# Switching Circuit for Cold Switching in Redundant High Power Solid State Pulsed Power Amplifier (SSPPA)

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***Abstract:***

***This paper describes the design of a switching circuit which is used to control medium-power electro-mechanical switches -- that inherently have very long switching time (in ms) and require cold switching -- along with low-power high-speed MMIC solid-state switches. This circuit is used in a Driver Amplifier unit with a redundant transmit path to ensure better availability. The redundant pulsed solid-state driver amplifier is used to feed transmit RF power to the T/R modules of an AAAU (Active Array Antenna Unit).***

***Keywords: Active Array Antenna Unit (AAAU), Solid State Pulsed Power Amplifier (SSPPA), High Power Switch, MMIC***

## I INTRODUCTION

The AAAU has multiple T/R Modules which are distributed into 4 quadrants. During Transmit, the Driver Amplifier unit has to generate a pulsed RF power output, which is drive all the T/R Modules distributed in 4 quadrants. The availability of this unit is very essential to avoid single point failure of the AAAU. Hence, in the RF design of the driver amplifier unit, there are two identical arms -- Main & Redundant -- as shown in ***Figure 1***. Each arm consists of a pre driver & a high power amplifier. If/when the main arm fails, it is turned off & the redundancy controls are given to switch in the redundant arm. For better efficiency of the Driver Amplifier Unit, at any given point of time, only one arm is kept ON, implying cold standby redundancy.

A DC switching circuit has been designed & realized which can be used for such amplifier designs that have a requirement of switching pulsed/CW high power between main & redundant paths. For pulsed radar applications, the synchronization of the signals & switching becomes even more critical & the realized switching circuitry caters to all these challenges.

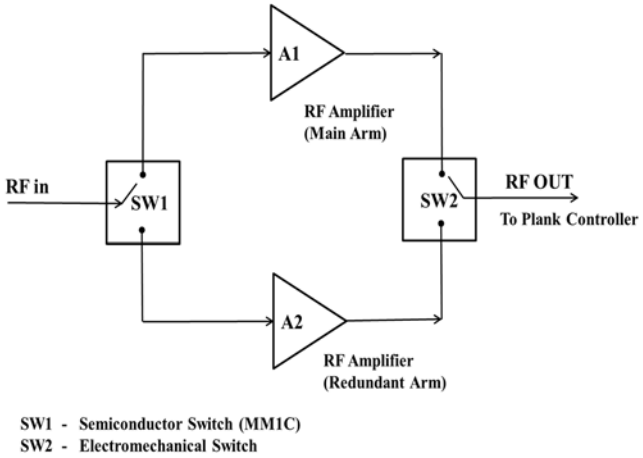


**Figure 1** RF Block diagram

## II DESIGN OF SWITCHING CIRCUIT

In the present design, to switch between the two arms of the driver amplifier unit, an MMIC-based switch is used at the input to switch the low power RF signal. At the output, an electromechanical switch is used for switching the high power pulsed RF signal. In case of electro-mechanical switches, cold switching -- with RF turned off, during switchover -- must be performed to ensure longer switch life.

The selected MMIC-based solid-state switch at the input has a very fast switching/settling time (in tens of ns), but the electromechanical switch at the output has a longer switching time (15ms max.).

Whenever the online amplifier fails, a failure signal is sent to an external controller. The controller then sends a redundancy switchover signal to the Driver Amplifier.

The instant a redundancy switchover control signal is received, first the DC bias circuits of the amplifiers in both the arms are turned off to ensure cold switching. This helps avoid ambiguous results at the final output & prevents damage to any of the active devices / switches.

A 1ms delay is introduced to allow the amplifiers to switch off completely. Then the low-power input switch is activated using the SW1 control (***Figure 2***).

The balance circuitry in ***Figure 2*** also ensures that the bias control pulses (Pulse 1 & Pulse 2) are kept off for at least 18ms from the time the redundancy control signal is received. This provides enough time for the slower electromechanical output switch to change its state. As the amplifier DC bias circuits are already off, this ensures cold switching. After 18ms delay, the selected arm's amplifier DC bias circuit is turned back on, while the other arm stays off.

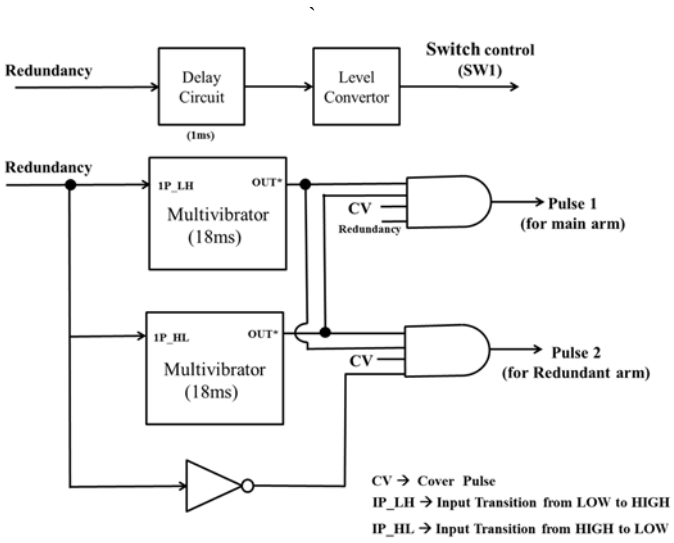


**Figure 2** Circuit to generate controls for low-power switch & pulsed DC amplifier bias for main and redundant arms.

The redundancy signal is used to generate a 16-ms control to switch the output latching-type electromechanical switch to the desired position. (***Figure 3***).

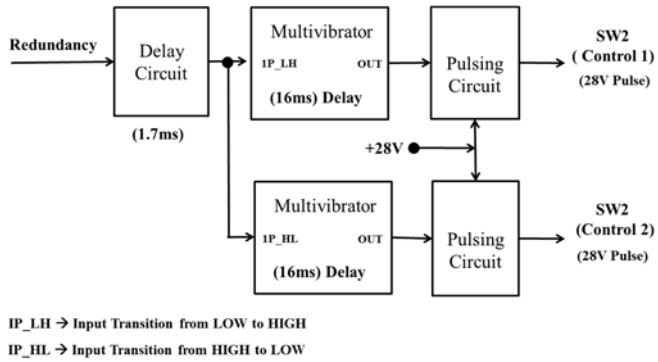


**Figure 3** Circuit to generate control for high power switch to ensure cold switching

The controls to both the switches & the amplifier bias circuitry are realised using logic circuits. A combination of delay generators & other logic circuits was designed and implemented on an FR4 PCB. A two-layer PCB was designed & successfully tested for switching from main chain to redundant chain & back with all the above-mentioned considerations.

***Figure 4*** depicts the timing diagram in detail. It clearly shows that the bias pulses for the main arm and redundant arm are disabled during switchover. The chosen arm (main / redundant) gets the bias pulse after the switchover is completed.

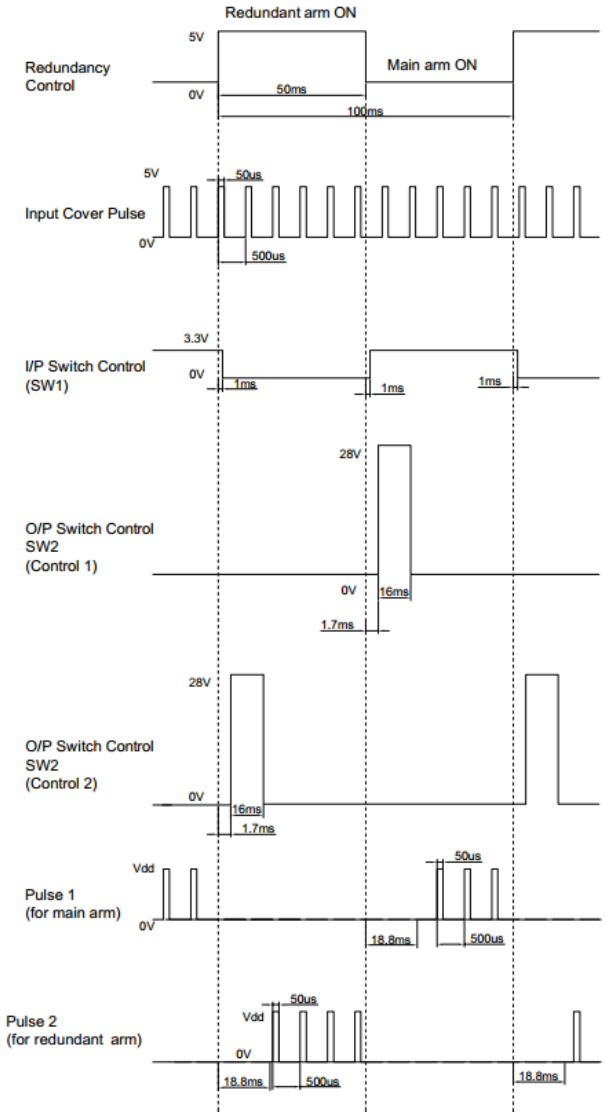


**Figure 4** Timing Diagram

## III LAYOUT AND FABRICATION

***Figure 5*** shows a photograph of the realised two-layer FR4 PCB that caters to all the above-mentioned requirements.

**Figure 5** Fabricated & Assembled PCB for Control circuit

## IV RESULTS

***Figure 6*** shows the measured switch controls for input & output switches.

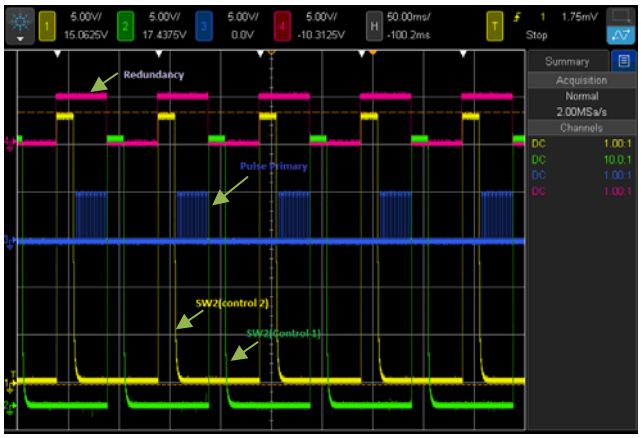


**Figure 6** Measured Switch controls.

***Figure 7*** shows the measured amplifier DC bias pulses for main and redundant arms.

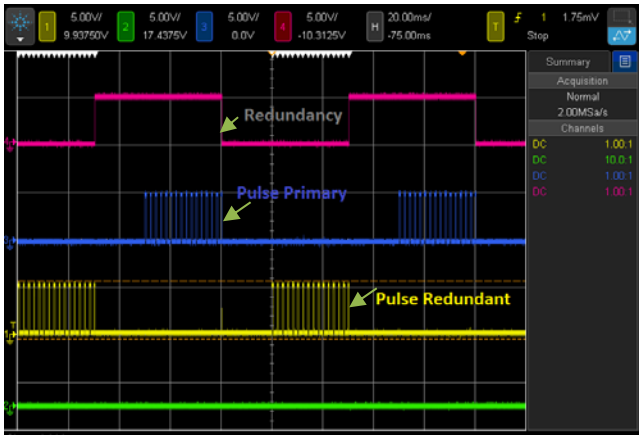


**Figure 7** Measured DC Bias Pulse for Primary and Redundant arm.

## V DESIGN VALIDATION

This circuit was successfully implemented in a Driver Amplifier unit to switch 46dBm (40W) of RF power between the main and redundant arms. This Driver Unit operates in the X-band and is used in AAAU of a radar.

## CONCLUSION

In this paper, a DC switching circuit has been successfully designed & realized, which can be used for amplifiers that have a requirement of switching pulsed/CW high power between main & redundant paths. For pulsed Radar applications, the synchronization of the signals & switching becomes even more critical & the realized switching circuitry caters to all these requirements. The designed circuit was also successfully implemented to

switch between the main and redundant arms of an X-band driver amplifier.

## ACKNOWLEDGMENT

The authors would like to thank Mr. Harikumar R, AGM (Central D&E - Microwave Components-II) for providing design support/guidance. The authors express their gratitude to Mr. Naresh Kumar S, AGM (Central D&E - Microwave Components-I) for his support.

## REFERENCES

[1] Forrest M, Mims III, Timer, OP Amp & Optoelectronics Circuits & Projects, Master Publishing Inc. 2013.

[2] Manmadha Rao. G, Rama Sudha K and Venkat Rao K., Pulse & Digital Circuit, Pearson India, June 2010.

[3] Kumar A. Anand, Switching Theory & Logic Design, Eastern Economy Edition 2016.

[4] Jene Russell & Ronald Cohn, Active Phased Array Radar, BookVika Publishing, Jan 2012.

[5] Datasheet "SR-2MIN-MIN-D-12-L" RLC Electronics.

[6] Datasheet "74HC4538" NXP/TI.

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