Low-Voltage Op-amp Design and Simulation Using C5 500nm Process

Cody McDonald EE420 Semester Project 5/8/2019

Design Specifications:

The goal of this design was to create an op-amp that using ON Semiconductor's C5 500nm process. The design would also need to operate with a minimum VDD of 2V while being able to drive a max 100pF and minimum 1K-Ohm loads. The additional parameters that needed to be fulfilled were the following:

- A DC open-loop gain greater than 66 dB under all load and VDD condition.
- A Gain-bandwidth product larger than 1 MHz
- A common mode rejection ratio (CMRR) greater than 90 dB at 100 kHz
- A power supply rejection ration greater than 90 dB at 100 kHz.
- A slew-rate with maximum load greater than 1V/microsecond.

MOSFET Characterization:

A vital aspect of this design is being able to correctly size the bodies of the transistors that we will be using in the start-up, beta-multiplier reference, diff-amp, and amplifier circuits.

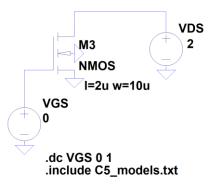
The threshold voltage for the NMOS and PMOS will be determined graphically by plotting the drain current versus V_{GS} and V_{SG} .

BSIM3 models for AMI Semiconductor's C5 process * Don't forget the .options scale=300nm if using drawn lengths and the MOSIS SUBM design rules

* 2<Ldrawn<500 10<Wdrawn<10000 Vdd=5V * Note minimum L is 0.6 um while minimum W is 3 u

		NMOS (LEVEL		8
+VERSION			TNOM		27	TOX		1.39E-8
+X3		1.5E-7	NCH		1.7E17	VTHØ		0.6696061
+K1		0.8351612	K2		-0.0839158	КЗ		23.1023856
+K3B		-7.6841108	MØ		1E-8	NLX		1E-9
+DVTØW		0	DVT1W	=		DVT2W		0
+DVT0		2.9047241	DVT1		0.4302695	DVT2		-0.134857
+U0		458.439679	UA		1E-13	UB		1.485499E-1
+UC		1.629939E-11	VSAT	=		AØ		0.6103537
+AGS	=		BØ	=		81		5E-6
+KETA		-2.640681E-3	A1		8.219585E-5	A2		0.3564792
+RDSW	-	1.387108E3	PRWG	-		PRWB	2	0.0363981
+WR	=		WINT		2.472348E-7	LINT		
+XL	=		XW		0	DWG		-1.287163E-
+DWB		5.306586E-8 0	VOFF		0			0.8365585
+CIT			CDSC		2.4E-4	CDSCD		
+CDSCB	=		ETAØ		0.0246738	ETAB		-1.406123E-
+DSUB		0.2543458	PCLM		2.5945188			-0.4282336
		2.311743E-3			-0.0272914	DROUT		0.7283566
+PSCBE1		5.598623E8	PSCBE2		5.461645E-5	PVAG		0
+DELTA		0.01	RSH		81.8	MOBMOD		1
+PRT		8.621	UTE		-1	KT1		-0.2501
+KT1L		-2.58E-9	KT2		0	UA1		5.4E-10
+UB1		-4.8E-19	UC1		-7.5E-11	AT		165
+WL	=		WLN		1	WW		0
+WWN	-		WWL		0	LL		0
+LLN	=		LW		0	LWN	=	
+LWL	=		CAPMOD		2	XPART		0.5
+CGDO		2E-10	CGSO	=	2E-10	CGBO		1E-9
+CJ		4.197772E-4	PB		0.99	MD		0.4515044
+CJSW	=	3.242724E-10	PBSW	=	0.1	MJSW	=	0.1153991
+CJSWG	=	1.64E-10	PBSWG	=	0.1	MJSWG	=	0.1153991
+CF	-	0	PVTH0	-	0.0585501	PRDSW	-	133.285505
+PK2	-	-0.0299638	WKETA	-	-0.0248758	LKETA	-	1.173187E-3
+AF	=	1	KF	=	0)			
•								
MODEL PI	103	5 PMOS (LEVEL		8
+VERSION			TNOM		27	TOX		1.39E-8
+X3		1.5E-7	NCH	=	1.7E17	VTH0	=	-0.9214347
+K1	=	0.5553722	К2	ļ	8.763328E-3	VTHØ K3	-	-0.9214347 6.3063558
+K1 +K3B	2	0.5553722	K2 W0	-	8.763328E-3 1.280703E-8	VTH0 K3 NLX	-	-0.9214347 6.3063558 2.593997E-8
+K1 +K3B +DVT0W	-	0.5553722 -0.6487362 0	K2 WØ DVT1W	-	8.763328E-3 1.280703E-8 0	VTHØ K3 NLX DVT2W	-	-0.9214347 6.3063558 2.593997E-8 0
+K1 +K3B +DVT0W +DVT0	-	0.5553722 -0.6487362 0 2.5131165	K2 WØ DVT1W DVT1		8.763328E-3 1.280703E-8 0 0.5480536	VTHØ K3 NLX DVT2W DVT2		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489
+K1 +K3B +DVT0W +DVT0 +U0		0.5553722 -0.6487362 0 2.5131165 212.0166131	K2 WØ DVT1W DVT1 UA		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9	VTHØ K3 NLX DVT2W DVT2 UB		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21
+K1 +K3B +DVT0W +DVT0 +U0 +UC		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11	K2 WØ DVT1W DVT1 UA VSAT		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5	VTHØ K3 NLX DVT2W DVT2 UB AØ		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21 0.8430019
+K1 +K3B +DVTØW +DVTØ +UØ +UC +AGS		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608	K2 W0 DVT1W DVT1 UA VSAT B0		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7	VTHØ K3 NLX DVT2W DVT2 UB AØ B1		-0.9214347 6.3063558 2.593997E-8 0 -0.1186489 1E-21 0.8430019 5E-6
+K1 +K3B +DVTØW +DVTØ +UØ +UC +AGS +KETA		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3	K2 W0 DVT1W DVT1 UA VSAT B0 A1		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21 0.8430019
+K1 +K3B +DVT0W +DVT0 +U0 +UC +AGS +KETA +RDSW		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3	K2 WØ DVT1W DVT1 UA VSAT BØ A1 PRWG		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E
+K1 +K3B +DVTØW +DVTØ +UØ +UC +AGS +KETA +RDSW +WR		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3	K2 W0 DVT1W DVT1 UA VSAT B0 A1		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E
+K1 +K3B +DVT0W +DVT0 +U0 +U0 +AGS +KETA +RDSW +NR +NR +XL		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.13226608 -3.674859E-3 2.837206E3 1 0	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRNG WINT XW		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-4 -1.606385E
+K1 +K3B +DVT0W +DVT0 +U0 +UC +AGS +KETA +RDSW +NR +XL +DWB		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3 1	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG NFACTOR		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-4
+K1 +K3B +DVT0W +DVT0 +U0 +UC +AGS +KETA +RDSW +NR +XL +XL +DWB		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3 1 0 2.266386E-8	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRNG WINT XW		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG		-0.9214347 6.3063558 2.593997E-4 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-4 -1.606385E
+K1 +K3B +DVT0W +DVT0 +U0 +UC +AGS +KETA +RDSW +WR +XL +DWB +CIT		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3 1 0 2.266386E-8 0	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG NFACTOR		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 1.606385E 0.9342488
+K1 +K3B +DVT0W +DVT0 +UC +AGS +KETA +RDSW +WR +XL +DWB +CIT +CDSCB		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E:11 0.1328608 -3.674859E-3 2.837206E3 1 0 2.266386E-8 0	K2 W0 DVT1W UA VSAT B0 A1 PRNG WINT XW VOFF CDSC		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512 2.4E-4	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 -1.606385E 0.9342488 0
+K1 +K3B +DVTØW +DVTØ +UØ +UC +AGS +KETA		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.837206E3 1 0 2.266386E-8 0 0	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512 2.4E-4 0.3251882	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 1.606385E 0.9342488 0 -0.0580325
+K1 +K38 +DVT0W +UVT0 +U0 +UC +AGS +KETA +RDSW +KETA +RDSW +VR +XL +DWB +CIT +CDSCB +DSUB +DSUB +PDIBLC2		0.5553722 0.6487362 0.2.5131165 212.0166131 -5.82128E-11 0.13226608 -3.674859E-3 180 2.266386E-8 0 1 3.355575E-3	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.838038E-7 0 -0.0558512 2.4E-4 0.3251802 2.2409567 -0.0551797	VTHØ K3 NLX DVT2W DVT2 UB AØ B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB PDIBLC1		-0.9214347 6.3663558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 -1.666385E 0.9342488 0 -0.9580325 0.6411445
+K1 +K3B +DVT0W +DVT0 +U0 +U0 +U0 +UC +AGS +KETA +RDSW +WR +KE +CIT +CDSCB +DSUB +PDIBLC2 +PSCBE1		0.5553722 0.6487362 0.2.5131165 212.0166131 -5.82128E-11 0.13226608 -3.674859E-3 180 2.266386E-8 0 1 3.355575E-3	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PDIBLCB		8.763328E-3 1.280703E-8 0 0.5486536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.4838038E-7 0 -0.8558512 2.4E-4 0.3251862 2.2404567 -0.30848E-10	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB B1 LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DROUT		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 -1.606385E 0.9342488 0 -0.0580325 0.0411445 0.2036901
+K1 +K3B +DVT0W +DVT0 +U0 +UC +AGS +KETA +RDSW +NR +KK +NR +CT +CDSCB +DSUB +PDIBLC2 +PSCBE1 +DELTA		0.555722 +0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1326068 -3.674859E-3 2.266386E-8 0 2.266386E-8 0 0 3.355575E-3 6.44809E9	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PDIBLCB PSCBE2		8.763328E-3 1.280703E-8 0 0.5486536 2.807115E-9 1.713601E5 7.117912E-7 4.77502E-5 -0.0363908 2.4838038E-7 0 -0.8558512 2.4E-4 0.3251862 2.2404567 -0.30848E-10	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG ETA8 PDIBLC1 DR0UT PVAG		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 -1.606385E 0.9342488 0 -0.9580325 0.0411445 0.2036901 0
+K1 +K3B +DVTØW +DVTØ +U0 +UC +AGS +KETA +RDSW +NR +XL +DWB +CIT +CDSCB +DSUB		0.5553722 -0.6487362 0.5131165 212.0166131 -5.82128E-11 0.1326066 -3.674859E-3 2.837206E3 1 0 2.266386E-8 0 1 1.3355575E-3 6.44809E9 0.01	K2 W0 DVT1W UVT1 VSAT B0 A1 PRWG WINT XW VOFF CDSC CDSC CDSC ETA0 PCLM PDIBLCB PSCBE2 RSH		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.71360125 7.117912E-7 4.77502E-5 -0.8363908 2.830038E-7 0 0.3551802 2.4E-4 0.4551797 6.300848E-10 181.6	VTH0 K3 NLX DVT2W DVT2 WB A0 B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DROUT PVAG MOBMOD		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E 5.528807E-1 -1.606385E 0.9342488 0 -0.0580325 0.0411445 0.2036901 0 1
+K1 +K3B +DVT0 +DVT0 +DVT0 +UC +AGS +KETA +RDSW +WR +XL +DWB +CIT +CDSCB +DSUB +PDIBLC2 +PSCBE1 +DELTA +PRTA		0.5553722 -0.6487362 0.25131165 212.0166131 -5.82128E-11 0.1328608 -3.674859E-3 2.2632668 0 1 3.355575E-3 6.44809E9 0.01	K2 WØ DVT1W DVT1 WA VSAT BØ A1 PRWG WINT XW VOFF CDSC ETAØ PCLM PDIBLCB PSCBE2 RSH UTE KT2		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.71360155 7.117912E-7 4.77502E-5 -0.03535087 2.830038E-7 0.0555512 2.4E-4 0.3251882 2.249567 -0.63551797 6.300948E-10 101.6	VTH0 K3 NLX DVT2W DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG PRWB LINT DWG CDSCD ETAB PDIBLC1 DROUT PVAG MOBMOD KT1		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E- 5.528807E-1 -1.606385E- 0.93424488 0 -0.9580325 0.0411445 0.2036901 0 1 -0.2942
+K1 +K3B +DVT0W +DVT0W +DVT0 +U0 +AGS +KETA +AGS +KETA +MR +WR +WR +WR +WR +WB +DWB +CIS +DSUB +PDIBLC2 +PSCBE1 +DPLTA +PRT +FTL +VB1		0.5553722 -0.6487362 0.25131165 212.0166131 -0.582128-111 0.1328608 -3.674859E-3 2.83720663 1 0 2.266386E-8 0 1 3.355575E-3 6.44809E9 0.01 1.68E-9 -6.3E-18	K2 W0 DVT1W DVT1 VSAT B0 A1 PRNG WINT XW VOFF CDSC ETA0 PSCLM PDIBLCB PSCBE2 RSH UTE KT2 UC1		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 4.77501E-7 4.77501E-7 4.77501E-7 -0.0363908 2.830038E-7 0.055512 2.4E-4 0.3251882 2.2409567 -0.0551797 6.3000448-10 101.6 -1 0 -1 E-10	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A0 B1 LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DROUT PVAG MOBMOD KT1 UA1 AT		-0.9214347 6.3063558 2.593997E-1 0 0.8430019 5E-6 0.8430019 5E-6 0.3 -1.016722E- 5.528807E-1 1.606385E- 0.9342488 0 -0.0580325 0.0411445 0.2036901 0 1 -0.2942 4.5E-9
+K1 +K3B +K3B +DVT0W +DVT0W +U0 +U0 +KETA +RDSW +WR +KETA +RDSW +HR +CDSCB +DSUB +PDIBLC2 +PSCBE1 +DELTA +PSCBE1 +FRT +KT1L +UB1 +HL		0.555722 0.6487362 0.25131165 212.0166131 212.0166131 212.0166131 212.0166131 2.3674859E-3 2.837206E3 0 2.266386E-8 0 0 1 3.355575E-3 6.44809E9 0.01 59.494 1.68E-9 -6.3E-18 0 0	K2 W0 DVT1W DVT1W UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PDIBLCB PSCBE2 RSH PDIBLCB RSH VTE KT2 UTE KT2 UC1 WLN		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 4.77501E-5 4.77501E-5 4.75501E-5 2.830638E-7 0.0363908 2.830638E-7 0.0355102 2.4824 0.3251882 2.2409567 -0.0551797 6.3000448-10 101.6 -1 0 -1 E-10	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DROUT PVAG NOBHOD KT1 UA1 AT WW		-0.9214347 6.3063558 2.593997E-1 0.1186489 1E-21 0.8430019 5E-6 0.3 -1.016722E- 5.528807E-1 -1.066385E 0.9342488 0.9342488 0.9342488 0.2036901 0 1 -0.2942 4.5E-9 1E3
+K1 +K3B +K57 +UVT0 +UV +UC +AGS +KETA +AGS +KETA +K1 +VUB +DSUB +		e.SSS3722 -0.6487362 0 2.S131165 212.0166131 -5.82128E-11 0.1326008 -3.674859E-3 2.83726623 1 2.266386E-8 0 0 2.266386E-8 0 0 0 1 1.68E-9 -6.3E-18 0 0.31575E-3 0.440059 0.01 1.68E-9 -6.3E-18 0 1	K2 W0 DVT1W DVT1W DVT1 WSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PDIBLCB PSCBE2 RSH UTE KT2 UC1 WLN WWL		8.763328E-3 1.280793E-8 0 0.5480536 2.807115E-9 1.711508155 7.117912E-7 -0.0563908 2.487402E-5 -0.0563908 2.452402 2.454402000000	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG CDSCD ETAB PVAG CDSCD ETAB PVAG WOBMOD KT1 UA1 AT WW LL		-0.9214347 6.3063558 2.593997E-1 0 0.84350019 5E-6 0.84350019 5E-6 0.3 -1.016722E 5.528007E-1 -1.066385E 0.9342488 0.9344488 0.934888 0.934488 0.934488 0.9344888 0.9344888 0.9344888 0.9344888 0.9344888 0.9344888 0.9344888 0.9344888 0.934488888888888888888888888888888888888
+K1 +K3B +VVT0W +DVT0W +U0 +U0 +405 +KETA +RDSW +WR +KETA +RDSW +WR +KT +CDSCB +DSUB +OELTA +PDIBLC2 +PSCBE1 +OELTA +PBT +CLN +WB +WB +WB +WN +UN		0.5553722 -0.6487362 0 2.5131165 212.0166131 -5.82128E-11 0.1526088 -3.674559E-3 -3.674559E-3 0 0 0 0 0 0 0 0 0 0 0 0 0	K2 W0 DVT1W DVT1W UA VSAT B0 A1 PRWG WINT XW VOFF CDFC CDFC CDFC CDFC CDFC CDFC ETA0 PCLM PDIBLCB PSCBE2 RSH VTE KT2 UC1 WLN WML LW		8.763328E-3 1.280703E-8 0 0.5480536 2.807115E-9 1.711560125 7.117912E 4.0435308 2.83038E-7 0 0.0555512 2.44E-4 0.3251882 2.2409567 -0.05551797 6.300044E-10 101.6 -1 -1 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG CDSCD ETA8 PDIBLC1 DROUT PVAG MOBMOD KT1 UA1 AT WW LL LWN		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.0167222 5.528807E-1 -1.066385E 0.9342488 0.9342488 0.9342488 0.9342488 0.2365681 0 1 -0.2942 4.5E-9 1E3 0 0 1
+K1 +K3B +OVT0W +DVT0W +U0 +U0 +AGS +KETA +RDSW +RDSW +RT +RDSW +VI +OMB +CIT +CDSCB +DSUB +PDIBLC2 +PSCBE1 +DSUB +PSCBE1 +DSLC1 +RT +VBL +WN +ULW +UWL		0.555722 0.6487362 0.247362 0.247362 0.247362 212.0166131 212.0166131 212.0166131 212.0166131 212.0166131 2.25032062 0.23720663 1.222663865-8 0.01 2.2663865-8 0.01 3.3555755-3 0.4480959 0.01 1.685-9 -6.35-18 0 1. 0 0 0 1. 0 0 0 0 0 0 0 0 0 0 0 0 0	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRW6 CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDS		8.763328E-3 1.280793E-8 0 0.5480536 2.807115E-9 1.713601E5 7.117912E-7 -0.0550512 2.48740 0.3251802 2.48440 0.32518567 2.245567 2.245567 0.3051857 0.305185757 0.305185757 0.305185757 0.305185757 0.3	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG ETA8 PRWB LINT DWG CDSCO ETA8 PDIBLC1 DROUT PVAG MOBMOD KT1 UA1 AT LWN XXPART		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.016722E- 5.528007E-1 -1.066735E- 0.9342488 0.401145 0.2036901 0 -0.9580325 0 0 0 1 1 -0.9242 4.5E-9 1 1 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
+K1 +K3B +OVT0W +DVT0W +U0 +UC +AGS +KETA +RDSW +NR +RTA +RDSW +NR +CSCB +DSUB +DSUB +DSUB +PDIBLC2 +PSCBE1 +DELTA +PDIBLC2 +PSCBE1 +HUL +HANN +LLN +LWL +CGDO		0.5553722 0.6487362 0.25131165 212.0166131 212.0166131 212.0166131 212.0166131 212.0166131 2.36745395-3 1.657272663 0 2.2663865-8 0 0 1.6355755-3 6.4480959 0.01 1.635-18 1.635-18 1.635-18 1.9 2.95-10 1.9 2.95-10 1.9 2.95-10 1.9 1.9 1.9 1.9 1.9 2.95-10 1.9 1.9 1.9 1.9 1.9 1.9 1.9 1.9	K2 W0 DVT1W DVT1W DVT1 UA VSAT B0 A1 PRW6 W1NT XW VOFF CDSC CDSC CDSC CDSC ETA0 PCLM PDIBLCB PSCBE2 RSH UTE KT2 UC1 UC1 WLN UC1 LW CAPMOD CGSO		8.763328-3 1.280703-8 0 0.5408536 2.807115E-9 1.7135012E-7 1.7135012E-7 4.073634038E-7 0 -0.0555512 2.4824 0.3251882 2.2409567 -0.65551797 6.300848E-10 101.6 -1 0 2.24945 -1 0 2.24954 -1 0 -1 0 2.24954 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 0 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG PWB NFACTOR CDSCD ETAB PDIBLC1 DWG PVAG MOBMOD KT1 UA1 AT WM LL LL LWN XPART CGBD		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.066722E 5.528097E-1 -1.66638E- 0.9342488 0 0.9342488 0 0.9342488 0 0.2055081 0 1 -0.2942 4.5E-9 1E3 0 0 0 1 -0.2942 4.5E-9
+K1 +K3B +OVT0W +DVT0W +U0 +UC +AGS +KETA +RDSW +RDSW +RTA +RDSW +CISCB +DSUB +CSUB +DSUB +CSUB		0.5553722 -0.6487362 0 2.513165 212.0166131 5.5221202161 -3.6748596-3 2.83720663 1 0 2.2653866-8 0 0 3.3555756-3 6.4480959 0.01 59.494 1.688-9 -6.36-18 0 2.96-10 7.2355286-4	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 VOFF CDSC ETA0 PDIBLC8 PSCBE2 RSH UTE VC1 WLN WLN WLN WLN WLN WLN WLN WLN WLN WLN		8.763328E-3 0.548653E 2.807115E9 2.807115E9 2.807115E9 4.77928E-5 0.8363988 2.839038E-7 0.8363988 7 0.8363988 7 0.8363988 7 0.3351867 6.300848E-10 10 0.16 -1E 0 0.9527355	VTHO K3 NUX DVT2W DVT2W DVT2 UB A0 B1 A2 PRWB LINT A4 PARB DWG DWG CDSCD CDSCD CDSCD CDSCD CDSCD FTAB PDIBLC1 DROUT PVAG MOBMOD K11 LWN LL LWN XCPART CGBO MJ		-0.9214347 6.3063558 2.593997E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.016722E- 5.528087E-1 -1.06635E- 0.9342488 0 0.481145 0.2036901 0 1 -0.2942 4.5E-9 1E-3 0 0 0.5 1E-5 0 0.5 1E-5 0 0.4455293 1 0.5 1E-5 0 0.4455293 1 0.5 1E-5 0 0.4455293 1 0.5 1E-5 0 0.4455293 1 0.5 1E-5 0 0.5 1E-5 0 0.5 1E-5 0 0.5 1E-5 0 0.5 1E-5 0 0.5 1E-5 1 0.44552283 1 0.5 1E-5 1 0.44552283 1 0.5 1E-5 1 0.44552283 1 0.5 1E-5 1 0.4555283 1 0.5 1E-5 1 0.4555283 1 0.5 1E-5 1E-5 1E-5 1E-5 1E-5 1E-5 1E-5 1E-
+K1 +K3B +VT0W +DVT0W +UC +UC +AGS +RETA +RDSW +RTA +RDSW +RTA +RDSW +CSCB +VSCB +VSCB +PSCBE1 +DELTA +PSCBE1 +HUL +HAN +UB1 +HAN +LWL +CGDO +C3SW		0.5553722 0.6487362 0 0.11165 11165 112.0166131 1.581286-11 1.582663 -3.6748598-3 2.83726663 1 0 0 1 1.33555758-3 6.4480959 0 0 1 1.6826-9 6.32-18 0 1 1.6926-9 6.318 0 2.955788-4 2.9	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PCLM PDIBLCB PSCBE2 RSH UTE KT2 UC1 WLN CAPMOD CGSO PBSW		8.7633285-3 1.2807085-8 9 9 9.28071155-9 1.71360125 7.1179126-7 4.775022-5 -0.8363988 2.83083857 0.4055398 2.83083857 2.4544 0.4555122 2.464-10 101.6 0.3251802 2.249567 -0.855127 0.4551797 6.3008448-10 101.6 0 2.954-10 0 0 0.9595 0 0 0.9595 0 0 0.9595 0 0 0.9595 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DWG PVAG NOBMOD KT1 UA1 AT WW XPART CGBO MJ SW		-0.9214347 6.3063558 2.539397E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.016722E 5.528807E-1 -1.066732E -0.9542488 0.9411445 0.641145 0.641145 0.6411450.641145 0.6411450.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.6411450 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.6411450000000000000000000000000000000000
+K1 +K3B +0VT0W +DVT0W +U0 +UC +KETA +RDSW +WR +RT +KETA +RDSW +WR +VL +DVB +DSUB +PDIBLC2 +PSCBE1 +DSLTA +PSCBE1 +HL +HLN +UN +UN +UN +CJSW +CJSW		0.553722 0.6487302 0.6487302 122.01645131 5.581248-11645131 5.581248-1164531 5.581248-1164531 5.581248-1164535-3 2.28578653 1 0 0 2.2857865-3 6.4489553 1 1 1 1.5855755-3 6.4489553 1.1585-3 6.449555 2.95786-3 0.401 1 1 1.688-9 -6.38-18 0 2.95-10 7.285388-4 2.95-10 6.44-11 2.955755-3 1.688-9 1.1585-3 1.688-9 2.95-10 0.49535555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.585555-3 1.585555-3 1.5855555-3 1.5855555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.5855555-3 1.585555-3 1.585555-3 1.585555-3 1.5855555-3 1.585555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.585555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.58555555-3 1.58555555555555-3 1.5855555555555555555555555555555555555	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC CDSC PDIBLCB PSCBE2 RSH UTE LW CAPMOD CGSO PBSWG PBSWG PSS		8.763328E-3 1.280708E-8 0 2.80701E-9 1.280708E-8 0.80711E-9 1.71360125 7.117912E-7 4.77502E-5 6.03863989 7.0.8053182 2.4E-4 0.32518027 2.4E-4 0.32518027 2.4E-4 0.32518027 2.4E-4 0.32518027 2.4E-10 18E-10 2.2E-10 2.952755 0.999	VTH0 K3 NUX DVT2W DVT2 UB A0 B1 A2 PRWB LINT A4 PWB UWG VFACTOR CDSCD CDSCD CDSCD CDSCD CDSCD PVAG CDSCD PDIBLCT DROUT PVAG AT WOBMOD KT1 UA1 AT LUN XPART CGBO MJSWG MJSWG		-0.5214347 6.3063558 2.553997E-1 0 -0.1186489 1E-21 0.8439019 55-52 0.5528007E-1 0.6650355 0.9342488 0.9458392 0.2588392 0.9258392 0.2588582 0.2588582 0.2588582 0.2588582 0.2588582 0.2588582 0.25885858 0.25885858 0.25885858 0.258858 0.25885858 0.2588
+K1 +K3B +VT0W +DVT0W +UC +UC +AGS +RETA +RDSW +RTA +RDSW +RTA +RDSW +CSCB +VSCB +VSCB +PSCBE1 +DELTA +PSCBE1 +HUL +HAN +UB1 +HAN +LWL +CGDO +C3SW		0.553722 0.6487302 0.6487302 122.01645131 5.581248-11645131 5.581248-1164531 5.581248-1164531 5.581248-1164535-3 2.28578653 1 0 0 2.2857865-3 6.4489553 1 1 1 1.5855755-3 6.4489553 1.1585-3 6.449555 2.95786-3 0.401 1 1 1.688-9 -6.38-18 0 2.95-10 7.285388-4 2.95-10 6.44-11 2.955755-3 1.688-9 1.1585-3 1.688-9 2.95-10 0.49535555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.585555-3 1.585555-3 1.5855555-3 1.5855555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.585555-3 1.5855555-3 1.585555-3 1.585555-3 1.585555-3 1.5855555-3 1.585555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.585555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.5855555-3 1.58555555-3 1.58555555555555-3 1.5855555555555555555555555555555555555	K2 W0 DVT1W DVT1 UA VSAT B0 A1 PRWG WINT XW VOFF CDSC ETA0 PCLM PCLM PDIBLCB PSCBE2 RSH UTE KT2 UC1 WLN CAPMOD CGSO PBSW		8.7633285-3 1.2807085-8 9 9 9.28071155-9 1.71360125 7.1179126-7 4.775022-5 -0.8363988 2.83083857 0.4055398 2.83083857 2.4544 0.4555122 2.464-10 101.6 0.3251802 2.249567 -0.855127 0.4551797 6.3008448-10 101.6 0 2.954-10 0 0 0.9595 0 0 0.9595 0 0 0.9595 0 0 0.9595 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	VTH0 K3 NLX DVT2W DVT2 UB A0 B1 A2 PRWB LINT DWG NFACTOR CDSCD ETAB PDIBLC1 DWG PVAG NOBMOD KT1 UA1 AT WW XPART CGBO MJ SW		-0.9214347 6.3063558 2.539397E-1 0 -0.1186489 1E-21 0.8439019 5E-6 0.3 -1.016722E 5.528807E-1 -1.066732E -0.9542488 0.9411445 0.641145 0.641145 0.6411450.641145 0.6411450.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.6411450 0.6411450 0.641145 0.6411450 0.641145 0.6411450 0.6411450000000000000000000000000000000000

Figure 1:LTSpice model providing the MOSFET parameters for the op-amp



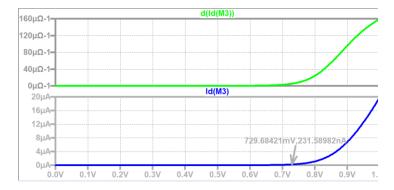
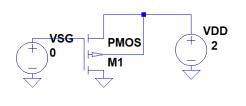


Figure 2: NMOS characterization - VGS vs ID

Sweeping V_{GS} from 0 to 1V reveals the threshold voltage to be approximately 0.73V. The derivative of the drain current is taken in the top plot plane to more easily see when the current begins to increase.



.dc VSG 2 0 .include C5_models.txt

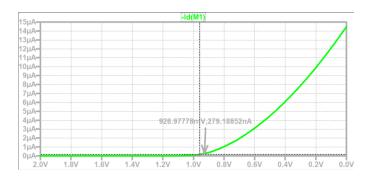


Figure 3: PMOS Characterization - V_{SG} vs I_D

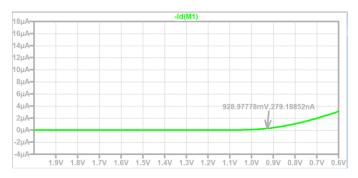


Figure 4: Zoomed view of Figure 2

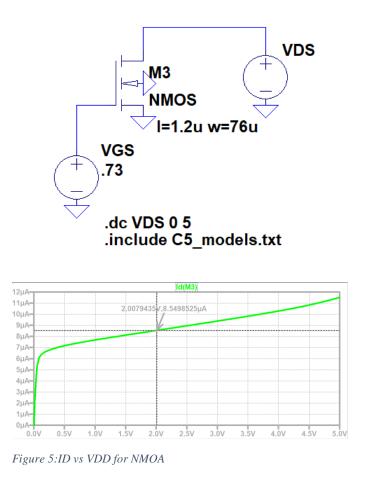
The PMOS was observed to have a threshold voltage of 0.93V.

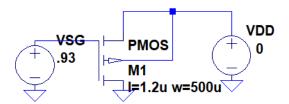
The next parameter to be found is the bias current. A low bias current will allow for a smaller overdrive voltage, which is necessary for a more resilient design.

Choosing Bias Current:

To choose the bias current I swept VDS and VSD vs VGS and determined the current at a VDD of 2V (the minimum operation voltage).

I chose a bias current of 8.5uA since a higher bias current would have resulted in a higher PMOS width length. I stopped around 8.5uA since the PMOS width appeared to be getting too large.





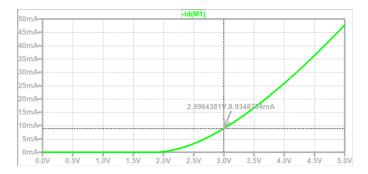


Figure 6:ID vs VDD for PMOS

Summarized Table:

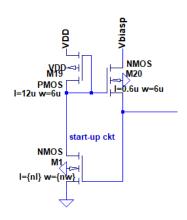
Characteristics	NMOS	PMOS
Bias Current I _D	8.5uA	8.5uA
W/L	76/1.2	500/1.2
W/L (Actual)	40/0.6	90/0.6
$V_{DS,Sat}$ and $V_{SD,Sat}$	55mV	55mV
V_{GS} and V_{SG}	785mV	875mV
V _{THN} and V _{THP}	730mV	930mV
K_{Pn} and K_{Pp}	$332uA/v^2$	$44.4uA/v^2$
Cox'	$2.4831 fF/um^2$	$2.4831 fF/um^2$
Cox_n and Cox_p	85.82fF	644fF
Cgs _n and Csg _p	31.6fF	25.9fF
Cgd_n and Cdg_p	7.9fF	25.9fF
gm_n and gm_p	227uA/V	228uA/V
lambda	0.25 v ⁻¹	0.138v ⁻¹

Table 1:MOSFET Characterization obtained from LTSpice error list of BMR Circuit

Building the Reference Circuit:

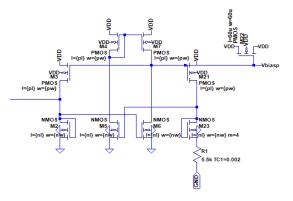
This device requires a biasing circuit to provide voltages references for the actual op-amp. The primary focus of this circuit is to ensure that the voltages and currents won't vary with changes in the power supply voltage (VDD). Alone a BMR circuit would be subject to this operation, however adding a diff-amp to the circuit would fix this problem.

Start-up circuit:



The startup circuit prevents the self-biased circuit from going into cut-off mode. Should the circuit turnoff, the circuit would have zero current flowing through it and render the design useless.

Diff-amp + BMR:



As previously stated, the Diff-amp/BMR combo prevents the current and voltage changes as a result of changes in VDD, however this design can cause instability throughout the rest of the circuit. The transistor, M22, is used to compensate for this effect.

Bias Circuit:

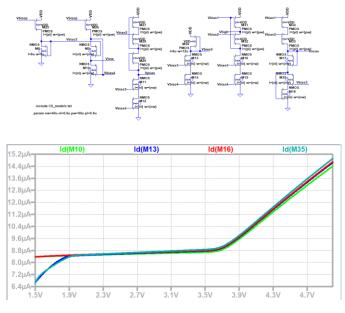


Figure 7:Bias currents through each of the branches

Sweeping VDD from 1.5V to 5V shows a stable current of 8.7uA from 1.5V to 3.7V. I assumed

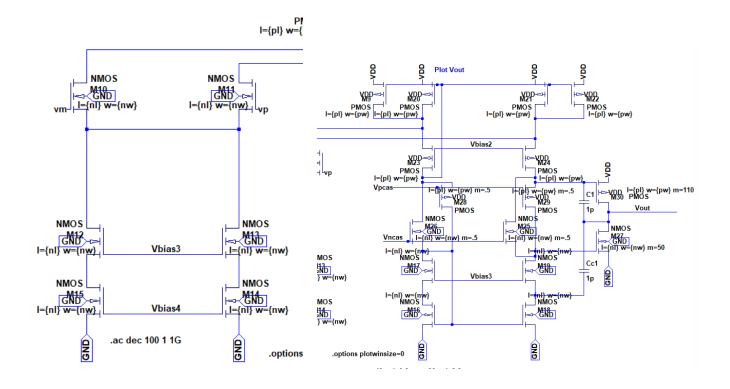
there would be instability in my circuit after I crossed 3.7V, however the op-amp appeared to operate normally.

Amplifier Design:

The amplification design of this device will utilize another Diff-Amp in conjunction with a Push-Pull amplifier.

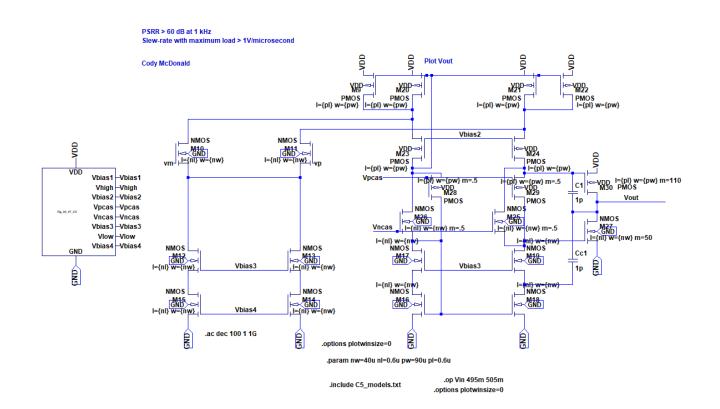
I originally selected my body sizes based on general design choices by selecting a length to be twice the times of the minimum length and choosing a width similar to body sizes calculated in Table 1. I would later change the length to the minimum length in order to obtain quicker speed. These body sizes would then be manipulated to achieve the desired specifications of the project.

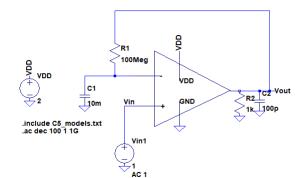
Push-pull:

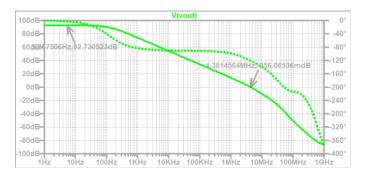


Diff-Amp:

Full Circuit:









With a full capacitive and resistive load, the DC open loop gain of this device is 92dB with a unity gain frequency of 4.3MHz, which satisfies the requirement of the gain bandwidth product over 1MHz.

Op-Amp Symbol for Circuit:

e de GND e

The is the symbol I used to represent the full circuit above including the bias circuit.

Op-Amp Performance:

DC Open Loop Gain:

The gain bandwidth product could also be calculated using the following pole splitting method:

$$f_{un} = \frac{g_{m1}}{C_c}$$

To calculate g_{m1} we must calculate the sums of the transconductances.

$$g_{m1} = g_{mn} + g_{mp} = 227 \frac{\mu A}{\nu} + 228 \frac{\mu A}{\nu} = 455 \frac{\mu A}{\nu}$$

Substituting this back into the unity frequency equation I get:

$$f_{un} = 4.55MHz$$

Step Response:

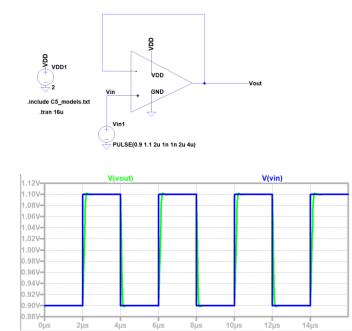


Figure 9: Step Response

The step response is a great indicator of the stability of the device and how it will operate given an input signal. This was tested by inputting a pulsed wave to resemble a step response into the op-amp. A high amount of overshoot means the device is rather unstable. I was able to correct this by decreasing the gain of the device. This was greatly influenced by adjusting the width multipliers in transistors M27 and M30.

Output Swing:

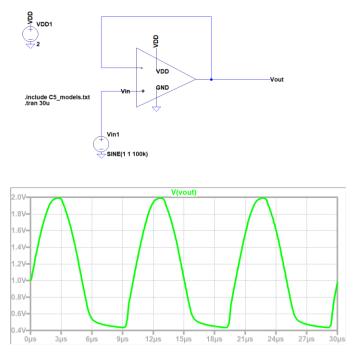
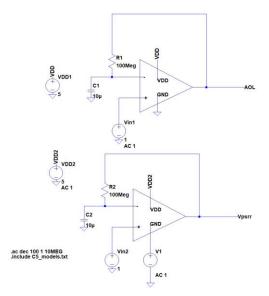


Figure 10: Output Swing

The output swing of the device extended from 0.42V to 2V. The upward swing of the output extended to 2V, which was the goal however the down swing of the signal didn't fully approach 0V.

Power Supply Rejection Ratio (PSRR):



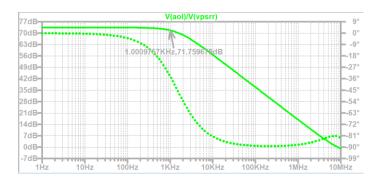


Figure 11:PSSR

The power supply rejection ratio comfortably fits within the design parameters as it measures out at 71.2dB at a frequency of 1KHz, which fits into the specification of 60dB at 1KHz. The PSRR was also tested at a VDD of 2v where I obtained a PSRR of 66.0dB

Common Mode Rejection Ratio:



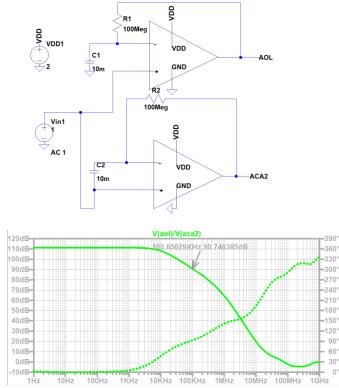


Figure 12: CMRR

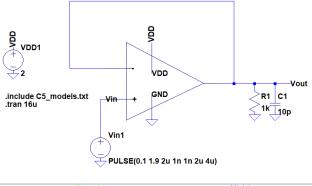
The CMRR of the device was able to meet specification of this design as the frequency response shows 90.7dB at 100KHz.

The CMRR can be calculated from the equation

$$CMRR = 20\log(\frac{A_{OL}(f)}{Ac*A_2})$$

Therefore, the CMRR can be increased by increasing the open-loop gain. This would become a challenge as I would have to choose between increasing gain in exchange for decreased device speed, which would affect the slew-rate.

Slew Rate:



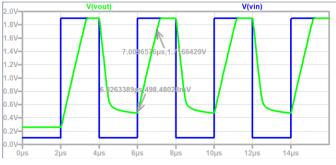


Figure 13:Slew Rate

The slew-rate is a good indicator of how quickly our device operates or responds to an input. Here I was able to calculate the slew-rate to be $1.71V - 498mV \rightarrow 1.282 \frac{V}{\mu S}$, which completes the requirement of a slew-rate being at 1V per microsecond. This parameter was slightly challenging as I needed to sacrifice gain in exchange for higher speed. However, after testing many different parameters, I found that changing the overall lengths of the MOSFETS to 0.6um greatly increased the speed.

Input CMR As A function of V_{DD}

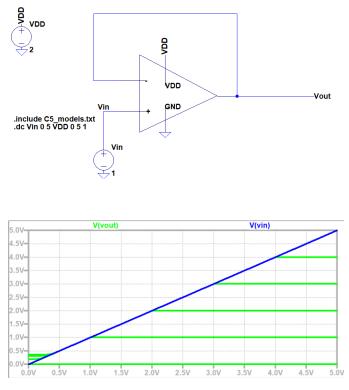
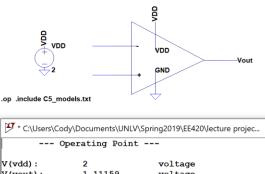


Figure 14: Vout vs incrementing VDD

Power Consumption:



V (vdd) :	2	voltage	
V(vout):	1.11159	voltage	
V(n001):	0	voltage	
V(n002):	0	voltage	
I (Vdd) :	-0.000627072	device_current	

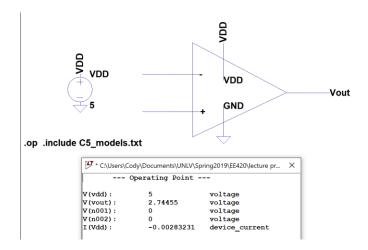
 \times

The quiescent current draw of the device is 0.62mA, so the power consumption would be:

Power = 0.62mA * 2v = 1.24mW

The overall power consumption would be 1.24mW

At a higher VDD of 5V I obtained the following:



The current draw at this VDD was 2.83mA, so the quiescent power consumption would be

Power = 2.83mA * 5v = 6.2mW

Temperature Testing:



This device's gain decreases with increases in temperature.

Summarized Data Table:

Specifications	2v	5v
Open-Loop Gain	92.6dB	90.4dB
Gain Bandwidth Product	4.38MHz	7.68MHz
Slew-Rate	1.282 v/uS	4.28v/uS
CMRR at 100KHz	90.7dB	84.3dB
PSRR at 1KHz	66.0dB	71.2dB
Quiescent Power Consumption	1.24mW	6.2mW

Output Swing	0.42v to 2v
VDD Operating Range	2v to 5v
Input CMR	-785mV to VDD + 685mV