Transient Analysis of EMI Effects on Voltage Regulator

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Abstract: When electromagnetic interference takes place with the input pins of Voltage Regulator it can cause operation variation. This paper deals with the investigation of EMI effects in Voltage Regulator circuit. This work presents evaluation of the EMI effects in Voltage Regulator by applying a range of EMI signals varying from 70MHz-90MHz at constant magnitude of 10mV in series along with the 50 KHz/1V original input signal. The EMI effects on the test Voltage Regulator are predicted using ORCAD in terms of total job time, time step and output waveform. All the results compose in the paper are simulated from the same. For easier understanding Bar graph is shown in this paper.

***Keywords*: EMI, Voltage Regulator circuit.**

I. INTRODUCTION

Electromagnetic interference is a disturbance that affects an electrical circuit due to either electromagnetic radiation or electromagnetic conduction emitted from an external source. The disturbance may interrupt, cramp, or otherwise degrade or limit the effective performance of the circuit. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as an electrical circuit. The elementary concept of electrical and electromagnetic interference involves pour source and an affected device or system. The transfer of energy between systems can occur through radiation, conduction, or induction. The actual transfer of energy is facilitated respectively through a transmission path, conductive path, or through magnetic coupling. The interference that affects wireless communication links is sometime the result of radiated or conductive energy transfer. The condition of a conductive affect occurs when the signal is picked-up by a conductor attached to affected system. Several studies related to EMI effects on electronic devices and circuits have been reported in the literature and EMI effects on Passive circuit elements such as resistor and the circuits containing these components have been investigated and analyze by experimental and simulation studies. The results of these studies indicate that EMI may cause significant changes and incorrect operation of electronic circuits. In this paper, we focused at EMI effects on voltage regulator circuit. The EMI effects on the Voltage Regulator circuit are analyze with the use of simulator ORCAD, with stimulating results.

Table 1: EMI Signal Used at Different Frequencies

Input Signal	EMI Signal Frequency Range	EMI Signal Amplitude
50KHz/1V	1KHz-50MHz	1V
50KHz/1V	1KHz-70MHz	500mV
50KHz/1V	1KHz-80MHz	100mV
50KHz/1V	1KHz-90MHz	10mV

Table 2: EMI Signal Used at Different Amplitudes

Input Signal	EMI Signal Frequency	EMI Signal Amplitude range
50KHz/1V	70MHz	10mV-500mV
50KHz/1V	80MHz	10mV-400mV
50KHz/1V	90MHz	10mV-100mV

II. Test Circuit

2.1 Voltage Regulator Circuit

A Voltage regulator is a system designed to automatically conserve a constant voltage level. A voltage regulator may use a basic feed-forward design or may involve negative feedback. It may use an electromechanical mechanism or electronic element. Depending on the design it may be used to regulate one or more AC or DC voltage. Electronic voltage regulators are found in

various devices such as computer power supplies where they stabilize the DC voltages used by the processor and other element. In this paper, test circuit is presented on which the EMI effects will be analyzed according to configuration shown in Table 1 and Table 2. Fig. 1 shows the voltage regulator circuit with input signal 50 KHz/1V and the output waveform of this circuit shown in Fig. 2.

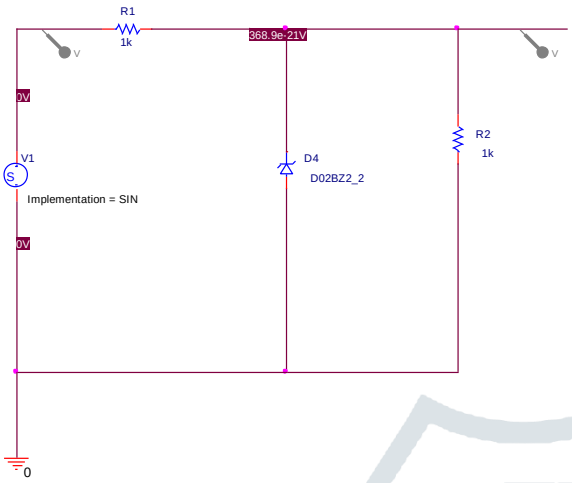


Figure 1: Voltage regulator circuit with 50 KHz/1V input signal

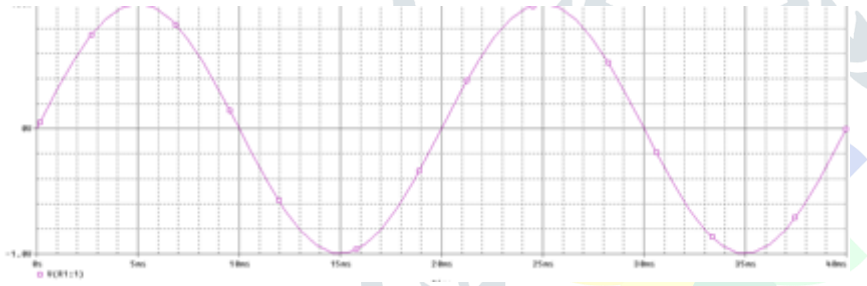


Figure 2: Transient Analysis of Voltage regulator circuit

III. Voltage regulator circuit With EMI Signal

In Fig. 3 EMI signal is injected in series with input signal and applied between Pin 5 (control voltage) and Pin 1(ground).

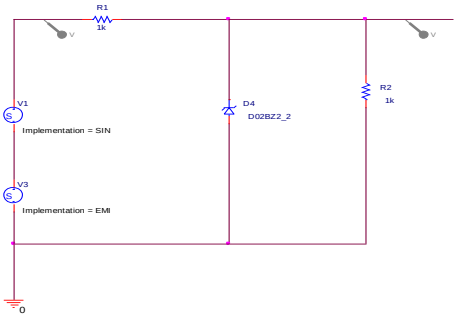


Figure 3: Voltage regulator circuit with 50 KHz/1V input Signal and 50MHz-90MHz/10mV EMI signal.

IV. Experimental Results

4.1 EMI Effects with EMI Signal at Frequency 1 KHz- 50 MHz/1V

Input Signal	EMI Signal	Time step	Total Job Time	Simulation

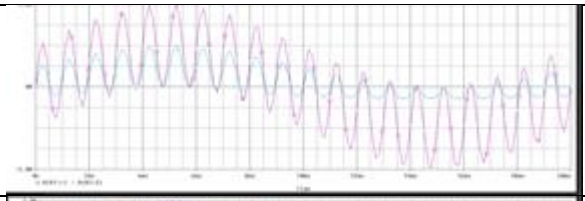
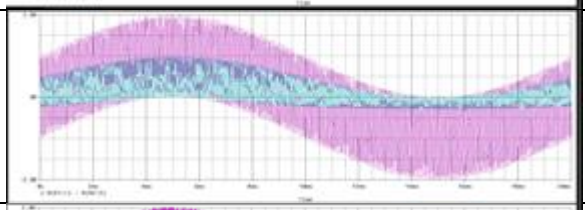
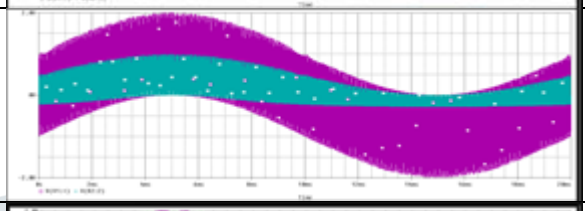
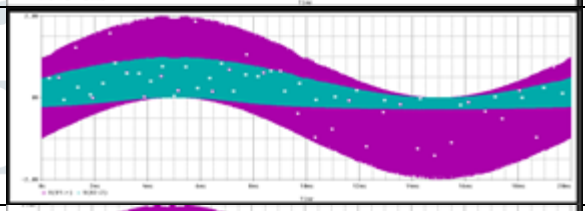
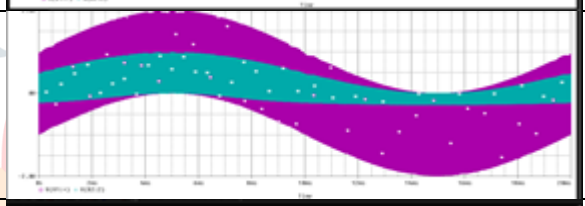
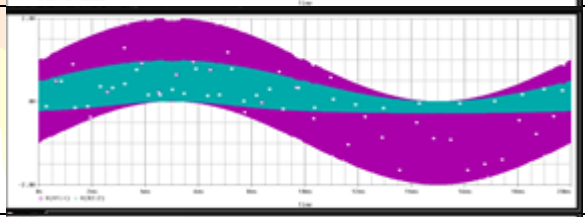
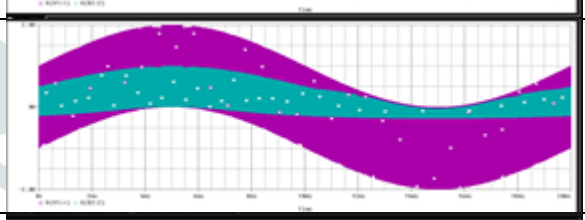
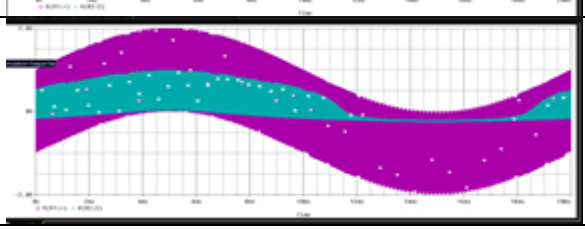
50Hz/1V	1KHz/1V	$29.77e^{-06}$	.5	
50Hz/1V	10KHz/1V	$1.108e^{-06}$	.13	
50Hz/1V	50KHz/1V	$257.6e^{-09}$	.47	
50Hz/1V	100KHz/1V	$273.1e^{-09}$	0.89	
50Hz/1V	500KHz/1V	$6.580e^{-09}$	4.41	
50Hz/1V	1MHz/1V	$991.2e^{-09}$	8.88	
50Hz/1V	10MHz/1V	$10.59e^{-09}$	81.75	
50Hz/1V	50MHz/1V	$1.568e^{-09}$	319.33	

Figure 4: Output Waveform of voltage regulator circuit

Here a range of signal frequency changing from 1 KHz-50MHz is applied keeping magnitude constant 1V. As we can see from fig.4 that the frequency varies from 1 KHz to 50MHz, total job time and time step keep on changing. At each frequency output waveform calculated and if EMI signal frequency is increased after 50MHz the system is extremely unstable. The EMI effect is maximum at 50MHz frequency shown in fig.4. The time step is high at 1 KHz and after that it will decrease. On the other hand Total job time is increasing with increase the frequency.

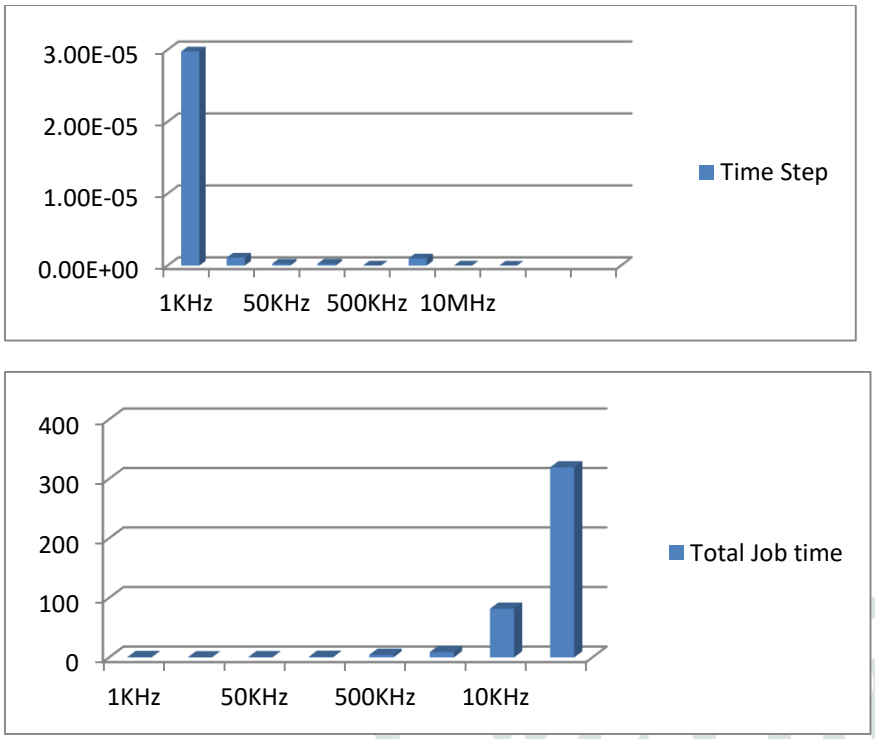
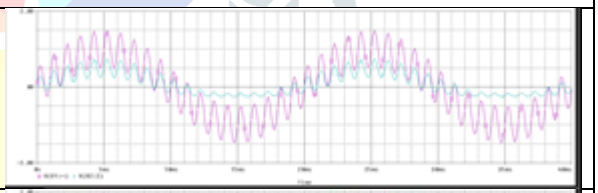
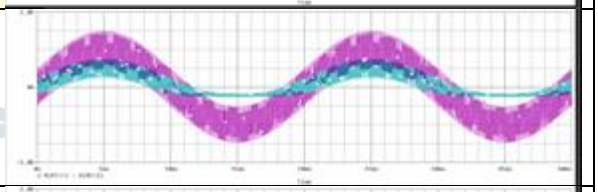
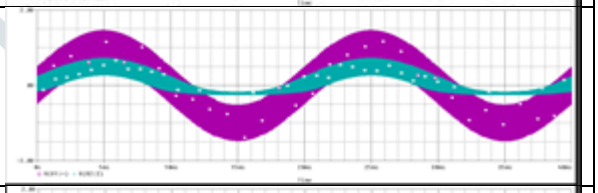
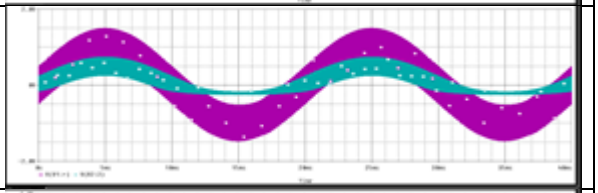
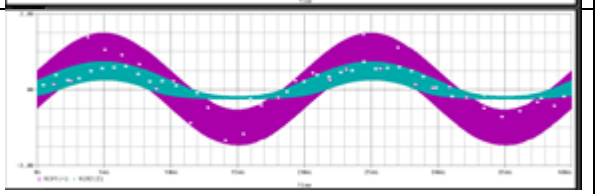


Figure 5: Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.2 EMI Effects with EMI Signal at Frequency 1 KHz-70MHz/500mV

Input Signal	EMI Signal	Time step	Total Job Time	Simulation
50Hz/1V	1KHz/500mV	$43.74e^{-06}$	.05	
50Hz/1V	10KHz/500mV	$1.399e^{-06}$	.20	
50Hz/1V	50KHz/500mV	$266.7e^{-09}$	.69	
50Hz/1V	100KHz/500mV	$377.7e^{-09}$	1.33	
50Hz/1V	500KHz/500mV	$20.43e^{-09}$	6.94	

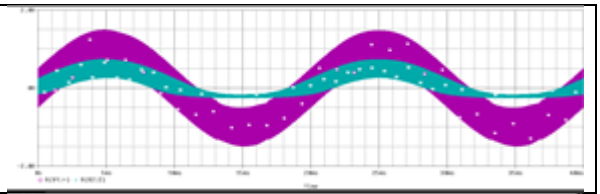
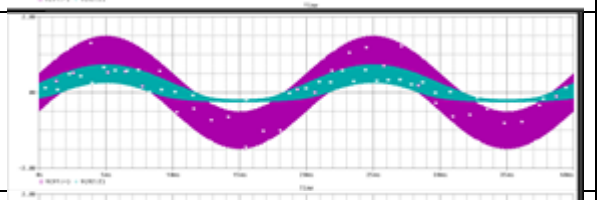
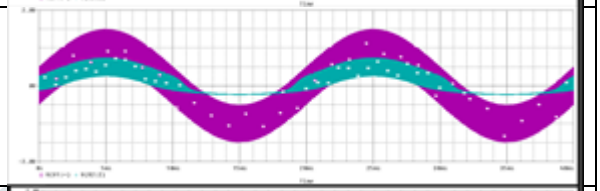
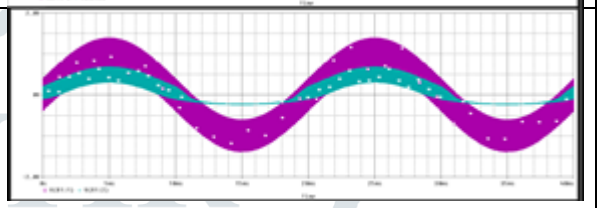
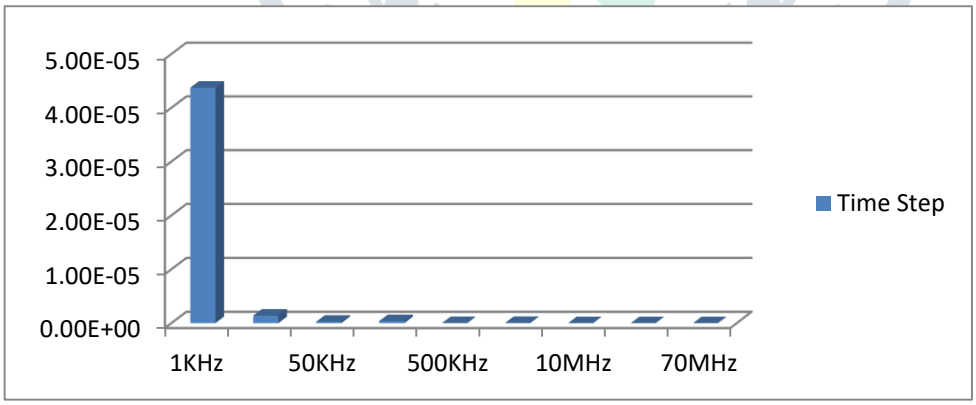
50Hz/1V	1MHz/500mV	$43.41e^{-09}$	13.27	
50Hz/1V	10MHz/500mV	$3.391e^{-09}$	135.95	
50Hz/1V	50MHz/500mV	$644.1e^{-12}$	583.02	
50Hz/1V	70MHz/500mV	$1.750e^{-09}$	777.27	

Figure 6: Output Waveform of voltage regulator circuit

Here a range of signal frequency changing from 1 KHz-70MHz is applied keeping magnitude constant 1V. As we can see from fig.6 that the frequency varies from 1 KHz to 70MHz, total job time and time step keep on changing. At each frequency output waveform calculated and if EMI signal frequency is increased after 70MHz the system is extremely unstable. The EMI effect is maximum at 50MHz frequency shown in fig.6. AND as shown in fig.7 the time step is high at 1 KHz and after that it will decrease. On the other hand Total job time is increasing with increase the frequency.



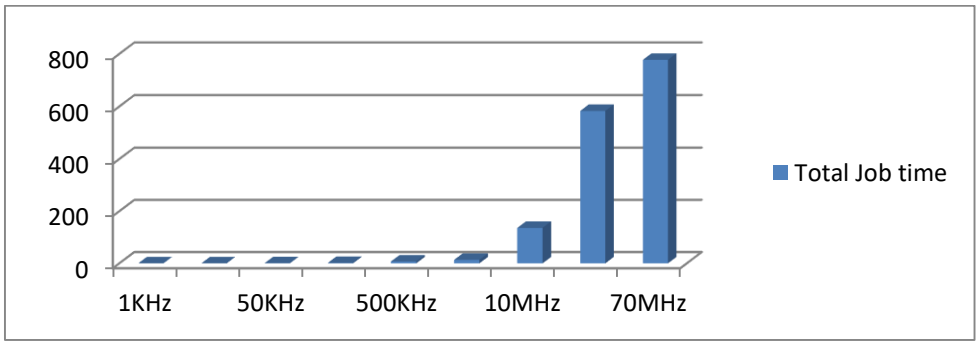
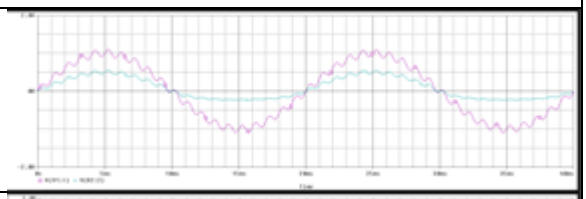
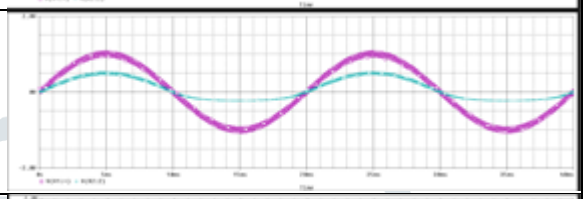
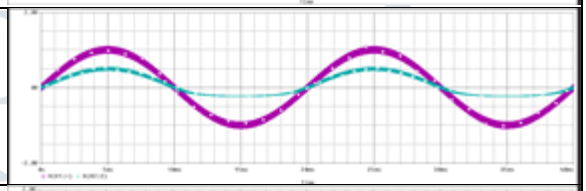
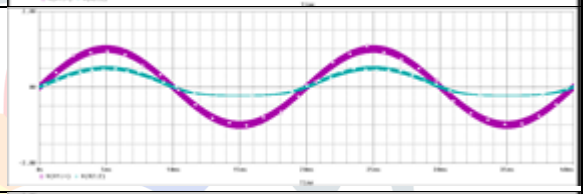
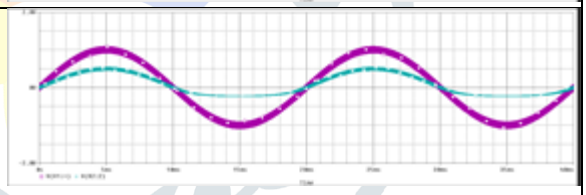
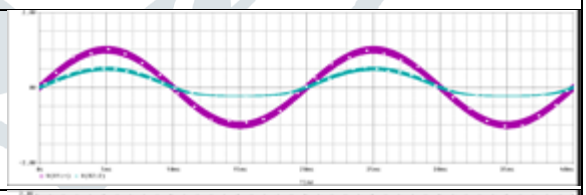
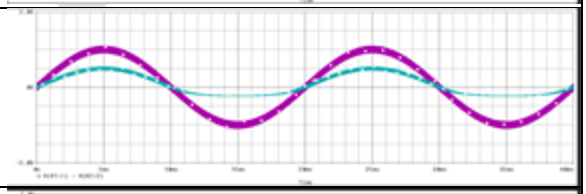
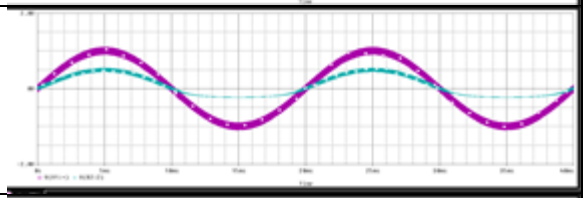
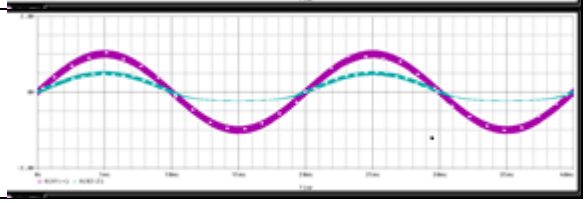


Figure 7: Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.3 EMI Effects with EMI Signal at Frequency 1 KHz- 80 MHz/100mV

Input Signal	EMI Signal	Time step	Total Job Time	Simulation
50KHz/1V	1KHz/100mV	$98.07e^{-06}$	.05	
50KHz/1V	10KHz/100mV	$9.105e^{-06}$	.30	
50KHz/1V	50KHz/100mV	$1.270e^{-06}$	.58	
50KHz/1V	100KHz/100mV	$425.1e^{-09}$	1.11	
50KHz/1V	500KHz/100mV	$59.32e^{-09}$	5.33	
50KHz/1V	1MHz/100mV	$10.23e^{-09}$	10.86	
50KHz/1V	10MHz/100mV	$993.3e^{-12}$	107.78	
50KHz/1V	50MHz/100mV	$1.187e^{-09}$	94.10	
50KHz/1V	70MHz/100mV	$1.699e^{-09}$	790.20	

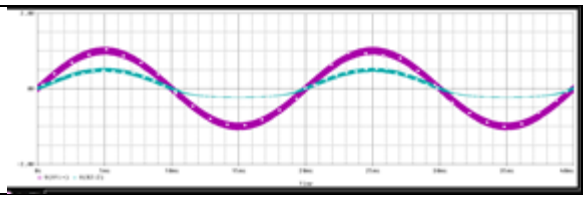
50KHz/1V	80MHz/100mV	$1.147e^{-09}$	882.88	

Figure 8: Output Waveform of voltage regulator circuit

Here a range of signal frequency changing from 1 KHz-80MHz is applied keeping magnitude constant 100mV. As we can see from fig.8 that the frequency varies from 1 KHz to 80MHz, total job time and time step keep on changing. At each frequency output waveform calculated and if EMI signal frequency is increased after 80MHz the system is extremely unstable. The EMI effect is maximum at 50MHz frequency shown in fig.8. AND as shown in fig.9 the time step is high at 1 KHz and after that it will decrease. On the other hand Total job time is increasing with increase the frequency.

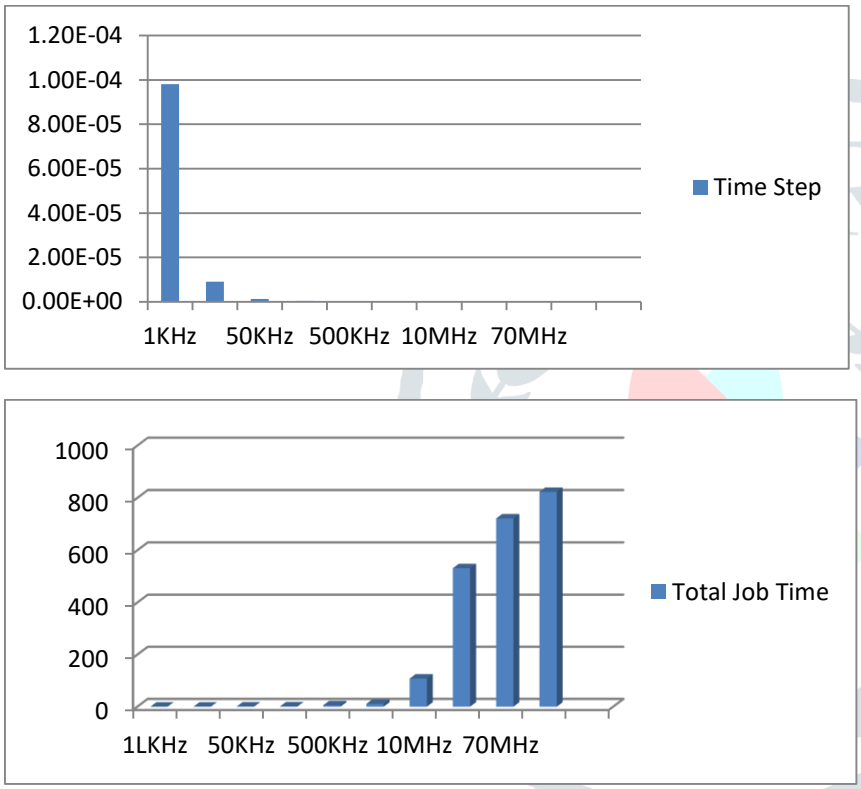
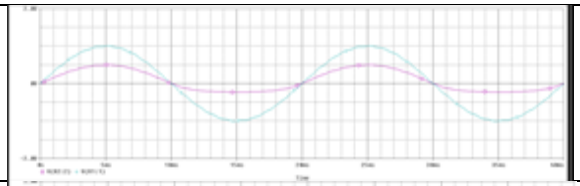
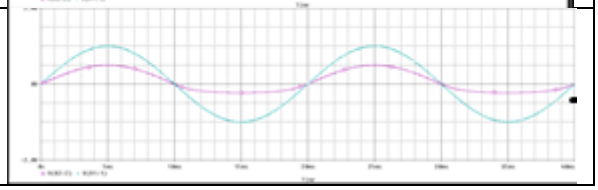


Figure 9 : Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.4 EMI Effects with EMI Signal at Frequency 1 KHz- 90 MHz/10mV

Input Signal	EMI Signal	Time step	Total Job Time	Simulation
50KHz/1V	1KHz/10mV	$89.99e^{-06}$	.05	
50KHz/1V	10KHz/10mV	$9.000e^{-06}$	.14	

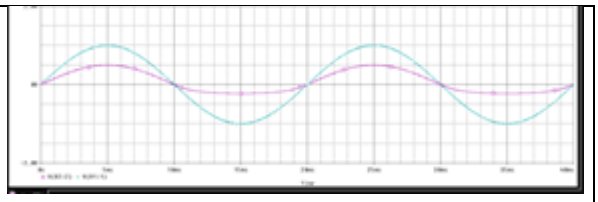
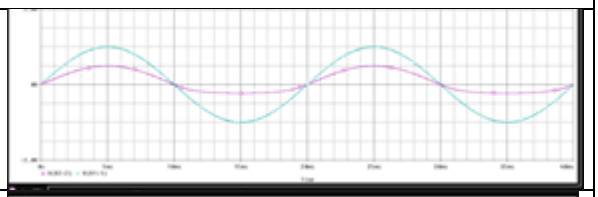
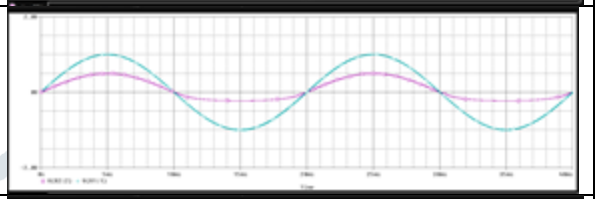
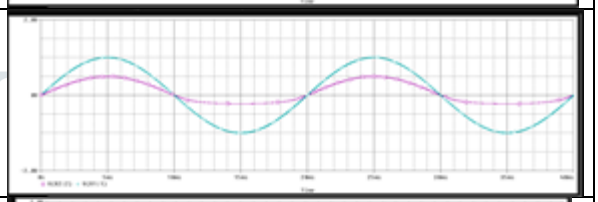
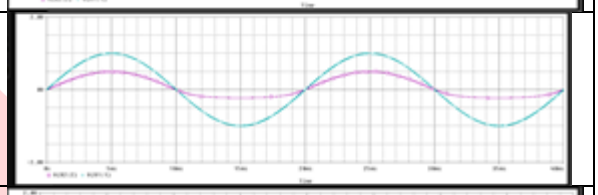
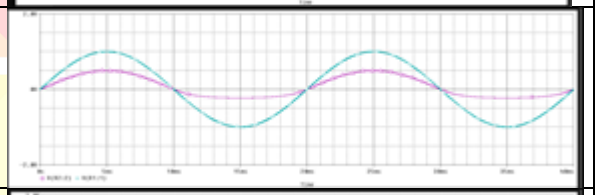
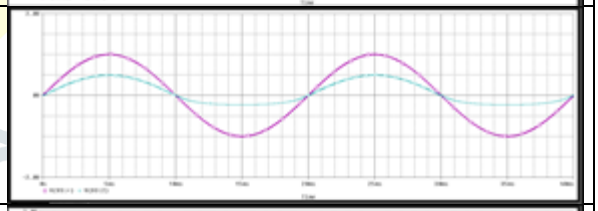
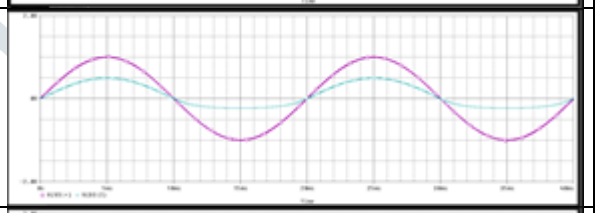
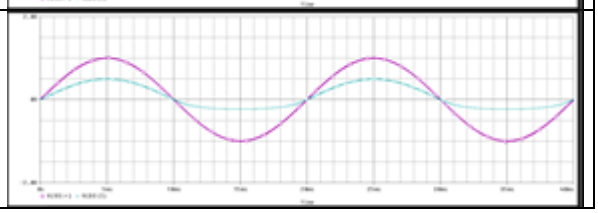
50KHz/1V	50KHz/10mV	$1.880e^{-06}$	.66	
50KHz/1V	100KHz/10mV	968.2^{e-09}	1.03	
50KHz/1V	500KHz/10mV	$20.31e^{-09}$	5.28	
50KHz/1V	1MHz/10mV	$55.41e^{-09}$	10.19	
50KHz/1V	10MHz/10mV	$9.358e^{-}$ 09	101.53	
50KHz/1V	50MHz/10mV	$258.0e^{-12}$	570.20	
50KHz/1V	70MHz/10mV	$724.1e^{-12}$	742.45	
50KHz/1V	80MHz/10mV	$810.4e^{-12}$	857.20	
50KHz/1V	90MHz/10mV	1.175e-09	958.56	

Figure 10: Output Waveform of voltage regulator circuit

Here a range of signal frequency changing from 1 KHz-90MHz is applied keeping magnitude constant 100mV. As we can see from fig.10 that the frequency varies from 1 KHz to 90MHz, total job time and time step keep on changing. At each frequency output waveform calculated and if EMI signal frequency is increased after 80MHz the system is extremely unstable. The EMI

effect is maximum at 50MHz frequency shown in fig.10. AND as shown in fig.11 the time step is high at 1 KHz and after that it will decrease. On the other hand Total job time is increasing with increase the frequency.

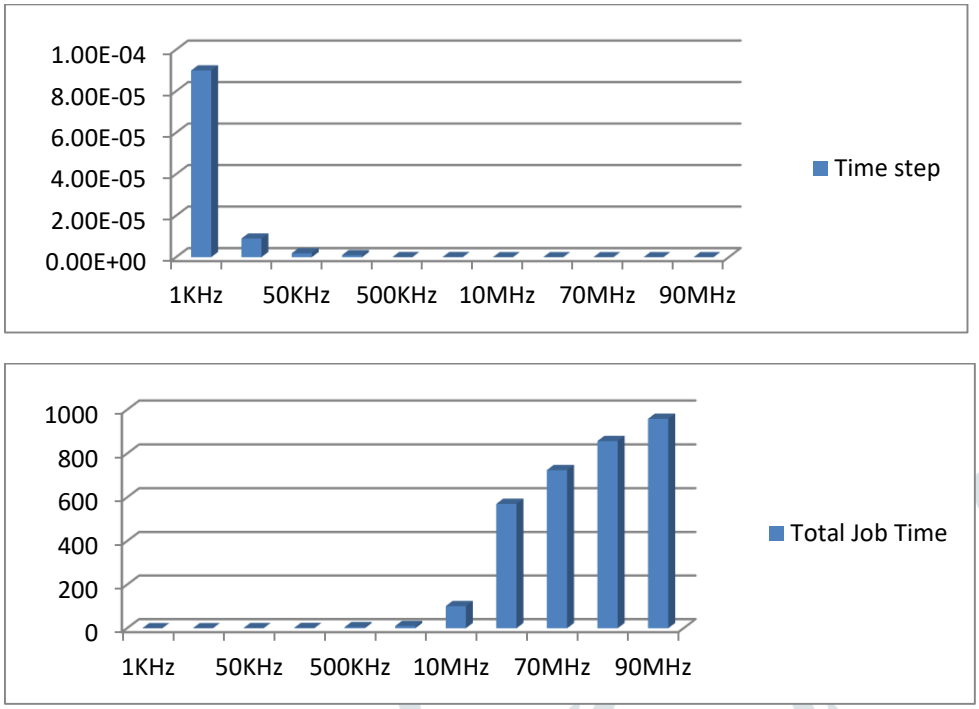


Figure 11: Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.5 EMI EFFECTS WITH EMI SIGNAL AT FREQUENY 70MHz/10mV-500mV

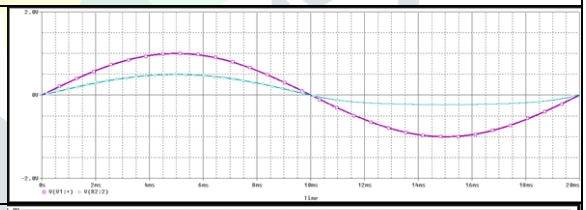
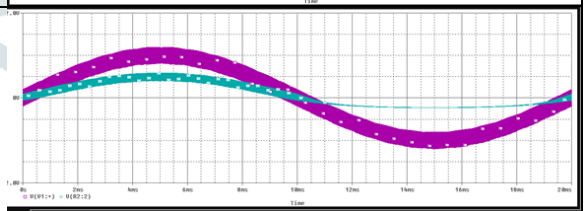
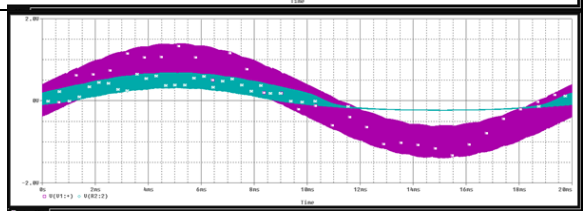
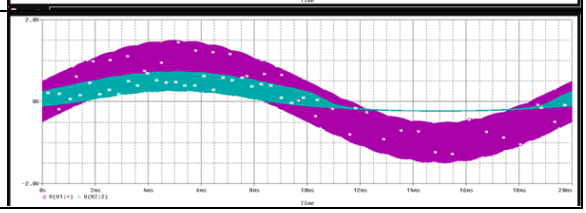
Input Signal	EMI Signal	Time step	Total Job Time	Simulation
50KHz/1V	70MHz/10mV	$187.7e^{-12}$	352.06	
50KHz/1V	70MHz/200mV	$1.783e^{-09}$	359.98	
50KHz/1V	70MHz/400mV	$596.5e^{-12}$	374.05	
50KHz/1V	70MHz/500mV	$1.493e^{-09}$	381.22	

Figure 12**:** Output Waveform of voltage regulator circuit

The amplitude is changes from 10mV to 500mV with constant frequency 70MHz the output waveform are calculated in figure 12. It is clear from fig.13 that time step is minimum at 10mV and more at 200Mv. And the total job time is increase with increase the amplitude. If the amplitude is increased after 500mV the system becomes unstable.

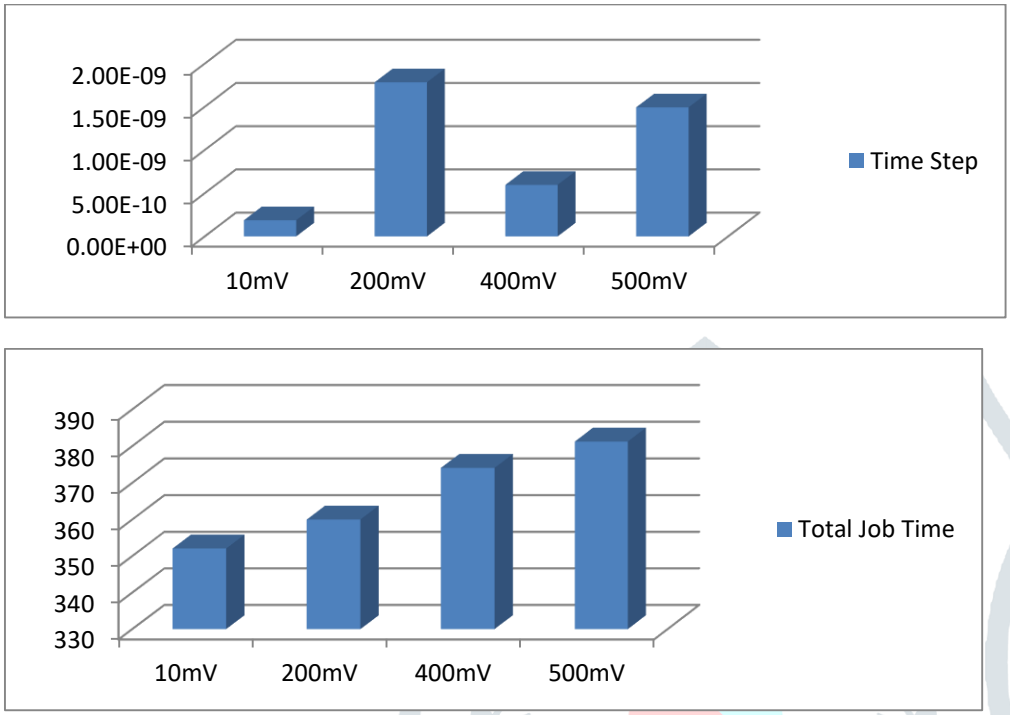
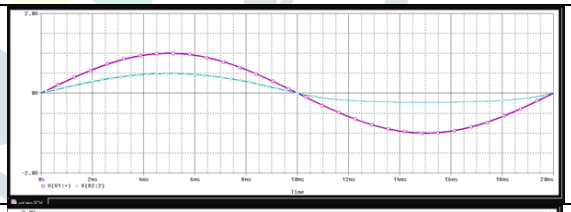
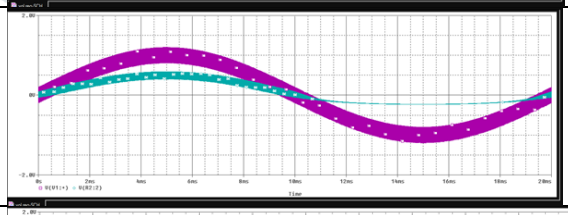
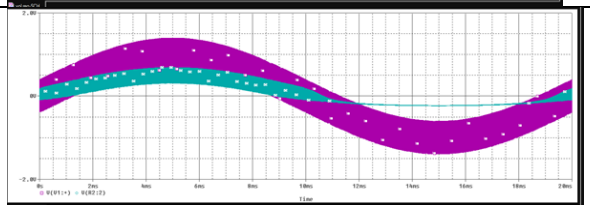


Figure 13: Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.6 EMI EFFECTS WITH EMI SIGNAL AT FREQUENY 80MHz/10mV-400mV

Input Signal	**EMI Signal**	**Time step**	**Total Job Time**	**Simulation**
50KHz/1V	70MHz/10mV	$989.1e^{-12}$	406.83	
50KHz/1V	70MHz/200mV	$629.1e^{-09}$	411.09	
50KHz/1V	70MHz/400mV	$445.8e^{-12}$	429.67	

Figur14: Output Waveform of voltage regulator circuit

The amplitude is changes from 10mV to 400mV with constant frequency 80MHz the output waveform are calculated in figure 14. It is clear from fig.15 that time step is minimum at 10mV or 400mV and more at 200mV. And the total job time is increase with increase the amplitude. If the amplitude is increased after 400mV the system is unstable.

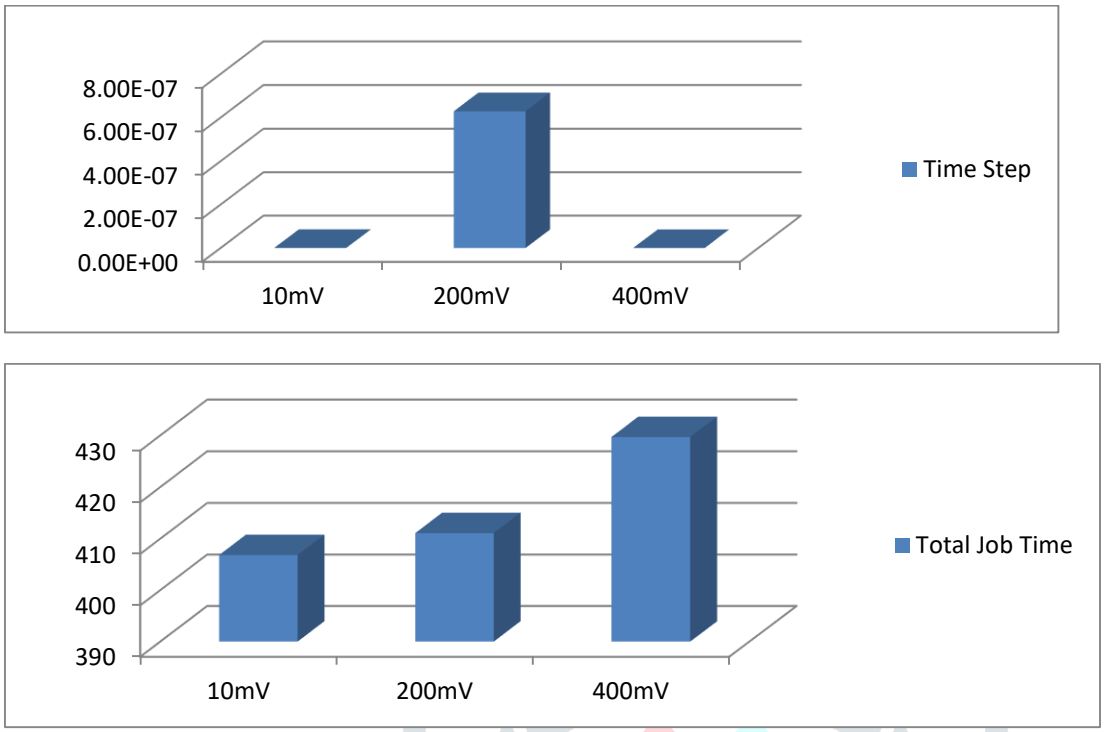


Figure 15: Bar Chart of Time Step and Total Job Time of Voltage Regulator

4.7 EMI EFFECTS WITH EMI SIGNAL AT FREQUENY 90MHz/10mV-100mV

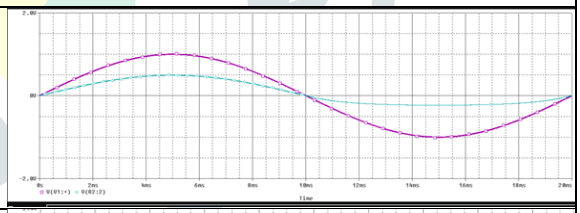
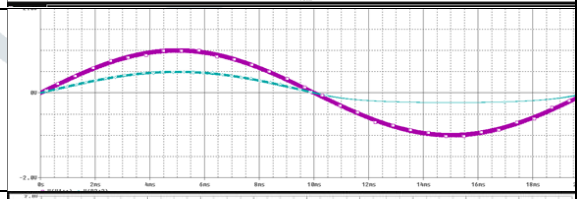
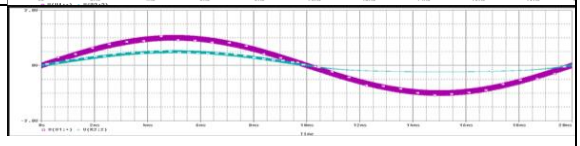
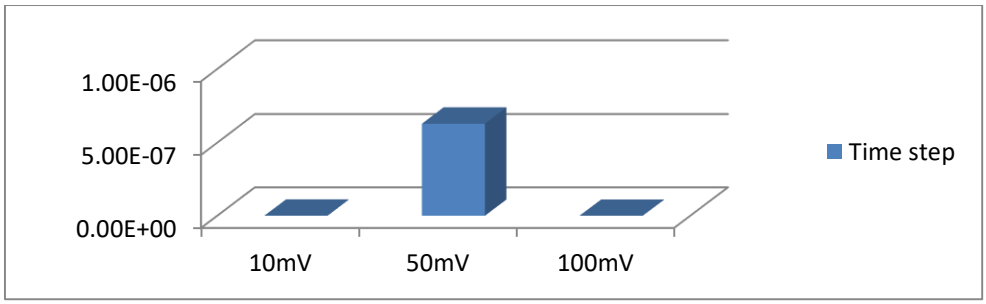
Input Signal	EMI Signal	Time step	Total Job Time	Simulation
50KHz/1V	70MHz/10mV	989.1e-12	406.83	
50KHz/1V	70MHz/50mV	629.1e-09	411.09	
50KHz/1V	70MHz/100mV	445.8e-12	429.67	

Figure16: Output Waveform of voltage regulator circuit

The amplitude is changes from 10mV to 100mV with constant frequency 90MHz the output waveform are calculated in figure 16. It is clear from fig.17 that time step is minimum at 10mV or 100mV and more at 200mV. And the total job time is increase with increase the amplitude. If the amplitude is increased after 100mV the system is unstable.



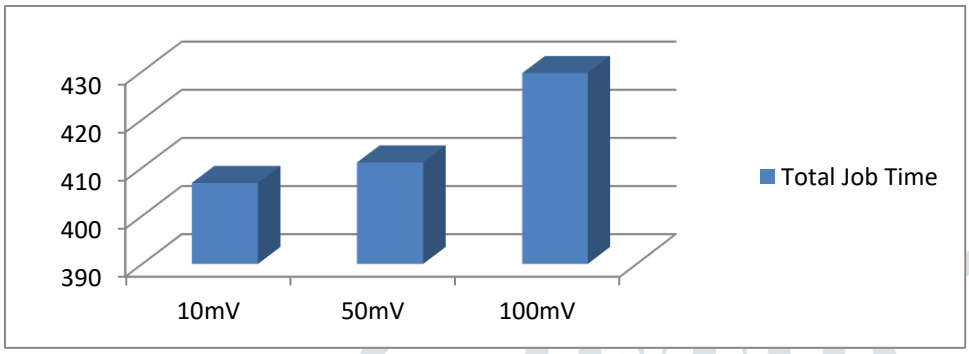


Figure 17: Bar Chart of Time Step and Total Job Time of Voltage Regulator

V. CONCLUSION

In this paper the study of EMI effect on voltage regulator circuit is analyzed and simulated. A briefly analysis is carried out for EMI signal is used different frequency and simulated result show that EMI can cause degradation of voltage regulator operation at 50KHz -50MHz/1V and after 90MHz/10mV.When EMI signal used at different amplitude then EMI can degradation of voltage regulator operation at 70MHz/200mV-500mV, 80MHz/200mV-400mV, 90MHz/100mV.From the simulation result it is concluded that EMI can cause degradation of voltage regulator mainly when the magnitude of EMI signal raised after 200mV and frequency range after 50MHz.

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