

SUB 1V BG Design

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Reference Used : B. Razavi, "The Design of a Low-Voltage Bandgap Reference [The Analog Mind]," in *IEEE Solid-State Circuits Magazine*, vol. 13, no. 3, pp. 6-16, Summer 2021, doi: 10.1109/MSSC.2021.3088963. keywords: {Integrated circuits;Low voltage;Photonic band gap;Perturbation methods;Switches;Voltage control;Transient analysis;Operational amplifiers;Resistors;Low-pass filters},

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Target Specs

Output Voltage : 0.3 Volts

Output Voltage Variation < 1 % (0 °C to 100 °C)

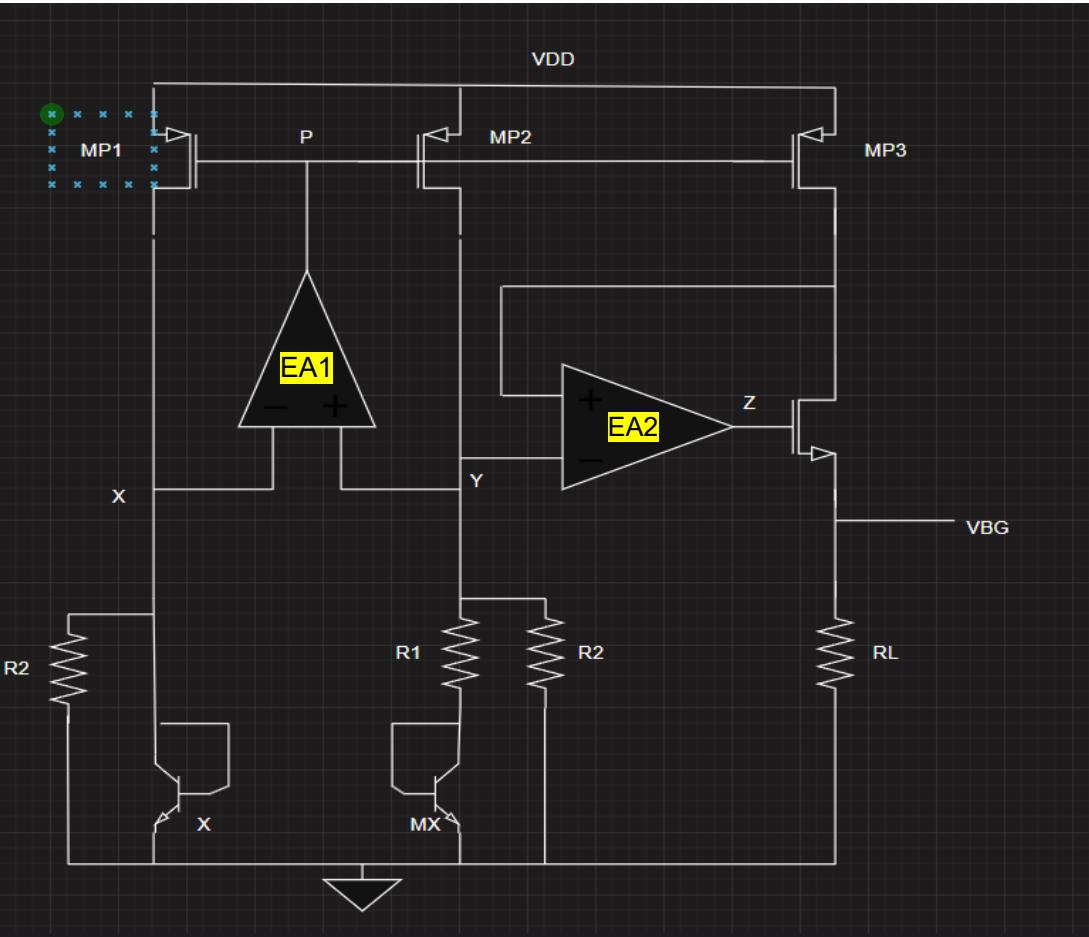
Sigma @ 27 < 5mV

Supply Rejection > 40 dB

Power Consumption < 1 mW

Supply Voltage : 1.2 Volts ± 5 % (1.14 to 1.26 Volts)

Topology Used



Note :

Startup circuit is included later in the schematics section

Both Error Amps have the same input common mode range but gain of $EA2$ was reduced to improve the stability of loop2.

Basic Operation

→ OPAMP Ensures $V_x = V_y$

$$\Rightarrow V_{be1} = V_{be2} + I_{R1} \cdot R1$$

$$\Rightarrow I_{R1} = V_t \cdot \ln(M) / R1$$

Now $I_{MP2} = I_{MP1}$ (their W/L is same)

$$\text{So } I_{MP} = V_t \cdot \ln(M) / R1 + V_{be1} / R2$$

$$V_{bg} = RL \cdot (I_{MP})$$

$$V_{bg} = RL / R1 \cdot (V_t \cdot \ln(M) + (R1 / R2) \cdot V_{be1})$$

Now resistors are sized such that tempco is zero (just at 27 degree centigrade)

- We can't cancel the tempco at all the temperatures since the slope also changes with temperature but cancelling the tempco just at 27 would give good accuracy.

$$V_{bg} = RL / R1 \cdot (PTAT + NTAT)$$

$$\text{Slope } (V_t \cdot \ln(M)) = (-1) \cdot \text{Slope } (R1 / R2 \cdot V_{be1})$$

$$0.087 \cdot \ln(M) = 1.702 \cdot (R1 / R2)$$

→ Cancellation is done only at 27 °C

→ Slope of V_{be} is confirmed from the simulation
(slide 6)

$$M=8$$

$$R1 / R2 = 0.106$$

$$R1 = 1.5 \text{ K}\Omega$$

$$R2 = 14.15 \text{ K}\Omega$$

Now for $V_{bg} = 0.3$ Volts

$$RL = 3.416 \text{ K}\Omega$$

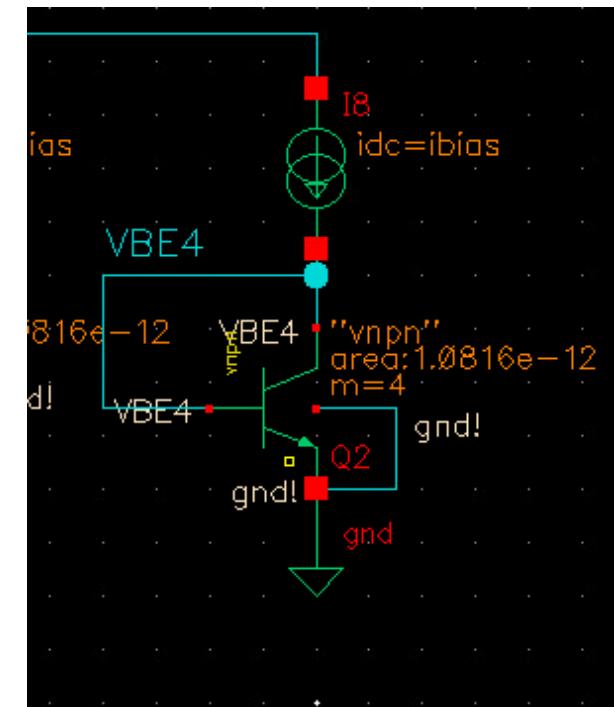
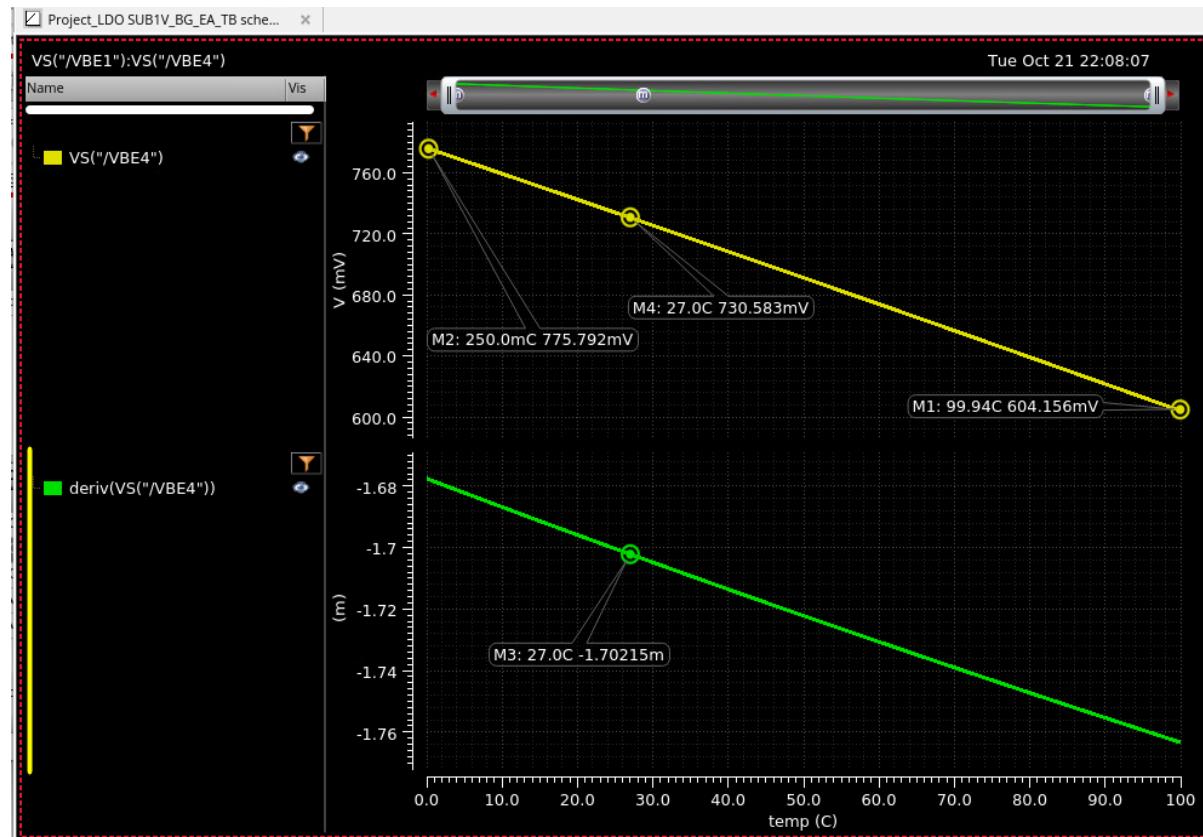
First Cut R numbers are :

$$R1 : 1.5 \text{ K}\Omega$$

$$R2 : 14.15 \text{ K}\Omega$$

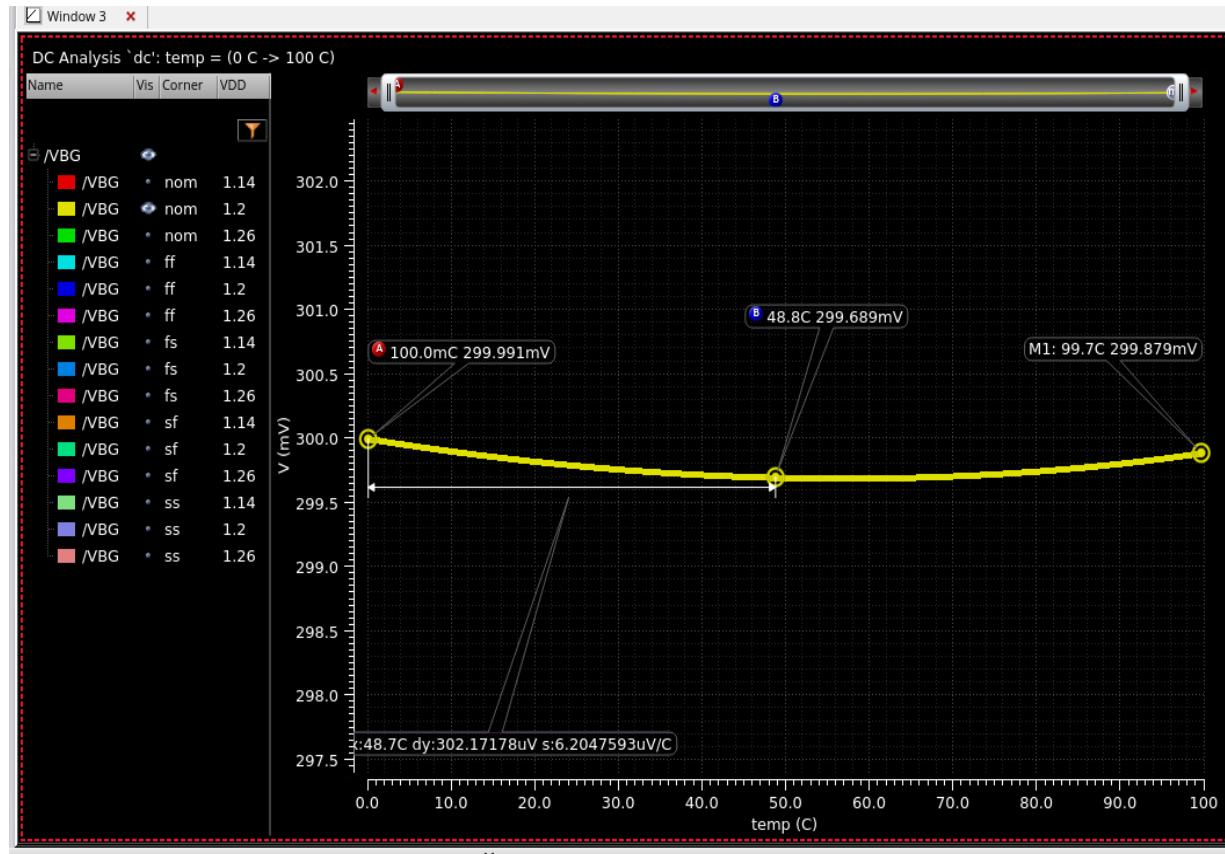
$$R3 : 3.416 \text{ K}\Omega$$

Ibias : 35uA ($Vt \ln(8)/1.5K$) assumed R1 : 1.5K

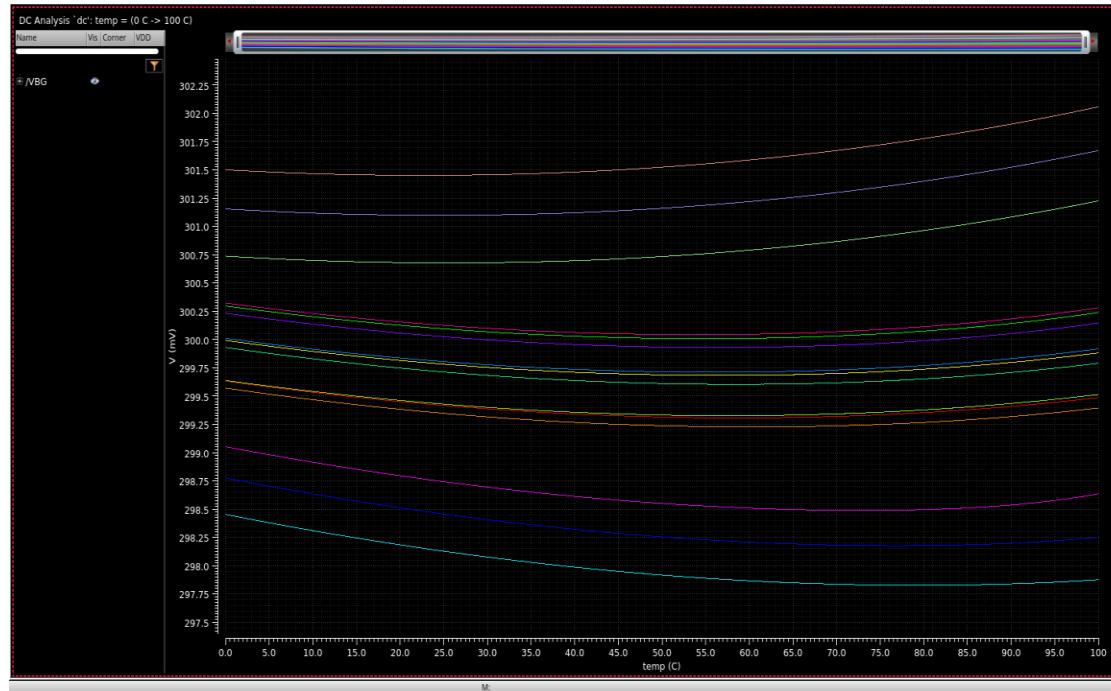


DC Sim (Nominal)

Note : The Handcalculation didn't give the umbrella curve so using simulation the resistor values were tweaked in order to achieve that



DC Sims Across PVT (5 Process corners, 3 Supply Corners, 3 Temperature points 0,27,100)



We can see that across the process V_{be} values change which changes the effective V_{bg} value as well, this requires resistor trimming techniques which ensures the slope cancellation and V_{bg} value maintained at 300mV.

Power Consumption

9/12 rows

Point	Test	Output	Nominal	Spec	Weight	Pass/Fail	Min	Max	ff	fs	sf	ss
Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter	Filter
Parameters: VDD=1.14												
1	DCSIM	I_27C	462.7u	< 800u		pass	436.7u	487.3u	487.3u	463.2u	461.9u	436.7u
1	DCSIM	I_100C	460.6u	< 800u		pass	436.7u	483.8u	483.8u	460.9u	459.9u	436.7u
1	DCSIM	I_0C	463.8u	< 800u		pass	437u	489u	489u	464.4u	462.9u	437u
Parameters: VDD=1.2												
2	DCSIM	I_27C	464.5u	< 800u		pass	438.6u	489u	489u	464.9u	463.8u	438.6u
2	DCSIM	I_100C	462.2u	< 800u		pass	438.4u	485.4u	485.4u	462.5u	461.5u	438.4u
2	DCSIM	I_0C	465.7u	< 800u		pass	438.9u	490.8u	490.8u	466.1u	464.9u	438.9u
Parameters: VDD=1.26												
3	DCSIM	I_27C	466u	< 800u		pass	440.2u	490.5u	490.5u	466.4u	465.4u	440.2u
3	DCSIM	I_100C	463.6u	< 800u		pass	439.9u	486.8u	486.8u	463.8u	463u	439.9u
3	DCSIM	I_0C	467.3u	< 800u		pass	440.6u	492.4u	492.4u	467.7u	466.6u	440.6u

$$\text{Max Power @ 1.2 Volts} = 1.2 * 490\mu\text{A} = 0.58\text{mW}$$

Current Distribution : Around 200uA in Error Amps, $3 * (0.3 / 3.86\text{K})$ in the three branches : 233uA

And some biasing branches

Why Choose M=8 ?

If we have a V_{os} (input referred offset of the opamp) then V_{bg} expression comes out to be :

$$V_{bg} = R_L/R_2(V_{be1} + R_2/R_1 * V_t * \ln(M) - (1+R_2/R_1)*V_{os})$$

Now to reduce the effect of the offset R_2/R_1 needs to be minimized, to still get the flat V_{bg} we need to increase value of M so that temperature slopes are cancelled.

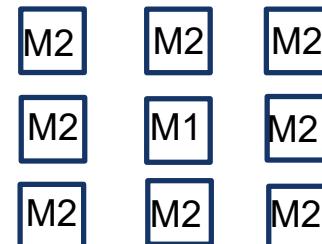
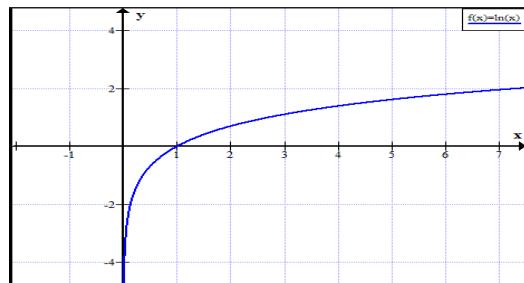
But we can't increase the value of M forever as it consumes significant area.

$$M=2, \ln(2) = 0.693$$

$$M=4, \ln(4) = 1.386$$

$$M=8, \ln(8) = 2.079$$

$$M=16, \ln(16) = 2.77$$

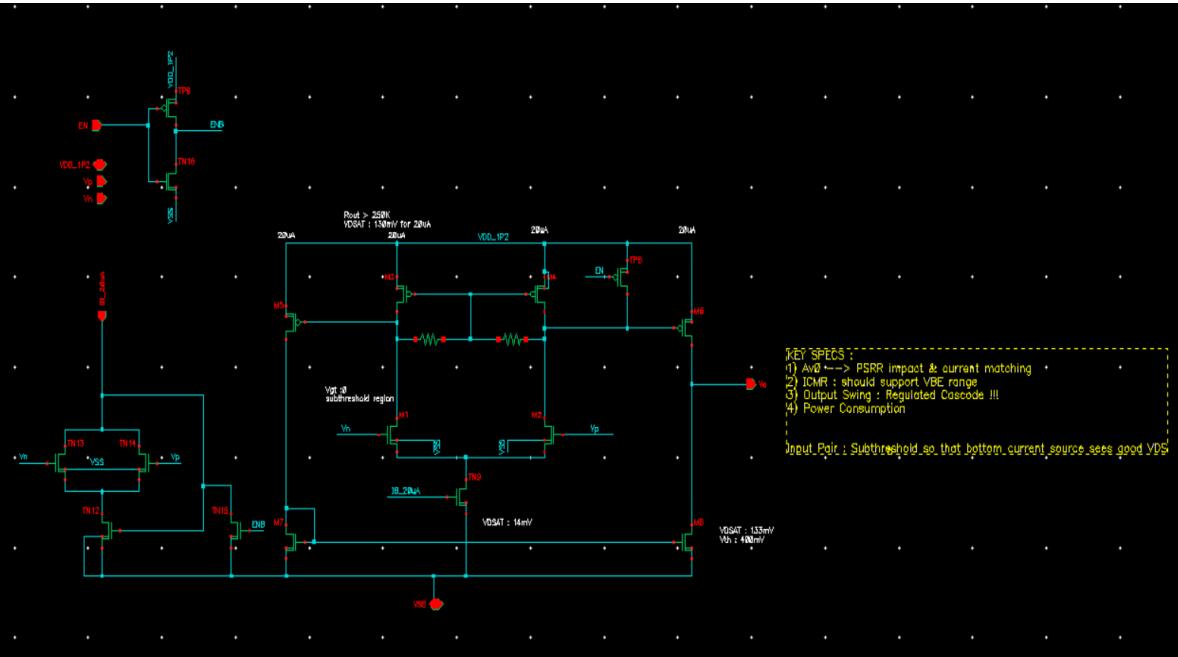


The percentage increase in the values as M increases seems to decrease, so choosing 8 seems to be good Tradeoff.

Error Amp Design

Since the input of the error amp is at voltage level of V_{be1} (V_x) that why the ICMR should be decided by that which is 601mV to 775mV (slide 6) → NMOS input pair-based ERROR AMP was chosen.

Current mirror type opamp but with some additional resistors in the first stage which gives boost to DC gain.



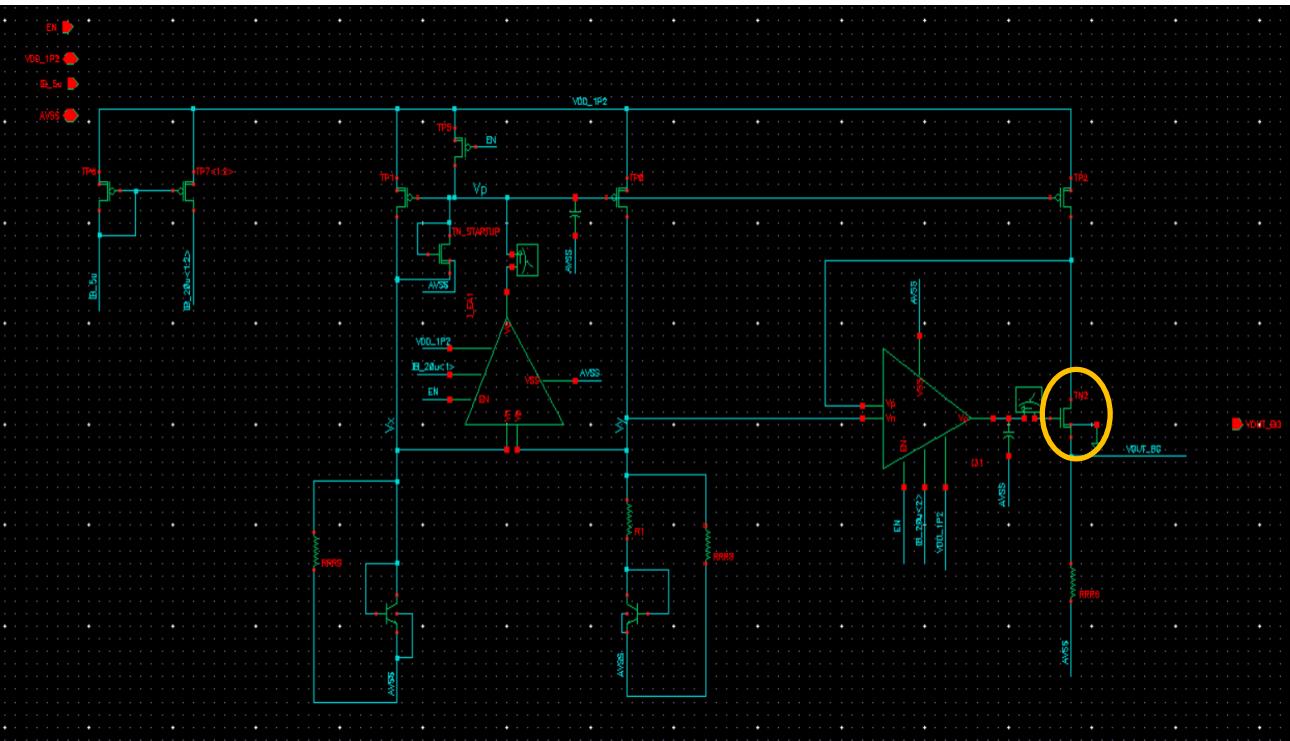
→ Gain : Impacts overall accuracy, PSRR

→ Should support a ICMR of VBE range across temperature (0.6 to 0.75mV)

→ Its output swing should also include $V_{bg}+V_{gs}$ (output stage of the bandgap circuit has a regulated cascode structure)

→ There are two high impedance nodes in this opamp so there was **external cap** used to stabilize the neg-fb loops in which this opamp was used.

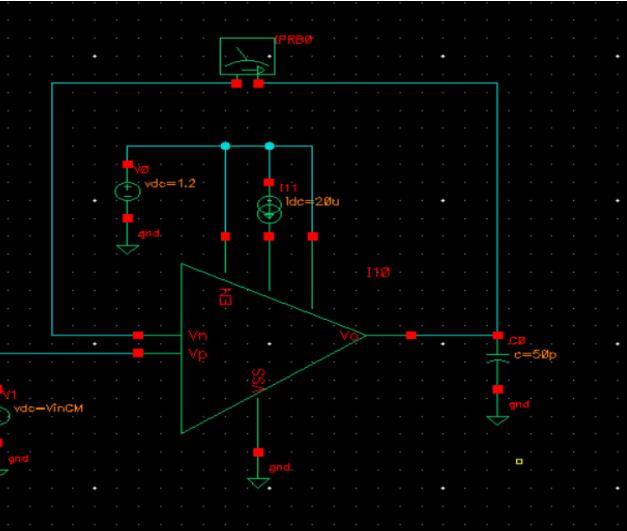
Error Amp Design



- Its output swing should also include $V_{bg}+V_{gs}$ (output stage of the bandgap circuit has a regulated cascode structure)
 - At the gate of the encircled transistor voltage will be **$V_{bg}+ V_{gs}$** (and V_{gs} will be slightly higher than usual due to body effect experienced by TN2)
 - So EA was designed such that output swing includes this point across temperature

Stand-Alone EA Sim Results

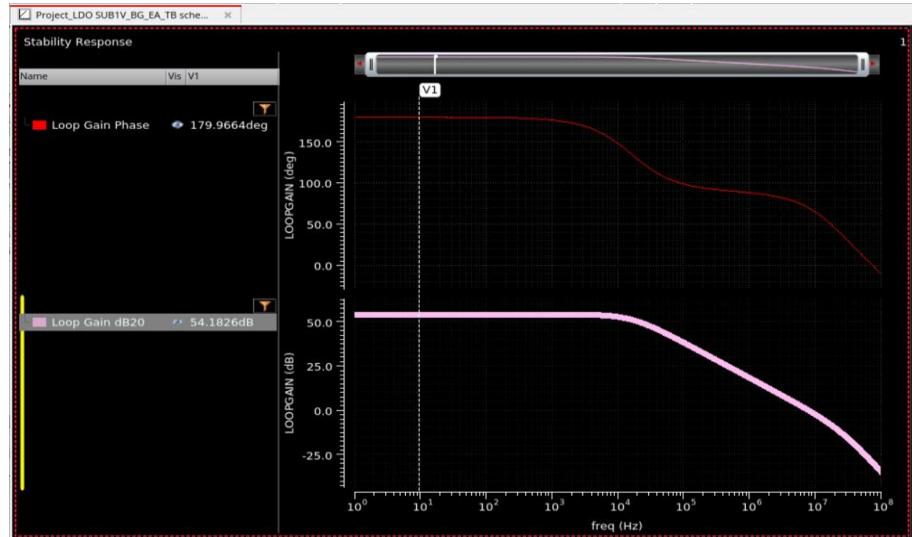
EA Current Consumption : 100uA



54dB DC gain

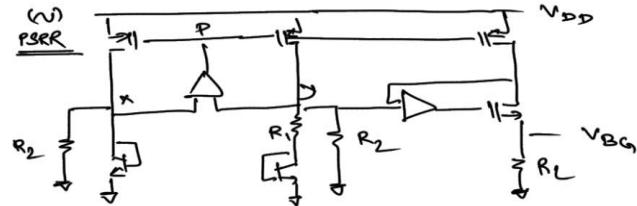
50pF output was just kept to ensure output node dominant pole

The –ve fb loop involving error amps uses lesser cap (more details in upcoming slides)



Output node impedance : 192Kohms
First Node Impedance : 30Kohms

PSRR Calculations



→ let say there is small signal volt. applied
@ V_{DD} that leads to some change in
current

$$V_{XY} = \Delta I_D (V_{gm} + R_1 - V_{gm})$$

(gm of bipolar depends just on current)
so same for both

$$\underline{V_{XY} = (A_{CA}) \Delta I_D R_1 = \Delta V_{DD}}$$

$$\Delta V_{BG} = R_L (\Delta I_D) = \frac{R_L}{A_{CA} R_1} \Delta V_{DD}$$

$$\Delta V_{BG} = \frac{R_L}{R_1} \frac{\Delta V_{DD}}{A_{CA}}$$

as $R_1 \uparrow$ $\Delta V_{BG} \downarrow$ Power consumption ↓

but $A_{CA} \uparrow$

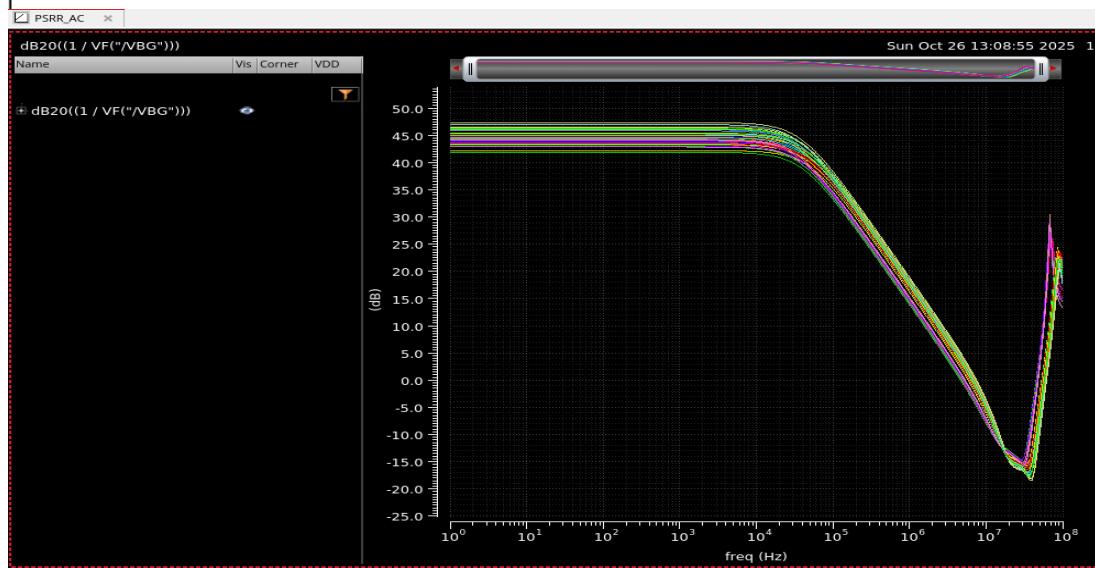
✓ A_{CA} is the knob for improving PSRR

Here it's assumed that OPAMP is able to reject all the supply noise, which is indeed the case. PSR of the opamp is high due to the 2-stage structure.

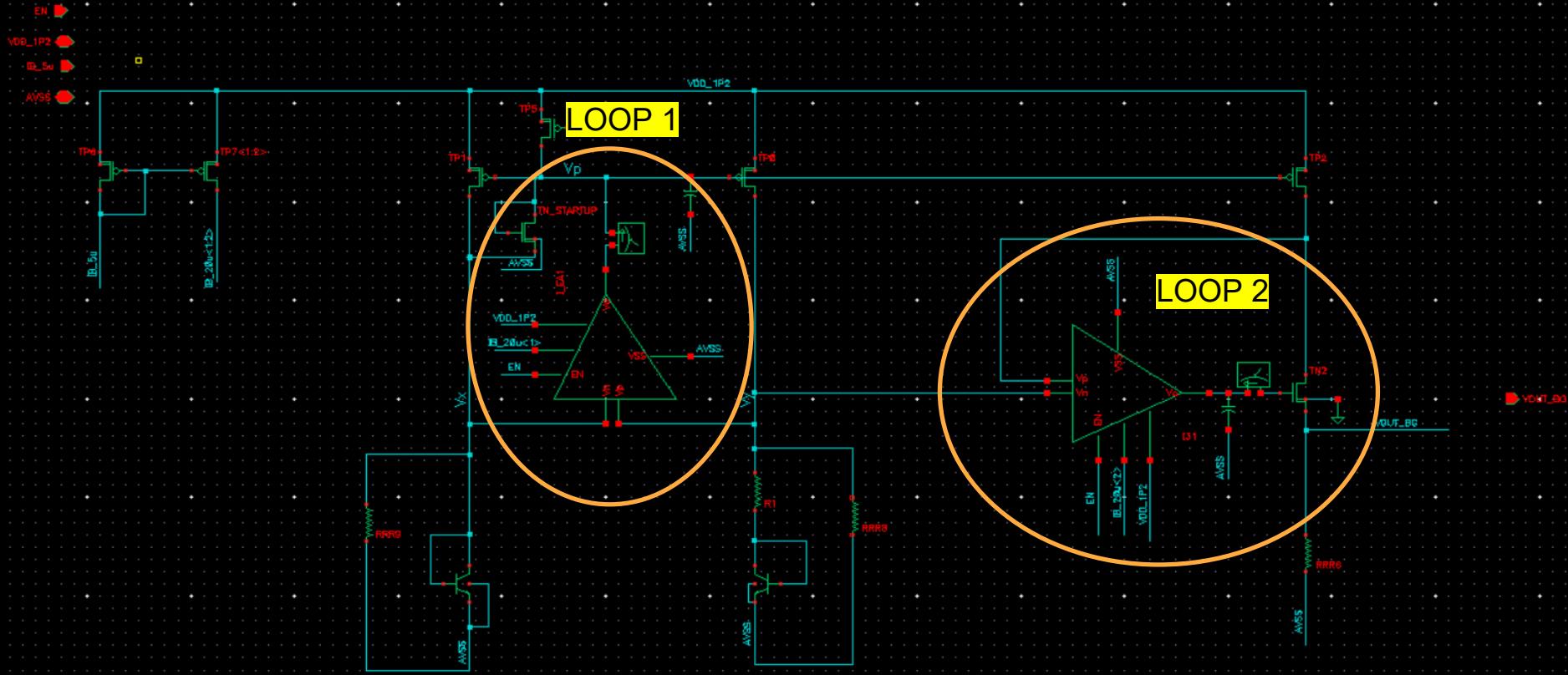
PSR of Bandgap depends on error-Amp gain, R_L , R_1 .

PSRR Sim Results & TB

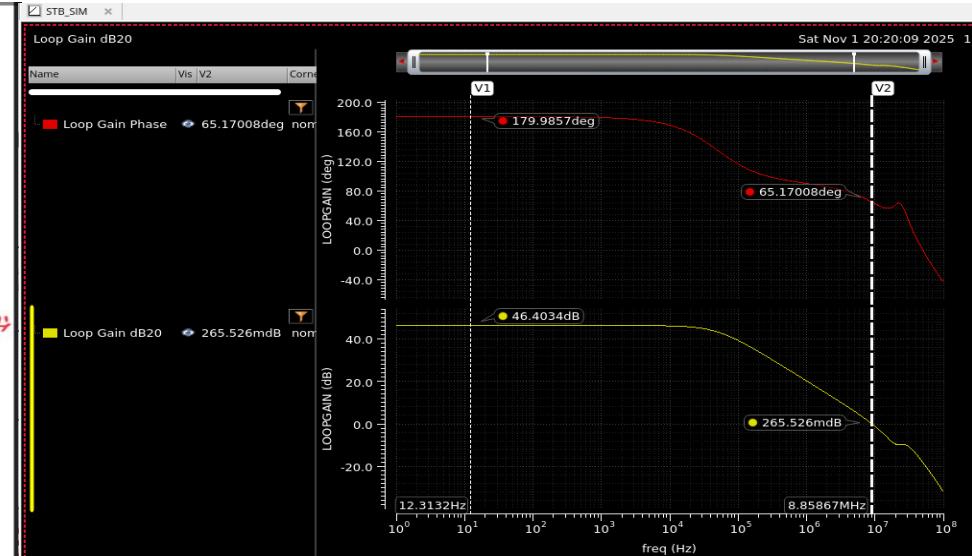
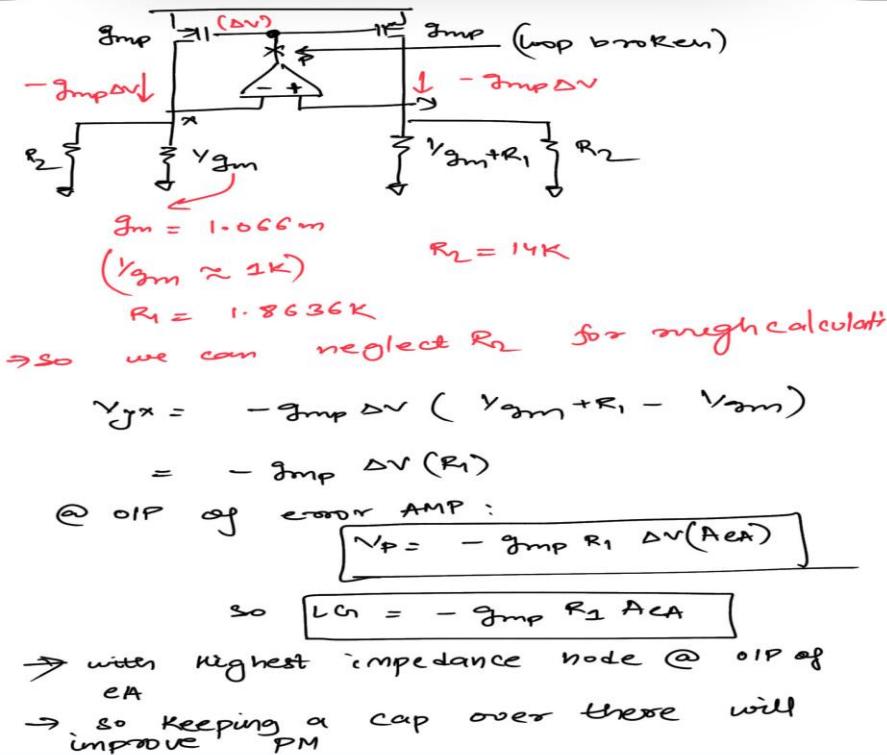
Point	Test	Output	Nominal	Spec	Weight	Pass/Fail	Min	Max
Filter	▼ Filter	▼ Filter	▼ Filter	▼ Filter	▼ Filter	▼ Filter	▼ Filter	▼ Filter
Parameters: VDD=1.2								
1	PSR_AC	PSR_DC	45.02	> 40		pass	43.26	46.13
Parameters: VDD=1.14								
2	PSRR_AC	PSR_DC	43.53	> 40		pass	41.89	44.62
Parameters: VDD=1.26								
3	PSRR_AC	PSR_DC	46.23	> 40		pass	42.88	47.34



-ve FB loops Stability



Loop1

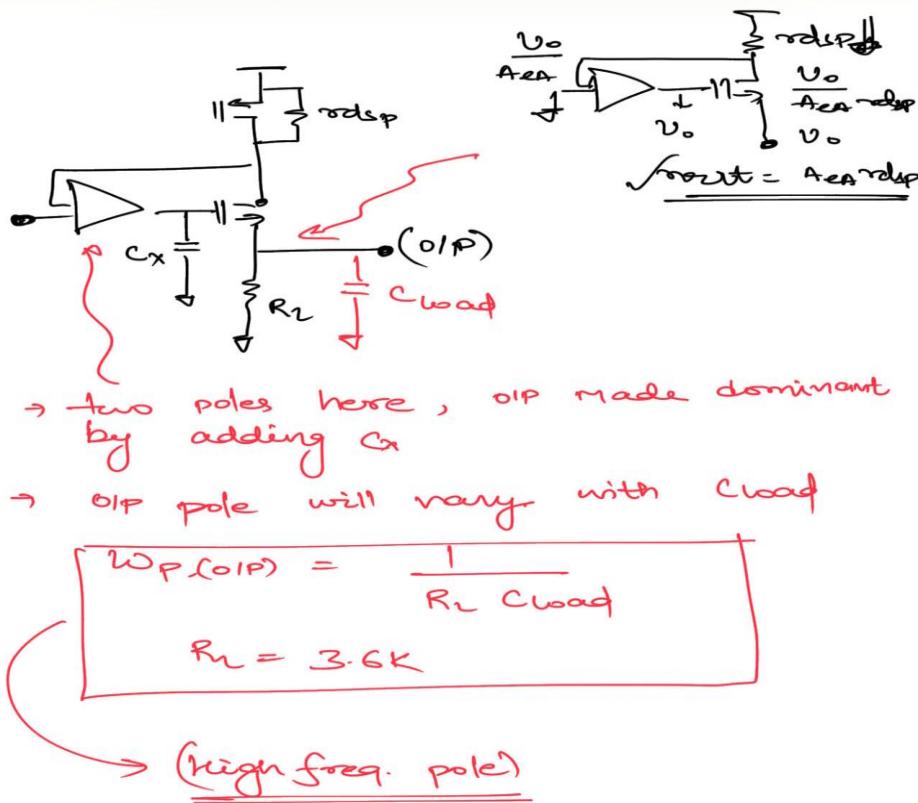


Test	Output	Nominal
Filter	Filter	Filter
STB_SIM	Loop Gain Phase	
STB_SIM	Loop Gain dB20	
STB_SIM	Phase Margin	64.65
STB_SIM	Av0	46.4

Loop1 Stb across Process & Temperature

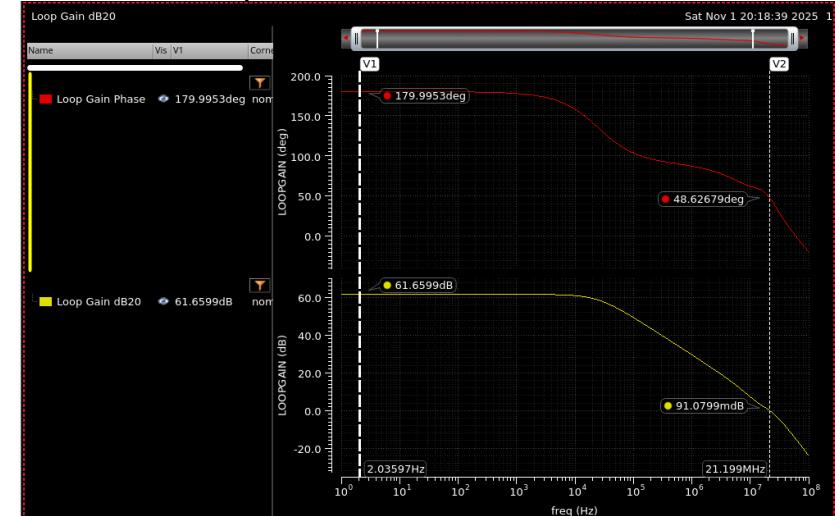
| Test | Output | Spec | Weight | Pass/Fail | Min | Max | ff_0 | ff_1 | ff_2 | fs_0 | fs_1 | fs_2 | sf_0 | sf_1 | sf_2 | sf_3 | sf_4 | sf_5 | sf_6 | sf_7 | sf_8 | sf_9 | sf_10 | sf_11 | sf_12 | sf_13 | sf_14 | sf_15 | sf_16 | sf_17 | sf_18 | sf_19 | sf_20 | sf_21 | sf_22 | sf_23 | sf_24 | sf_25 | sf_26 | sf_27 | sf_28 | sf_29 | sf_30 | sf_31 | sf_32 | sf_33 | sf_34 | sf_35 | sf_36 | sf_37 | sf_38 | sf_39 | sf_40 | sf_41 | sf_42 | sf_43 | sf_44 | sf_45 | sf_46 | sf_47 | sf_48 | sf_49 | sf_50 | sf_51 | sf_52 | sf_53 | sf_54 | sf_55 | sf_56 | sf_57 | sf_58 | sf_59 | sf_60 | sf_61 | sf_62 | sf_63 | sf_64 | sf_65 | sf_66 | sf_67 | sf_68 | sf_69 | sf_70 | sf_71 | sf_72 | sf_73 | sf_74 | sf_75 | sf_76 | sf_77 | sf_78 | sf_79 | sf_80 | sf_81 | sf_82 | sf_83 | sf_84 | sf_85 | sf_86 | sf_87 | sf_88 | sf_89 | sf_90 | sf_91 | sf_92 | sf_93 | sf_94 | sf_95 | sf_96 | sf_97 | sf_98 | sf_99 | sf_100 | sf_101 | sf_102 | sf_103 | sf_104 | sf_105 | sf_106 | sf_107 | sf_108 | sf_109 | sf_110 | sf_111 | sf_112 | sf_113 | sf_114 | sf_115 | sf_116 | sf_117 | sf_118 | sf_119 | sf_120 | sf_121 | sf_122 | sf_123 | sf_124 | sf_125 | sf_126 | sf_127 | sf_128 | sf_129 | sf_130 | sf_131 | sf_132 | sf_133 | sf_134 | sf_135 | sf_136 | sf_137 | sf_138 | sf_139 | sf_140 | sf_141 | sf_142 | sf_143 | sf_144 | sf_145 | sf_146 | sf_147 | sf_148 | sf_149 | sf_150 | sf_151 | sf_152 | sf_153 | sf_154 | sf_155 | sf_156 | sf_157 | sf_158 | sf_159 | sf_160 | sf_161 | sf_162 | sf_163 | sf_164 | sf_165 | sf_166 | sf_167 | sf_168 | sf_169 | sf_170 | sf_171 | sf_172 | sf_173 | sf_174 | sf_175 | sf_176 | sf_177 | sf_178 | sf_179 | sf_180 | sf_181 | sf_182 | sf_183 | sf_184 | sf_185 | sf_186 | sf_187 | sf_188 | sf_189 | sf_190 | sf_191 | sf_192 | sf_193 | sf_194 | sf_195 | sf_196 | sf_197 | sf_198 | sf_199 | sf_200 | sf_201 | sf_202 | sf_203 | sf_204 | sf_205 | sf_206 | sf_207 | sf_208 | sf_209 | sf_210 | sf_211 | sf_212 | sf_213 | sf_214 | sf_215 | sf_216 | sf_217 | sf_218 | sf_219 | sf_220 | sf_221 | sf_222 | 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sf_667 | sf_668 | sf_669 | sf_670 | sf_671 | sf_672 | sf_673 | sf_674 | sf_675 | sf_676 | sf_677 | sf_678 | sf_679 | sf_680 | sf_681 | sf_682 | sf_683 | sf_684 | sf_685 | sf_686 | sf_687 | sf_688 | sf_689 | sf_690 | sf_691 | sf_692 | sf_693 | sf_694 | sf_695 | sf_696 | sf_697 | sf_698 | sf_699 | sf_700 | sf_701 | sf_702 | sf_703 | sf_704 | sf_705 | sf_706 | sf_707 | sf_708 | sf_709 | sf_710 | sf_711 | sf_712 | sf_713 | sf_714 | sf_715 | sf_716 | sf_717 | sf_718 | sf_719 | sf_720 | sf_721 | sf_722 | sf_723 | sf_724 | sf_725 | sf_726 | sf_727 | sf_728 | sf_729 | sf_730 | sf_731 | sf_732 | sf_733 | sf_734 | sf_735 | sf_736 | sf_737 | sf_738 | sf_739 | sf_740 | sf_741 | sf_742 | sf_743 | sf_744 | sf_745 | sf_746 | sf_747 | sf_748 | sf_749 | sf_750 | sf_751 | sf_752 | sf_753 | sf_754 | sf_755 | sf_756 | sf_757 | sf_758 | sf_759 | sf_760 | sf_761 | sf_762 | sf_763 | sf_764 | sf_765 | sf_766 | sf_767 | sf_768 | sf_769 | sf_770 | sf_771 | sf_772 | sf_773 | sf_774 | sf_775 | sf_776 | sf_777 | sf_778 | sf_779 | sf_780 | sf_781 | sf_782 | sf_783 | sf_784 | sf_785 | sf_786 | sf_787 | sf_788 | sf_789 | sf_790 | sf_791 | sf_792 | sf_793 | sf_794 | sf_795 | sf_796 | sf_797 | sf_798 | sf_799 | sf_800 | sf_801 | sf_802 | sf_803 | sf_804 | sf_805 | sf_806 | sf_807 | sf_808 | sf_809 | sf_810 | sf_811 | sf_812 | sf_813 | sf_814 | sf_815 | sf_816 | sf_817 | sf_818 | sf_819 | sf_820 | sf_821 | sf_822 | sf_823 | sf_824 | sf_825 | sf_826 | sf_827 | sf_828 | sf_829 | sf_830 | sf_831 | sf_832 | sf_833 | sf_834 | sf_835 | sf_836 | sf_837 | sf_838 | sf_839 | sf_840 | sf_841 | sf_842 | sf_843 | sf_844 | sf_845 | sf_846 | sf_847 | sf_848 | sf_849 | sf_850 | sf_851 | sf_852 | sf_853 | sf_854 | sf_855 | sf_856 | sf_857 | sf_858 | sf_859 | sf_860 | sf_861 | sf_862 | sf_863 | sf_864 | sf_865 | sf_866 | sf_867 | sf_868 | sf_869 | sf_870 | sf_871 | sf_872 | sf_873 | sf_874 | sf_875 | sf_876 | sf_877 | sf_878 | sf_879 | sf_880 | sf_881 | sf_882 | sf_883 | sf_884 | sf_885 | sf_886 | sf_887 | sf_888 | sf_889 | sf_890 | sf_891 | sf_892 | sf_893 | sf_894 | sf_895 | sf_896 | sf_897 | sf_898 | sf_899 | sf_900 | sf_901 | sf_902 | sf_903 | sf_904 | sf_905 | sf_906 | sf_907 | sf_908 | sf_909 | sf_910 | sf_911 | sf_912 | sf_913 | sf_914 | sf_915 | sf_916 | sf_917 | sf_918 | sf_919 | sf_920 | sf_921 | sf_922 | sf_923 | sf_924 | sf_925 | sf_926 | sf_927 | sf_928 | sf_929 | sf_930 | sf_931 | sf_932 | sf_933 | sf_934 | sf_935 | sf_936 | sf_937 | sf_938 | sf_939 | sf_940 | sf_941 | sf_942 | sf_943 | sf_944 | sf_945 | sf_946 | sf_947 | sf_948 | sf_949 | sf_950 | sf_951 | sf_952 | sf_953 | sf_954 | sf_955 | sf_956 | sf_957 | sf_958 | sf_959 | sf_960 | sf_961 | sf_962 | sf_963 | sf_964 | sf_965 | sf_966 | sf_967 | sf_968 | sf_969 | sf_970 | sf_971 | sf_972 | sf_973 | sf_974 | sf_975 | sf_976 | sf_977 | sf_978 | sf_979 | sf_980 | sf_981 | sf_982 | sf_983 | sf_984 | sf_985 | sf_986 | sf_987 | sf_988 | sf_989 | sf_990 | sf_991 | sf_992 | sf_993 | sf_994 | sf_995 | sf_996 | sf_997 | sf_998 | sf_999 | sf_1000 | sf_1001 | sf_1002 | sf_1003 | sf_1004 | sf_1005 | sf_1006 | sf_1007 | sf_1008 | sf_1009 | sf_1010 | sf_1011 | sf_1012 | sf_1013 | sf_1014 | sf_1015 | sf_1016 | sf_1017 | sf_1018 | sf_1019 | sf_1020 | sf_1021 | sf_1022 | sf_1023 | sf_1024 | sf_1025 | sf_1026 | sf_1027 | sf_1028 | sf_1029 | sf_1030 | sf_1031 | sf_1032 | sf_1033 | sf_1034 | sf_1035 | sf_1036 | sf_1037 | sf_1038 | sf_1039 | sf_1040 | sf_1041 | sf_1042 | sf_1043 | sf_1044 | sf_1045 | sf_1046 | sf_1047 | sf_1048 | sf_1049 | sf_1050 | sf_1051 | sf_1052 | sf_1053 | sf_1054 | sf_1055 | sf_1056 | sf_1057 | sf_1058 | sf_1059 | sf_1060 | sf_1061 | sf_1062 | sf_1063 | sf_1064 | sf_1065 | sf_1066 | sf_1067 | sf_1068 | sf_1069 | sf_1070 | sf_1071 | sf_1072 | sf_1073 | sf_1074 | sf_1075 | sf_1076 | sf_1077 | sf_1078 | sf_1079 | sf_1080 | sf_1081 | sf_1082 | sf_1083 | sf_1084 | sf_1085 | sf_1086 | sf_1087 | sf_1088 | sf_1089 | sf_1090 | sf_1091 | sf_1092 | sf_1093 | sf_1094 | sf_1095 | sf_1096 | sf_1097 | sf_1098 | sf_1099 | sf_1100 | sf_1101 | sf_1102 | sf_1103 | sf_1104 | sf_1105 | sf_1106 | sf_1107 | sf_1108 | sf_1109 | sf_1110 | sf_1111 | sf_1112 | sf_1113 | sf_1114 | sf_1115 | sf_1116 | sf_1117 | sf_1118 | sf_1119 | sf_1120 | sf_1121 | sf_1122 | sf_1123 | sf_1124 | sf_1125 | sf_1126 | sf_1127 | sf_1128 | sf_1129 | sf_1130 | sf_1131 | sf_1132 | sf_1133 | sf_1134 | sf_1135 | sf_1136 | sf_1137 | sf_1138 | sf_1139 | sf_1140 | sf_1141 | sf_1142 | sf_1143 | sf_1144 | sf_1145 | sf_1146 | sf_1147 | sf_1148 | sf_1149 | sf_1150 | sf_1151 | sf_1152 | sf_1153 | sf_1154 | sf_1155 | sf_1156 | sf_1157 | sf_1158 | sf_1159 | sf_1160 | sf_1161 | sf_1162 | sf_1163 | sf_1164 | sf_1165 | sf_1166 | sf_1167 | sf_1168 | sf_1169 | sf_1170 | sf_1171 | sf_1172 | sf_1173 | sf_1174 | sf_1175 | sf_1176 | sf_1177 | sf_1178 | sf_1179 | sf_1180 | sf_1181 | sf_1182 | sf_1183 | sf_1184 | sf_1185 | sf_1186 | sf_1187 | sf_1188 | sf_1189 | sf_1190 | sf_1191 | sf_1192 | sf_1193 | sf_1194 | sf_1195 | sf_1196 | sf_1197 | sf_1198 | sf_1199 | sf_1200 | sf_1201 | sf_1202 | sf_1203 | sf_1204 | sf_1205 | sf_1206 | sf_1207 | sf_1208 | sf_1209 | sf_1210 |<th
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Loop 2



Loop Gain is higher in this case due to the presence of common-source stage. Due to which Error Amp used here was of less gain in order to place less cap (C_x) to make it stable.

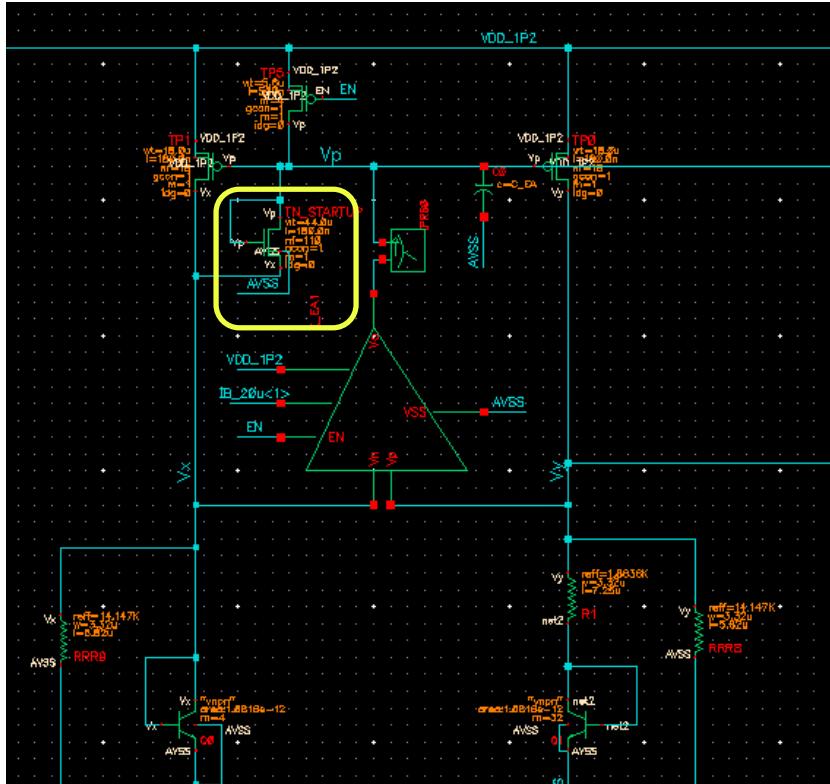
C_x used : 40pF



Loop2 stability across Process and Temperature

Test	Output	Spec	Weight	Pass/Fail	Min	Max	ff_0	ff_1	ff_2	fs_0	fs_1	fs_2	sf_0	sf_1	sf_2	sf_3	sf_4	sf_5	sf_6	sf_7	sf_8	sf_9	sf_10	sf_11	sf_12	sf_13	sf_14	sf_15	sf_16	sf_17	sf_18	sf_19	sf_20	sf_21	sf_22	sf_23	sf_24	sf_25	sf_26	sf_27	sf_28	sf_29	sf_30	sf_31	sf_32	sf_33	sf_34	sf_35	sf_36	sf_37	sf_38	sf_39	sf_40	sf_41	sf_42	sf_43	sf_44	sf_45	sf_46	sf_47	sf_48	sf_49	sf_50	sf_51	sf_52	sf_53	sf_54	sf_55	sf_56	sf_57	sf_58	sf_59	sf_60	sf_61	sf_62	sf_63	sf_64	sf_65	sf_66	sf_67	sf_68	sf_69	sf_70	sf_71	sf_72	sf_73	sf_74	sf_75	sf_76	sf_77	sf_78	sf_79	sf_80	sf_81	sf_82	sf_83	sf_84	sf_85	sf_86	sf_87	sf_88	sf_89	sf_90	sf_91	sf_92	sf_93	sf_94	sf_95	sf_96	sf_97	sf_98	sf_99	sf_100	sf_101	sf_102	sf_103	sf_104	sf_105	sf_106	sf_107	sf_108	sf_109	sf_110	sf_111	sf_112	sf_113	sf_114	sf_115	sf_116	sf_117	sf_118	sf_119	sf_120	sf_121	sf_122	sf_123	sf_124	sf_125	sf_126	sf_127	sf_128	sf_129	sf_130	sf_131	sf_132	sf_133	sf_134	sf_135	sf_136	sf_137	sf_138	sf_139	sf_140	sf_141	sf_142	sf_143	sf_144	sf_145	sf_146	sf_147	sf_148	sf_149	sf_150	sf_151	sf_152	sf_153	sf_154	sf_155	sf_156	sf_157	sf_158	sf_159	sf_160	sf_161	sf_162	sf_163	sf_164	sf_165	sf_166	sf_167	sf_168	sf_169	sf_170	sf_171	sf_172	sf_173	sf_174	sf_175	sf_176	sf_177	sf_178	sf_179	sf_180	sf_181	sf_182	sf_183	sf_184	sf_185	sf_186	sf_187	sf_188	sf_189	sf_190	sf_191	sf_192	sf_193	sf_194	sf_195	sf_196	sf_197	sf_198	sf_199	sf_200	sf_201	sf_202	sf_203	sf_204	sf_205	sf_206	sf_207	sf_208	sf_209	sf_210	sf_211	sf_212	sf_213	sf_214	sf_215	sf_216	sf_217	sf_218	sf_219	sf_220	sf_221	sf_222	sf_223	sf_224	sf_225	sf_226	sf_227	sf_228	sf_229	sf_230	sf_231	sf_232	sf_233	sf_234	sf_235	sf_236	sf_237	sf_238	sf_239	sf_240	sf_241	sf_242	sf_243	sf_244	sf_245	sf_246	sf_247	sf_248	sf_249	sf_250	sf_251	sf_252	sf_253	sf_254	sf_255	sf_256	sf_257	sf_258	sf_259	sf_260	sf_261	sf_262	sf_263	sf_264	sf_265	sf_266	sf_267	sf_268	sf_269	sf_270	sf_271	sf_272	sf_273	sf_274	sf_275	sf_276	sf_277	sf_278	sf_279	sf_280	sf_281	sf_282	sf_283	sf_284	sf_285	sf_286	sf_287	sf_288	sf_289	sf_290	sf_291	sf_292	sf_293	sf_294	sf_295	sf_296	sf_297	sf_298	sf_299	sf_300	sf_301	sf_302	sf_303	sf_304	sf_305	sf_306	sf_307	sf_308	sf_309	sf_310	sf_311	sf_312	sf_313	sf_314	sf_315	sf_316	sf_317	sf_318	sf_319	sf_320	sf_321	sf_322	sf_323	sf_324	sf_325	sf_326	sf_327	sf_328	sf_329	sf_330	sf_331	sf_332	sf_333	sf_334	sf_335	sf_336	sf_337	sf_338	sf_339	sf_340	sf_341	sf_342	sf_343	sf_344	sf_345	sf_346	sf_347	sf_348	sf_349	sf_350	sf_351	sf_352	sf_353	sf_354	sf_355	sf_356	sf_357	sf_358	sf_359	sf_360	sf_361	sf_362	sf_363	sf_364	sf_365	sf_366	sf_367	sf_368	sf_369	sf_370	sf_371	sf_372	sf_373	sf_374	sf_375	sf_376	sf_377	sf_378	sf_379	sf_380	sf_381	sf_382	sf_383	sf_384	sf_385	sf_386	sf_387	sf_388	sf_389	sf_390	sf_391	sf_392	sf_393	sf_394	sf_395	sf_396	sf_397	sf_398	sf_399	sf_400	sf_401	sf_402	sf_403	sf_404	sf_405	sf_406	sf_407	sf_408	sf_409	sf_410	sf_411	sf_412	sf_413	sf_414	sf_415	sf_416	sf_417	sf_418	sf_419	sf_420	sf_421	sf_422	sf_423	sf_424	sf_425	sf_426	sf_427	sf_428	sf_429	sf_430	sf_431	sf_432	sf_433	sf_434	sf_435	sf_436	sf_437	sf_438	sf_439	sf_440	sf_441	sf_442	sf_443	sf_444	sf_445	sf_446	sf_447	sf_448	sf_449	sf_450	sf_451	sf_452	sf_453	sf_454	sf_455	sf_456	sf_457	sf_458	sf_459	sf_460	sf_461	sf_462	sf_463	sf_464	sf_465	sf_466	sf_467	sf_468	sf_469	sf_470	sf_471	sf_472	sf_473	sf_474	sf_475	sf_476	sf_477	sf_478	sf_479	sf_480	sf_481	sf_482	sf_483	sf_484	sf_485	sf_486	sf_487	sf_488	sf_489	sf_490	sf_491	sf_492	sf_493	sf_494	sf_495	sf_496	sf_497	sf_498	sf_499	sf_500	sf_501	sf_502	sf_503	sf_504	sf_505	sf_506	sf_507	sf_508	sf_509	sf_510	sf_511	sf_512	sf_513	sf_514	sf_515	sf_516	sf_517	sf_518	sf_519	sf_520	sf_521	sf_522	sf_523	sf_524	sf_525	sf_526	sf_527	sf_528	sf_529	sf_530	sf_531	sf_532	sf_533	sf_534	sf_535	sf_536	sf_537	sf_538	sf_539	sf_540	sf_541	sf_542	sf_543	sf_544	sf_545	sf_546	sf_547	sf_548	sf_549	sf_550	sf_551	sf_552	sf_553	sf_554	sf_555	sf_556	sf_557	sf_558	sf_559	sf_560	sf_561	sf_562	sf_563	sf_564	sf_565	sf_566	sf_567	sf_568	sf_569	sf_570	sf_571	sf_572	sf_573	sf_574	sf_575	sf_576	sf_577	sf_578	sf_579	sf_580	sf_581	sf_582	sf_583	sf_584	sf_585	sf_586	sf_587	sf_588	sf_589	sf_590	sf_591	sf_592	sf_593	sf_594	sf_595	sf_596	sf_597	sf_598	sf_599	sf_600	sf_601	sf_602	sf_603	sf_604	sf_605	sf_606	sf_607	sf_608	sf_609	sf_610	sf_611	sf_612	sf_613	sf_614	sf_615	sf_616	sf_617	sf_618	sf_619	sf_620	sf_621	sf_622	sf_623	sf_624	sf_625	sf_626	sf_627	sf_628	sf_629	sf_630	sf_631	sf_632	sf_633	sf_634	sf_635	sf_636	sf_637	sf_638	sf_639	sf_640	sf_641	sf_642	sf_643	sf_644	sf_645	sf_646	sf_647	sf_648	sf_649	sf_650	sf_651	sf_652	sf_653	sf_654	sf_655	sf_656	sf_657	sf_658	sf_659	sf_660	sf_661	sf_662	sf_663	sf_664	sf_665	sf_666	sf_667	sf_668	sf_669	sf_670	sf_671	sf_672	sf_673	sf_674	sf_675	sf_676	sf_677	sf_678	sf_679	sf_680	sf_681	sf_682	sf_683	sf_684	sf_685	sf_686	sf_687	sf_688	sf_689	sf_690	sf_691	sf_692	sf_693	sf_694	sf_695	sf_696	sf_697	sf_698	sf_699	sf_700	sf_701	sf_702	sf_703	sf_704	sf_705	sf_706	sf_707	sf_708	sf_709	sf_710	sf_711	sf_712	sf_713	sf_714	sf_715	sf_716	sf_717	sf_718	sf_719	sf_720	sf_721	sf_722	sf_723	sf_724	sf_725	sf_726	sf_727	sf_728	sf_729	sf_730	sf_731	sf_732	sf_733	sf_734	sf_735	sf_736	sf_737	sf_738	sf_739	sf_740	sf_741	sf_742	sf_743	sf_744	sf_745	sf_746	sf_747	sf_748	sf_749	sf_750	sf_751	sf_752	sf_753	sf_754	sf_755	sf_756	sf_757	sf_758	sf_759	sf_760	sf_761	sf_762	sf_763	sf_764	sf_765	sf_766	sf_767	sf_768	sf_769	sf_770	sf_771	sf_772	sf_773	sf_774	sf_775	sf_776	sf_777	sf_778	sf_779	sf_780	sf_781	sf_782	sf_783	sf_784	sf_785	sf_786	sf_787	sf_788	sf_789	sf_790	sf_791	sf_792	sf_793	sf_794	sf_795	sf_796	sf_797	sf_798	sf_799	sf_800	sf_801	sf_802	sf_803	sf_804	sf_805	sf_806	sf_807	sf_808	sf_809	sf_810	sf_811	sf_812	sf_813	sf_814	sf_815	sf_816	sf_817	sf_818	sf_819	sf_820	sf_821	sf_822	sf_823	sf_824	sf_825	sf_826	sf_827	sf_828	sf_829	sf_830	sf_831	sf_832	sf_833	sf_834	sf_835	sf_836	sf_837	sf_838	sf_839	sf_840	sf_841	sf_842	sf_843	sf_844	sf_845	sf_846	sf_847	sf_848	sf_849	sf_850	sf_851	sf_852	sf_853	sf_854	sf_855	sf_856	sf_857	sf_858	sf_859	sf_860	sf_861	sf_862	sf_863	sf_864	sf_865	sf_866	sf_867	sf_868	sf_869	sf_870	sf_871	sf_872	sf_873	sf_874	sf_875	sf_876	sf_877	sf_878	sf_879	sf_880	sf_881	sf_882	sf_883	sf_884	sf_885	sf_886	sf_887	sf_888	sf_889	sf_890	sf_891	sf_892	sf_893	sf_894	sf_895	sf_896	sf_897	sf_898	sf_899	sf_900	sf_901	sf_902	sf_903	sf_904	sf_905	sf_906	sf_907	sf_908	sf_909	sf_910	sf_911	sf_912	sf_913	sf_914	sf_915	sf_916	sf_917	sf_918	sf_919	sf_920	sf_921	sf_922	sf_923	sf_924	sf_925	sf_926	sf_927	sf_928	sf_929	sf_930	sf_931	sf_932	sf_933	sf_934	sf_935	sf_936	sf_937	sf_938	sf_939	sf_940	sf_941	sf_942	sf_943	sf_944	sf_945	sf_946	sf_947	sf_948	sf_949	sf_950	sf_951	sf_952	sf_953	sf_954	sf_955	sf_956	sf_957	sf_958	sf_959	sf_960	sf_961	sf_962	sf_963	sf_964	sf_965	sf_966	sf_967	sf_968	sf_969	sf_970	sf_971	sf_972	sf_973	sf_974	sf_975	sf_976	sf_977	sf_978	sf_979	sf_980	sf_981	sf_982	sf_983	sf_984	sf_985	sf_986	sf_987	sf_988	sf_989	sf_990	sf_991	sf_992	sf_993	sf_994	sf_995	sf_996	sf_997	sf_998	sf_999	sf_1000
Test	Output	Spec	Weight	Pass/Fail	Min	Max	ff_0	ff_1	ff_2	fs_0	fs_1	fs_2	sf_0	sf_1	sf_2	sf_3	sf_4	sf_5	sf_6	sf_7	sf_8	sf_9	sf_10	sf_11	sf_12	sf_13	sf_14	sf_15	sf_16	sf_17	sf_18	sf_19	sf_20	sf_21	sf_22	sf_23	sf_24	sf_25	sf_26	sf_27	sf_28	sf_29	sf_30	sf_31	sf_32	sf_33	sf_34	sf_35	sf_36	sf_37	sf_38	sf_39	sf_40	sf_41	sf_42	sf_43	sf_44	sf_45	sf_46	sf_47	sf_48	sf_49	sf_50	sf_51	sf_52	sf_53	sf_54	sf_55	sf_56	sf_57	sf_58	sf_59	sf_60	sf_61	sf_62	sf_63	sf_64	sf_65	sf_66	sf_67	sf_68	sf_69	sf_70	sf_71	sf_72	sf_73	sf_74	sf_75	sf_76	sf_77	sf_78	sf_79	sf_80	sf_81	sf_82	sf_83	sf_84	sf_85	sf_86	sf_87	sf_88	sf_89	sf_90	sf_91	sf_92	sf_93	sf_94	sf_95	sf_96	sf_97	sf_98	sf_99	sf_100																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																				

Startup Circuitry

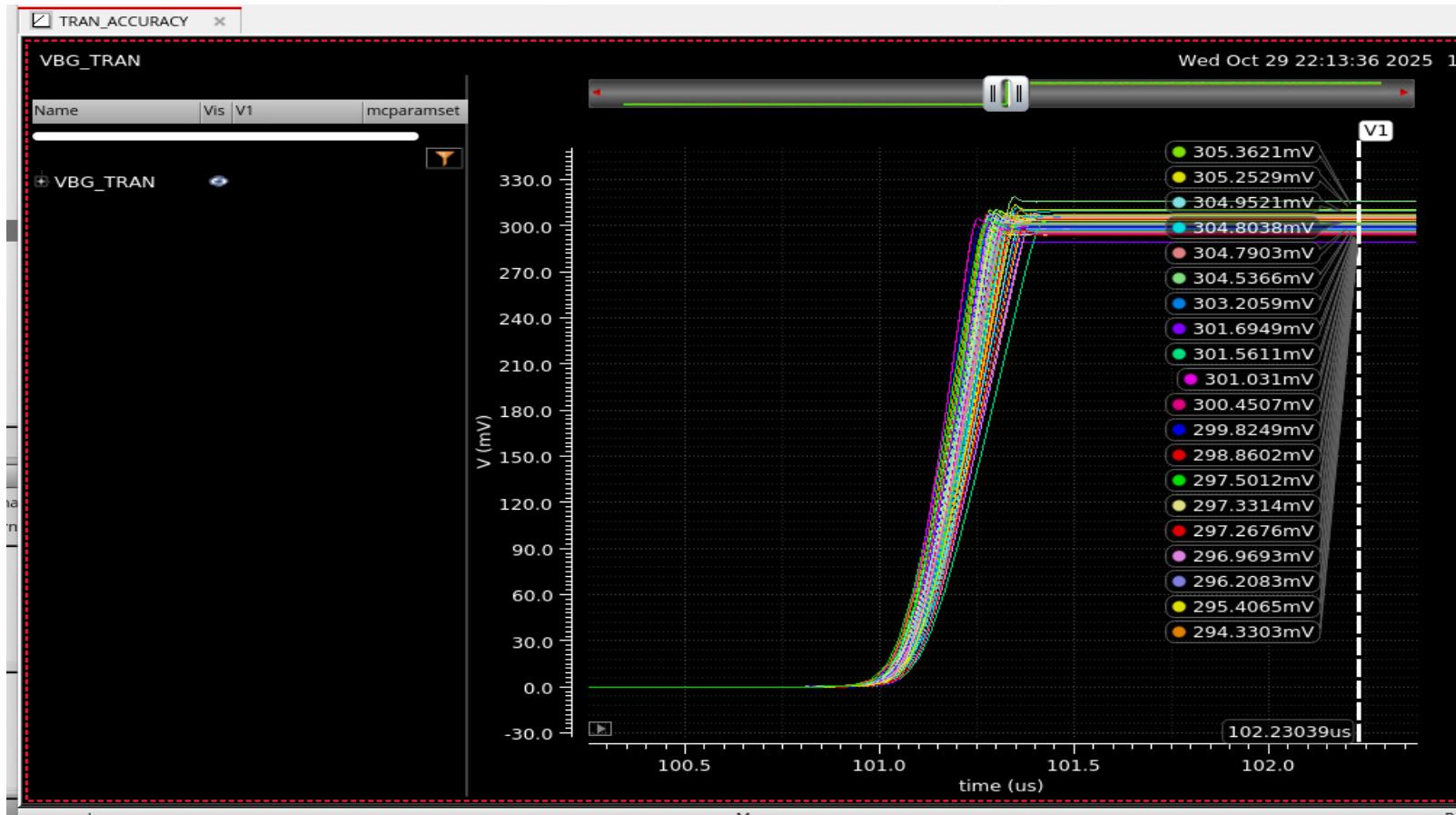


Operation :

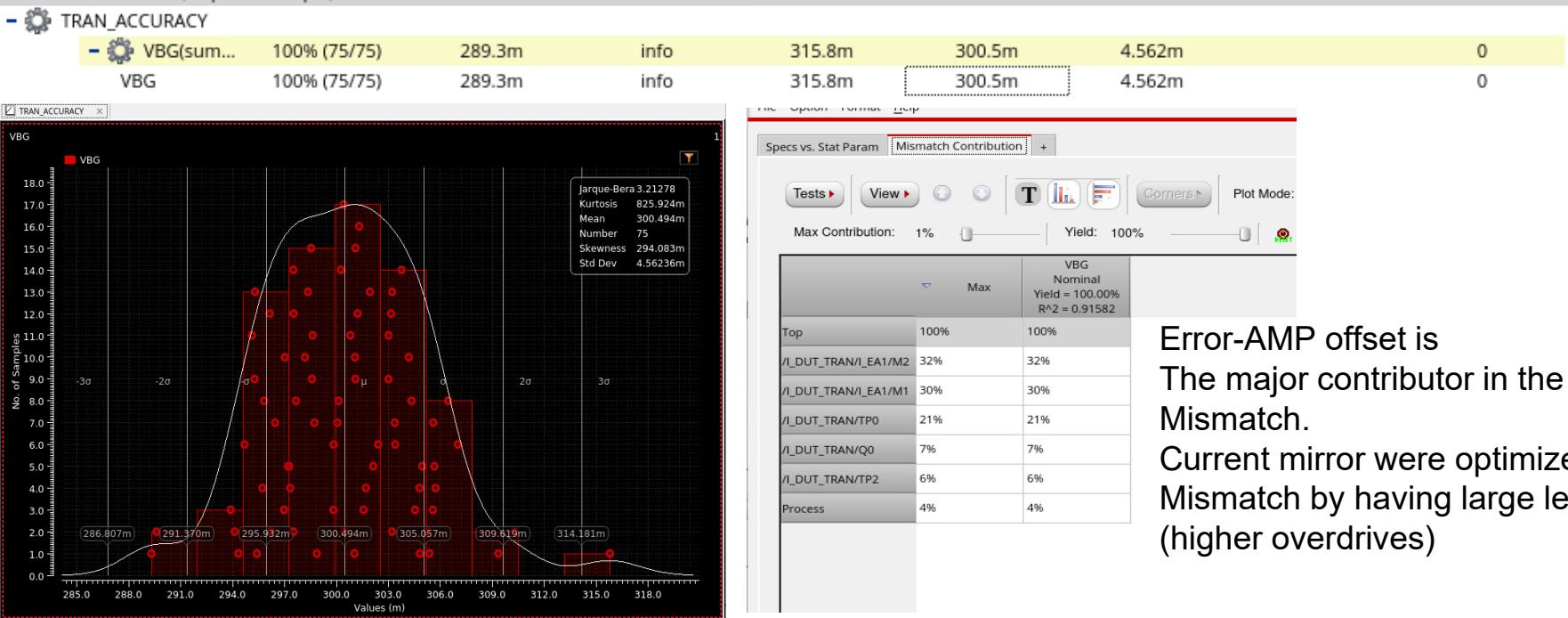
So if the startup device was not there than Vx& Vy can just stay at zero with Vp : VDD

Now due to inclusion of this device, it will perturb the node Vx,Vy during the startup and during the steady state it won't be drawing any current so won't be disturbing the normal operation.

StartUP Sims (1M Ramp Rate at the Supply)



Monte Carlo Sim



SCM

	SPEC	Simulation
DC Accuracy	< 1% across temperature	@nominal 302uV Slide 7
PSRR DC	>40dB	Min PSRR achieved : 41.89 dB (across PVT) Slide 15
Power Consumption	<1mW	0.58mW Slide 9
Sigma (@27)	5mV	4.5mV Slide 21