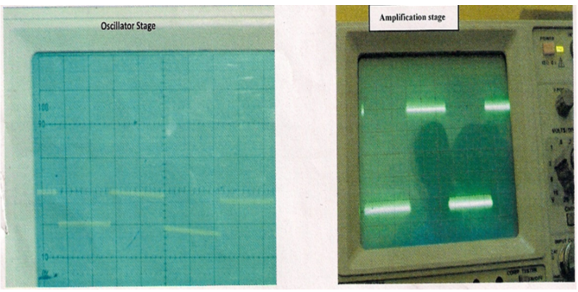


Fig.4. Showing the output voltages of the oscillator and amplifier stages displayed on the oscilloscope.

Fig.5. Showing the device while charging batteries.

## IV. Conclusion

In this paper, design, implementation and evaluation of 120Watt dc – dc amplifier for solar cell module applications are presented. The device can be used to charge two 12V, 60AH. One major problem encountered in the implementation of the device is the unwanted harmonic generated at the output which could be hazardous to load. The problem was solved by employing RC filter network and switching regulator. However, there is no existing work to compare with to the best of my knowledge. For further work, any other technique can be adopted such that the output of the amplification stage can be free from harmonics.

## References

[1] R.W. Miles, *An Overview of State of the Art Development and Progressing Crystal Growth characterization of Photovoltaic Solar cell module.* Ontario, Canada, ISBN 51:1-42, 2005, pp. 445 – 446.

[2] E. A. Parr, *Newnes Electronics Pocket Book.* International Student Edition, 5th Edition, ISBN: 0-434-91521-1, Oxford, William Heinemann Ltd., 1986, pp. 42 – 89.

[3] Len Jones, *Basic Electronics.* Low Price Edition, ISBN: 0-521-58687-9, Great Britain, Cambridge University Press, 1996 pp. 60 – 85.

[4] A. P. Malvino, *Electronic Principles.* Sixth Edition, ISBN: 0-02-802833-3, New York, Glencoe McGraw-Hill, 1999 pp. 444 – 836.

[5] A. Bakker, K. Thiele, and J. Huijsing (2000). A CMOS Nested-Chopper Instrumentation Amplifier with 100nV offset. *IEEE J. Solid-State Circuits*. [Online]. 35(12). Available: http://www.en.wikipedia.org/wiki/chopper-(electronics)

[6] B. Berglund, J. Johansson, and T. Lejon (2006): High efficiency power amplifiers. *Ericsson Review Letter* [Online]. *No. 3.* pp. 92 – 96. Available: http://www.ericsson.edu.ng

[7] R. Boylestad, and L. Nashelky, *Electronic Device and Theory.* 6th Edition, ISBN:0-13-39455-9, U.S.A. Upper Saddle River 2002:pp 669 – 682.

[8] P.C. Seni, *Power Electronics.* 25th Edition, Tata McGraw – Hill U.S.A,/ ISBN: 0.07-462400-8 2005 pp. 726 – 727.

[9] M. O. Alade, and S. F. Akande (2010, December). On various oscillators and power amplifiers design methods employed for the development of power inverters. International Journal of Research and Reviews in Applied Sciences. 5(3). pp. 294 – 304. Available: www.arpapress.com

International Journal of Electronics Communication and Computer Engineering
Volume 3, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

## AUTHOR'S PROFILE

**Alade Olusope Michael**
was born in Nigeria, in 1970. He received the B.Sc, M.Sc degrees from University of Jos, Nigeria in 1994 and 1998 respectively. Also, he received the Ph.D. from Ladoke Akintola University of Technology, Nigeria in 2005.

His research interests include design, construction and analysis of electronic devices; and radio wave propagations. From 2010 to till date he is working as Associate Professor of Communication Physics.