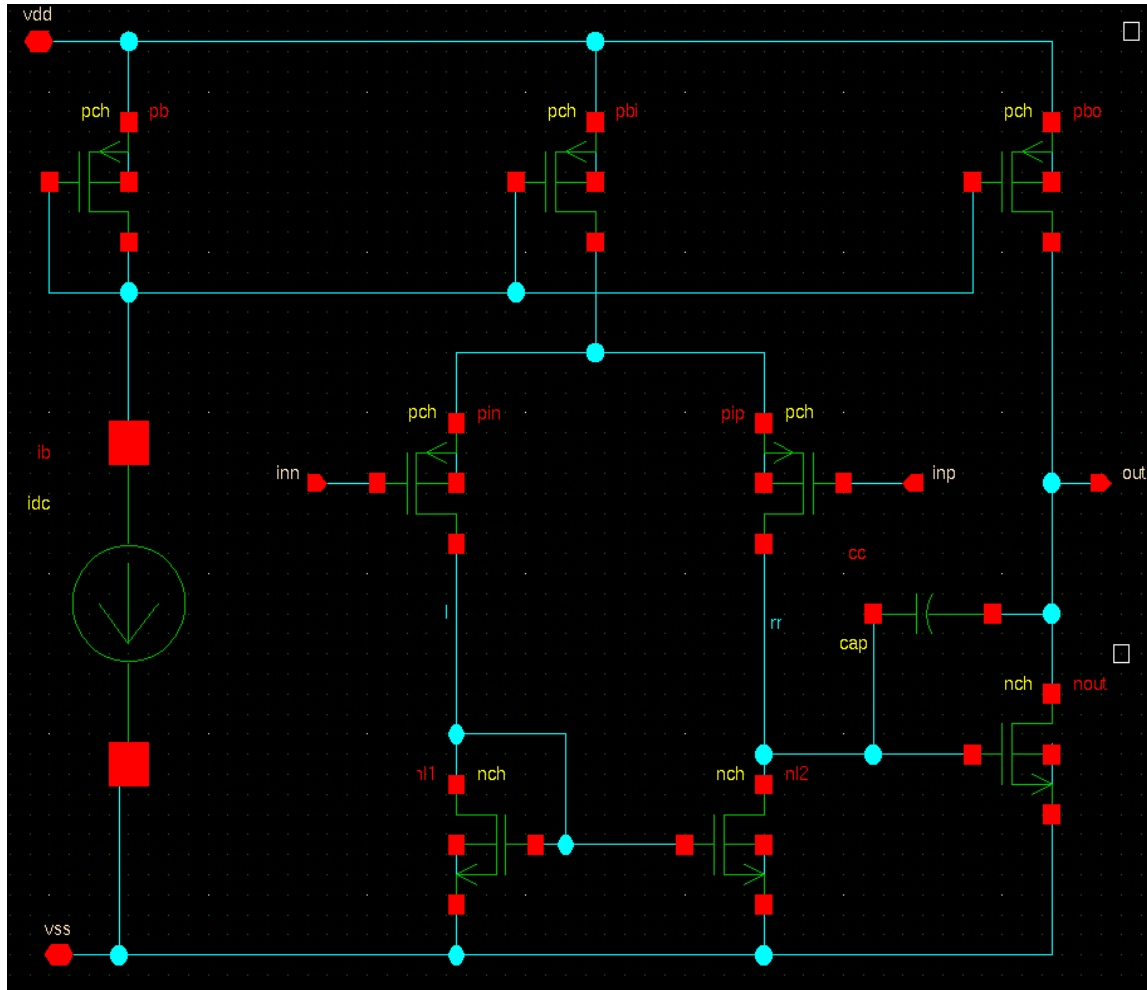


# Optimisation of a 2 stage Op-Amp Using Motivated

- Op-amp circuits commonly used across all analogue electronics, in particular for active filters.
- Circuits are re-used and re-targeted for different applications or moved to a new technology node, requiring tweaking of output parameters and performance which is time consuming and repetitive
- How do parametric changes affect the circuit performance? What is the envelope of operation? How are conflicting performance objectives determined?
- Ideal target for MOTIVATED multi-objective automated optimisation process

# Example Op\_amp schematic and netlist



```
.subckt amp2 inp inn out vdd vss
+ ib=10u mpb=1 mpbi=4 mpbo=8 mdiff=6 mnload=1 mnout=10 $ "architecture"
+ wpb=10u lpb=1u wpin=20u lpin=1u wnl=10u lnl=4u wout=40u lout=1u ccv=2p

ib ibias vss dc=ib
xpb ibias ibias vdd vdd pch w=wpb l=lpb m=mpb
xpbi com ibias vdd vdd pch w=wpb l=lpb m=mpbi
xpbo out ibias vdd vdd pch w=wpb l=lpb m=mpbo

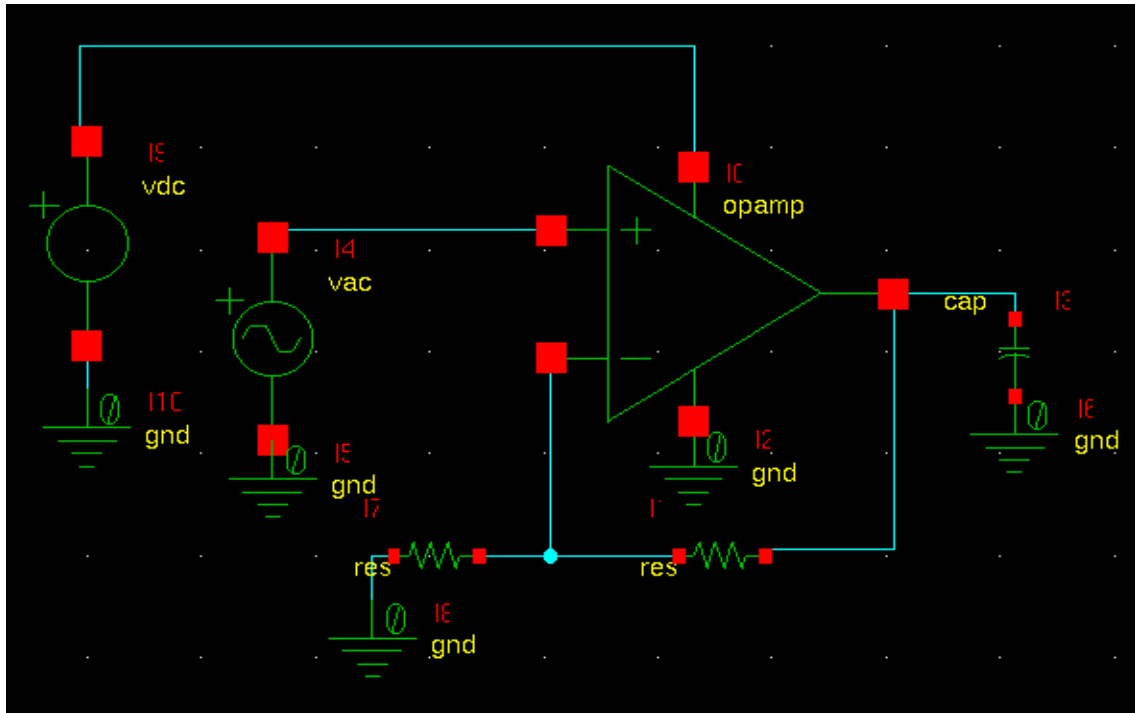
xpin ll inn com com pch w=wpin l=lpin m=mdiff
xpip rr inp com com pch w=wpin l=lpin m=mdiff

xn11 ll ll vss vss nch w=wnl l=lnl m=mnload
xn12 rr ll vss vss nch w=wnl l=lnl m=mnload

xnout out rr vss vss nch w=wout l=lout m=mnout
cc out rr ccv
.ends
```

Note: fully parametrised netlist.

# Test bench set up



Includes “objective” measurement/calculations for the optimisation. For this example simply looking at gain, bandwidth & phase

```
.lib './models.sp' ttt
.inc amp2.sp

.inc 'genes_def_set.sp'
*.param wpb=10u lpb=4u wpin=20u lpin=4u wnl=10u lnl=4u wout=40u lout=4u ccv=2p ib=1

xa inp inn out vdd gnd amp2
+ ib=10u mpb=mpb mpbi=mpbi mpbo=mpbo mdiff=mdiff mnload=mnload mnout=mnout
+ wpb=wpb lpb=lpb wpin=wpin lpin=lpin wnl=wnl lnl=lnl wout=wout lout=lout ccv=ccv

.param sup=2.5 rshort=0.1 ropen=1e9 cload=1p
**
rfb inn out r=rshort ac=ropen
rin inn gnd r=ropen ac=rshort

vacin inp gnd dc='sup/2.0' ac=1

cl out gnd c=clload

vsup vdd gnd dc=sup

.control
ac dec 50 1 1e8
source satM.sp
let Gmag=20*log10(mag(out))
let Gph=phase(out)*180/PI
plot Gmag Gph xlog xlabel 'Frequency [Hz]' ylabel 'Mag [dB, deg]'

**measurements
let gdc_obj=Gmag[0]
let gmag3=gdc_obj-3
print gdc_obj
meas ac bw3_obj when Gmag=gmag3
meas ac bw0_obj when Gmag=0
meas ac ph0_obj find Gph at=bw0_obj

.endc
```

# “Genes” file to specify design variables (optimisation parameters)

Define design variables (optimisation parameters), initial values, limits and steps

Place-holders for optimisation parameters values

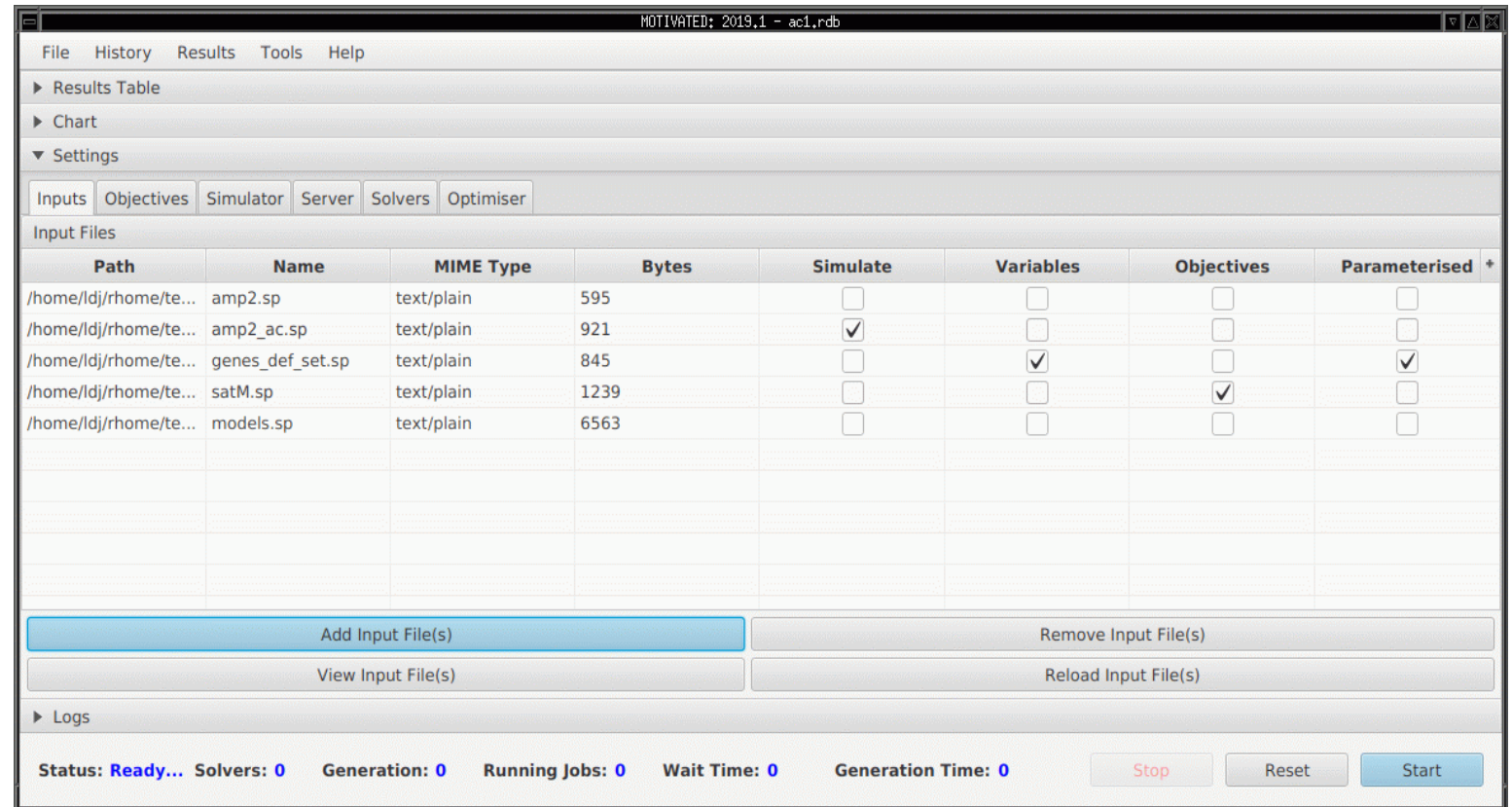
```
* &GENE: 0, 24e-6, 1e-6, 100e-6, 1e-6 $ wpb
* &GENE: 1, 6e-6, 0.4e-6, 20e-6, 0.05e-6 $ lpb
* &GENE: 2, 32e-6, 1e-6, 100e-6, 1e-6 $ wpin
* &GENE: 3, 6e-6, 0.4e-6, 20e-6, 0.05e-6 $ lpin
* &GENE: 4, 24e-6, 1e-6, 100e-6, 1e-6 $ wnl
* &GENE: 5, 6e-6, 0.4e-6, 20e-6, 0.05e-6 $ lnl
* &GENE: 6, 48e-6, 1e-6, 100e-6, 1e-6 $ wout
* &GENE: 7, 6e-6, 0.4e-6, 20e-6, 0.05e-6 $ lout
* &GENE: 8, 2e-12, 0.1e-12, 100e-12, 0.5e-12 $ ccv
* &GENE: 9, 1, 1, 20, 1 $ mpb
* &GENE: 10, 4, 1, 20, 1 $ mpbi
* &GENE: 11, 16, 1, 20, 1 $ mpbo
* &GENE: 12, 6, 1, 20, 1 $ mdiff
* &GENE: 13, 1, 1, 20, 1 $ mnload
* &GENE: 14, 10, 1, 20, 1 $ mnout

.param wpb=&0
.param lpb=&1
.param wpin=&2
.param lpin=&3
.param wnl=&4
.param lnl=&5
.param wout=&6
.param lout=&7
.param ccv=&8
.param mpb=&9
.param mpbi=&10
.param mpbo=&11
.param mdiff=&12
.param mnload=&13
.param mnout=&14
```

# MOTIVATED GUI Settings: Inputs

Add in the target circuit, test bench, model files, “genes” file.  
Can be fully hierarchical.

Select which are simulated,  
which have the parameters &  
objectives



# MOTIVATED GUI Settings: Objectives

Objectives are automatically picked up by the Optimiser.

Select which are to be optimised and if they are maximised, minimised or have any constraints

Once set, the Optimiser is started, using a simulation engine of choice

ID	Key Name	Type	Optimise	Maximise	Constraint	Value
0	gdc_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	NONE	
1	bw3_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	NONE	
2	bw0_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	NONE	
3	ph0_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	BETWEEN	-120.0,60.0
4	satM_xpbi_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	MORE_THAN	0.15
5	satM_xpbo_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	MORE_THAN	0.15
6	satM_xpin_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	MORE_THAN	0.15
7	satM_xpip_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	MORE_THAN	0.15
8	satM_xnout_obj	KEY_VALUE	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	MORE_THAN	0.15

# MOTIVATED GUI – Optimisation process results

As the Optimiser progresses, the results of each “objective” are put in a table and marked against a reference (initial / typical performance) – green highlights an improvement

As the number of generations increases, the optimiser selects the “fittest” out of the population to move on to the next generation

Once all generations are complete, the table displays the best objectives of the final generation

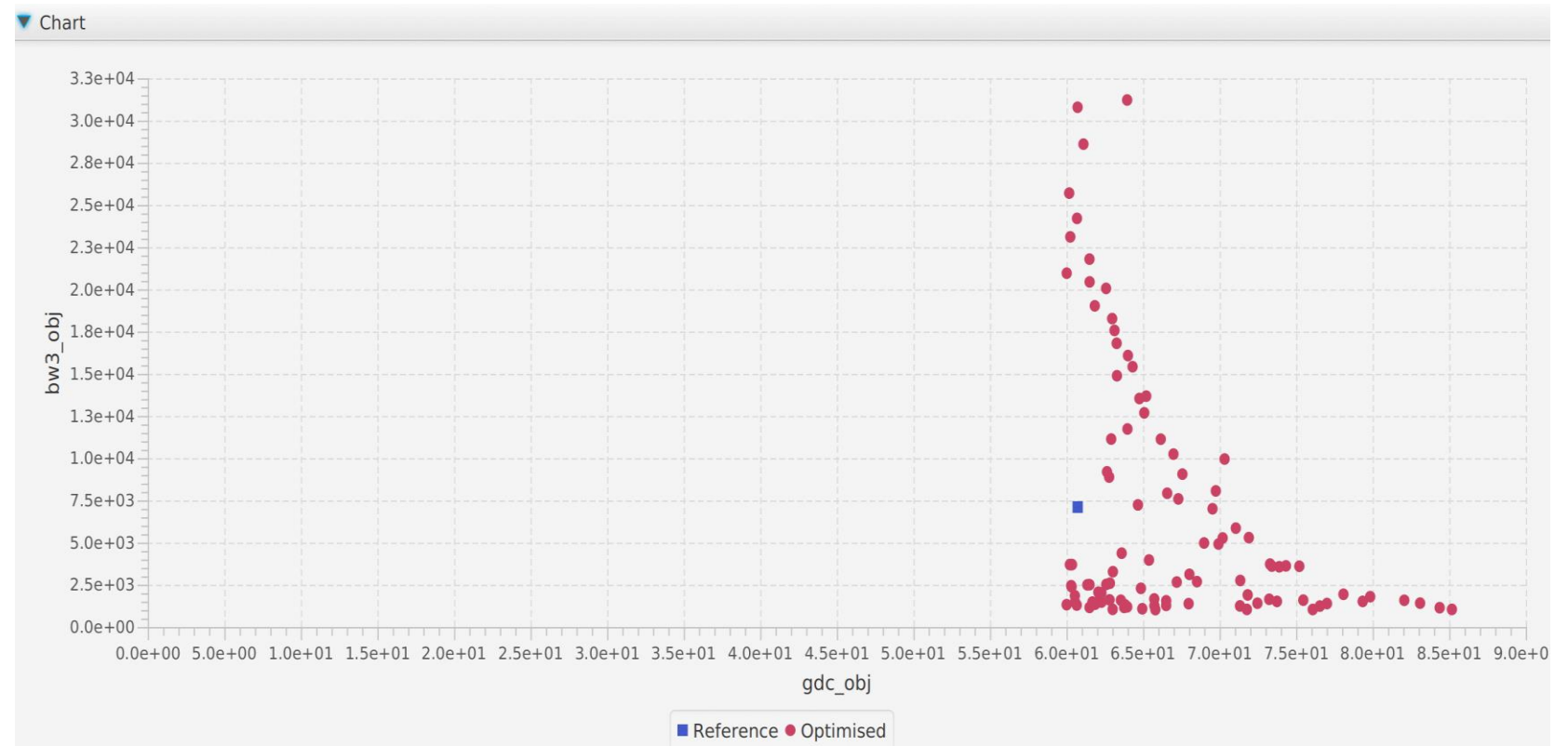
Individual	Rank	gdc_obj ↑	bw3_obj ↑	bw0_obj ↑	ph0_obj ↑	satM_xpbi...	satM_xpbo...	satM_xpin...	satM_xpip...	satM_xnout...
-1	-1	60.73282E0	7.103604E3	6.327571E6	-135.6022E0	575.014E-3	779.1893E-3	623.4896E-3	858.9788E-3	1.006953E0
32	1	27.2508E0	2.422186E3	56.02294E3	-91.62198E0	1.668372E0	1.047026E0	623.8284E-3	610.7125E-3	1.231262E0
34	1	65.8383E0	282.4309E0	552.0044E3	-105.3383E0	526.2659E-3	709.2627E-3	1.58496E0	1.017397E0	1.496683E0
61	1	73.99221E0	17.1238E0	86.62364E3	-102.5881E0	759.3223E-3	891.1611E-3	1.157345E0	373.3534E-3	742.4776E-3
78	1	42.01875E0	6.434443E3	813.9935E3	-107.0951E0	894.3354E-3	1.131592E0	913.2067E-3	1.074412E0	1.108555E0
91	1	23.34552E0	5.534095E3	81.64345E3	-92.97555E0	1.121796E0	1.291339E0	762.15E-3	1.08312E0	927.5837E-3
101	1	47.92118E0	176.4936E0	46.91786E3	-110.9642E0	899.1749E-3	1.007082E0	1.271641E0	1.158915E0	1.270117E0
104	1	83.51348E0	3.179632E0	46.58073E3	-103.7514E0	1.152669E0	973.4202E-3	1.150545E0	906.0637E-3	1.230555E0
106	1	47.50603E0	2.009409E3	513.5616E3	-115.289E0	1.208516E0	887.8753E-3	573.1432E-3	728.2229E-3	1.118273E0
108	1	47.88203E0	1.101683E3	278.759E3	-108.242E0	1.334549E0	1.169666E0	614.9153E-3	870.428E-3	1.107173E0
113	1	88.43834E0	8.780963E0	233.8392E3	-112.2265E0	938.5125E-3	951.1736E-3	1.197836E0	882.4454E-3	1.118797E0
120	1	59.96754E0	332.362E0	325.5536E3	-108.6992E0	443.9849E-3	771.9792E-3	1.095039E0	790.8205E-3	1.000384E0
124	1	23.0116E0	1.153419E3	16.31777E3	-87.7423E0	764.8707E-3	979.8741E-3	1.077953E0	1.0509E0	1.207229E0
127	1	66.91756E0	27.77651E0	69.97507E3	-119.9771E0	725.1314E-3	930.0133E-3	1.309752E0	1.119099E0	1.292402E0
142	1	81.71167E0	8.43048E0	109.1384E3	-115.059E0	1.03565E0	1.123958E0	984.546E-3	584.1216E-3	874.2477E-3
143	1	58.81346E0	443.7319E0	393.1548E3	-99.40646E0	219.7362E-3	464.263E-3	1.798771E0	1.04094E0	1.742949E0
145	1	59.9302E0	408.3002E0	422.1941E3	-112.8189E0	404.8643E-3	1.069555E0	1.165511E0	1.153144E0	1.111318E0
148	1	54.91354E0	37.21244E0	20.81066E3	-93.01325E0	1.075726E0	873.7873E-3	1.205005E0	1.040752E0	1.371821E0
150	1	68.4936E0	963.4959E0	17.01911E6	55.75254E0	992.2458E-3	1.104526E0	1.058107E0	569.8432E-3	849.0271E-3
152	1	71.33482E0	15.02362E0	55.65483E3	-96.26856E0	1.248637E0	1.062525E0	1.049522E0	954.343E-3	1.202647E0
153	1	34.50426E0	433.7468E0	23.24036E3	-96.0851E0	975.9184E-3	1.034071E0	1.175273E0	1.11597E0	1.246248E0
165	1	31.26399E0	695.2804E0	25.74837E3	-97.17051E0	1.105037E0	1.214329E0	1.047559E0	1.135717E0	1.08707E0
172	1	56.70945E0	126.9516E0	88.10726E3	-104.2718E0	1.045343E0	1.077818E0	1.067869E0	1.079989E0	1.153707E0
174	1	73.11023E0	112.3522E0	508.6153E3	-103.087E0	670.6142E-3	1.019273E0	977.2563E-3	1.058096E0	1.084641E0

# MOTIVATED GUI – Optimisation process results

The results can also be displayed during, and at the end of the optimisation as a plot of one objective against another, effectively a pareto curve.

Each point on the curve represents a fully optimised solution where each objective is at it's maximum and can only be improved at the detriment of a different objective.

This allows the engineer to select the best solution and trade off of all objectives simply





# MOTIVATED GUI – Optimisation process results

- Curve “zoomed in” for greater clarity
- Results based on a constraint of Gain >60 and Bw3 >1k

