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APPENDIX A

DATA OF PHASE ANGLE

IN

BAND PASS CONSTANT 90 DEGREES PHASE SHIFT CIRCUIT

The Phase Angles of Phase Shift Network Whose $f_{01} = 743$ Hz , $Q_1 = 0.2405612$

f_{Hz}	$\frac{f_{01}}{f} = \frac{743}{f}$	$\frac{f}{f_{01}} = \frac{f}{743}$	$\frac{f_{01}}{f} - \frac{f}{f_{01}}$	$\emptyset_1 = 2\tan^{-1} Q_1 \left[\frac{f_{01}}{f} - \frac{f}{f_{01}}\right]$
50	14.8600	0.0672947	14.792706	148.60
60	12.383330	0.0807537	12.302577	142.66
70	10.614285	0.0942126	10.519773	136.87
80	9.287550	0.1076716	9.1798284	131.27
90	8.255555	0.1211306	8.1344245	125.86
100	7.430000	0.1345895	7.2954105	120.65
200	3.715000	0.2691790	3.445821	79.31
300	2.476666	0.4037685	2.0728981	53.00
400	1.857500	0.5383580	1.3191420	35.21
500	1.486000	0.6729475	0.8130525	22.18
600	1.238333	0.8075350	0.4307963	11.83
700	1.061428	0.9421265	0.1193020	3.28
800	0.928750	1.0767160	-0.1479660	-4.07
900	0.825550	1.2113055	-0.3857500	-10.60
1000	0.743000	1.345895	-0.6028950	-16.50
2000	0.371500	2.691790	-2.3202900	-58.33
3000	0.247666	4.037685	-3.7900184	-84.71
4000	0.185750	5.383580	-5.1978300	-102.69
5000	0.148600	6.7294751	-6.580875	-115.44
6000	0.123833	8.0753701	-7.9515368	-124.80
7000	0.106142	9.4212651	-9.3151223	-131.90
8000	0.092870	10.76716	-10.66873	-137.42
9000	0.082555	12.113055	-11.287505	-139.56
10000	0.074300	13.458950	-13.384615	-145.49
20000	0.037150	26.917900	-26.88075	-162.41

Angles are in degrees*

The Constant Phase Shift Network Whose f_{01} = 743 Hz, f_{02} = 3700 Hz, Q = 0.245612

f_{Hz}	$\frac{f_{02}}{f} = \frac{3700}{f}$	$\frac{f}{f_{02}} = \frac{f}{3700}$	$\frac{f_{02}}{f} - \frac{f}{f_{02}}$	Phase Angle $\phi_2 = 2\tan^{-1}Q\left[\frac{f_{02}}{f} - \frac{f}{f_{02}}\right]$	Phase difference $\phi_2 - \phi_1$
50	74.0	0.0135135	73.986487	173.56	24.96
60	61.666666	0.0162162	61.650450	172.28	29.62
70	52.837142	0.0189189	52.838224	171.00	34.13
80	46.250000	0.0216216	46.228379	169.72	38.45
90	41.111111	0.0243243	41.086787	168.44	42.58
100	37.00000	0.027027	36.972973	167.17	46.52
200	18.5	0.054054	18.445946	154.60	75.29
300	12.33333	0.081081	12.252252	142.51	89.51
400	9.25	0.1081081	9.1418919	131.09	95.88
500	7.4	0.1351351	7.2648649	120.44	98.31
600	6.166666	0.1621621	6.0045045	110.60	98.77
700	5.2857142	0.1891891	5.0965251	101.59	98.31
800	4.625	0.2162162	4.4087838	93.36	97.43
900	4.11111	0.2432432	3.8678679	85.87	96.47
1000	3.7	0.2702702	3.4297298	79.04	95.54
2000	1.85	0.5405405	1.309495	34.96	93.29
3000	1.23333	0.8108108	0.4225225	11.60	96.31
4000	0.925	1.081081	-0.156081	-4.30	98.38
5000	0.74	1.3513513	-0.6113513	-16.73	98.70
6000	0.616666	1.6216216	-1.0049550	-27.18	97.61
7000	0.5285714	1.8918918	-1.3633204	-36.31	95.58
8000	0.4625	2.1621621	-1.6996621	-44.47	92.94
9000	0.411111	2.4324324	-2.0213213	-51.86	87.69
10000	0.37	2.7027027	-2.3327027	-58.59	86.89
20000	0.185	5.4054054	-5.2204054	-102.94	59.46

Angles are in degrees*

The Constant Phase Shift Network Whose f_{01} = 743 Hz, f_{02} = 3500 Hz, Q = 0.2405612.

f_{Hz}	$\frac{f_{02}}{f} = \frac{3500}{f}$	$\frac{f}{f_{02}} = \frac{f}{3500}$	$\frac{f_{02}}{f} - \frac{f}{f_{02}}$	Phase Angle $\phi_2 = 2\tan^{-1}Q\left(\frac{f_{02}}{f} - \frac{f}{f_{02}}\right)$	Phase difference $\phi_2 - \phi_1$
50	70.0	0.0142857	69.985715	173.20	24.60
60	58.333333	0.0171428	58.316191	171.84	29.18
70	50.0	0.02	49.98	170.49	33.62
80	43.75	0.0228571	43.727143	169.13	37.86
90	38.88888	0.0257142	38.863174	167.78	41.92
100	35.0	0.0285714	34.971429	166.44	45.79
200	17.5	0.0571428	17.442858	153.19	73.88
300	11.66666	0.0857142	11.580952	140.50	87.50
400	8.75	0.1142857	8.6357143	128.59	93.37
500	7.0	0.1428571	6.8571429	117.54	95.41
600	5.833333	0.17114285	5.1190483	101.84	90.01
700	5.0	0.2	4.8	98.21	94.93
800	4.3750	0.2285714	4.1464286	89.85	93.92
900	3.88888	0.2571428	3.6317452	82.28	92.88
1000	3.5	0.2857142	3.2142858	75.42	91.92
2000	1.75	0.5714285	1.1785715	31.65	89.98
3000	1.166666	0.8571428	0.3095238	8.51	93.22
4000	0.87500	1.1428571	-0.267871	-7.37	95.31
5000	0.7	1.4285714	-0.7285714	-19.88	95.55
6000	0.583333	1.7142857	-1.1309524	-30.43	94.36
7000	0.5	2.0	-1.5	-39.68	92.21
8000	0.4375	2.2857142	-1.8482142	-47.94	89.47
9000	0.38888	2.5714285	-2.1825397	-55.40	84.15
10000	0.35	2.8571428	-2.5071428	-62.19	83.29
20000	0.175	5.7142857	-5.5392857	-106.22	54.18

Angles are in degrees*

The Discrepancy of The Approximation Phase Angle Equation

f_{Hz}	$\ln\frac{f}{f_{01}} = \ln\frac{f}{743}$	$\phi_1 \Rightarrow -4Q\ln\frac{f}{f_{01}}$	$\phi_1 = 2\tan^{-1} Q\left[\frac{f_{01}}{f} - \frac{f}{f_{01}}\right]$	Discrepancy
50	-2.69873	143.76	148.60	-5.16
60	-2.516351	138.73	142.66	-3.93
70	-2.362201	130.23	136.87	-6.64
80	-2.228669	122.87	131.27	-8.40
90	-2.110889	116.38	125.86	-9.48
100	-2.005526	110.55	120.65	-10.10
200	-1.312379	72.34	79.31	-6.97
300	-0.906913	49.99	53.00	-3.01
400	-0.619231	34.13	35.21	-1.08
500	-0.396088	21.83	22.13	-0.30
600	-0.213766	11.78	11.83	-0.05
700	-0.059616	3.28	3.28	0.0
800	0.073916	-4.07	-4.07	0.0
900	0.191699	-10.56	-10.60	-0.04
1000	0.297059	-16.37	-16.50	-0.13
2000	0.990206	-54.58	-58.38	-3.75
3000	1.395672	-76.93	-84.71	-7.78
4000	1.683354	-92.79	-102.69	-9.90
5000	1.906497	-105.09	-115.44	-10.35
6000	2.088819	-115.15	-124.80	-9.65
7000	2.242969	-123.64	-131.90	-8.26
8000	2.376501	-131.00	-137.42	-6.42
9000	2.494284	-137.50	-139.56	-2.06
10000	2.599644	-143.31	-145.49	-2.18
20000	3.292791	-181.52	-162.41	+19.11

Angles are in degrees* f_{01}=743 Hz , Q=0.2405612

The Discrepancy of The Approximation Phase Angle Equation in Phase Shift Network

f_{Hz}	$\ln \frac{f}{f_{02}} = \ln \frac{f}{3700}$	$\phi_2 = -4Q \ln \frac{f}{f_{02}}$	$\phi_2 = 2\tan^{-1} Q\left(\frac{f_{02}}{f} - \frac{f}{f_{02}}\right)$	Discrepancy
50	-4.304066	237.27	173.56	63.71
60	-4.121745	227.21	172.28	54.93
70	-3.967594	218.72	171.00	47.72
80	-3.834063	211.36	169.72	41.64
90	-3.71628	204.86	168.44	36.42
100	-3.610919	199.05	167.17	31.88
200	-2.917771	160.84	154.60	6.24
300	-2.512306	138.49	142.51	-4.02
400	-2.224624	122.63	131.09	-8.46
500	-2.00148	110.33	120.44	-10.11
600	-1.819159	100.28	110.60	-10.32
700	-1.665008	91.78	101.59	-9.81
800	-1.531477	84.42	93.36	-8.93
900	-1.413694	77.93	85.87	-7.93
1000	-1.308334	72.12	79.04	-6.91
2000	-0.615185	33.91	34.96	-1.04
3000	-0.20972	11.56	11.60	-0.03
4000	0.077961	-4.29	-4.30	0.01
5000	0.301105	-16.59	-16.73	0.13
6000	0.483426	-26.64	-27.18	0.53
7000	0.637577	-35.14	-36.31	1.16
8000	0.771108	-42.50	-44.47	1.96
9000	0.888891	-49.00	-51.86	2.85
10000	0.994252	-54.81	-58.59	3.77
20000	1.6874	-93.02	-102.94	9.91

Angles are in degrees* f_{02}=3700 Hz , Q= 0.2405612

The Discrepancy of The Approximation Phase Angle Equation in Phase Shift Network

f_{Hz}	$\ln \frac{f}{f_{O2}} = \ln \frac{f}{3500}$	$\phi_2 = -4Q \ln \frac{f}{f_{O2}}$	$\phi_2 = 2\tan^{-1} Q\left(\frac{f_{02}}{f} - \frac{f}{f_{02}}\right)$	Discrepancy
50	-4.248496	234.20	173.20	61.00
60	-4.066177	224.15	171.84	52.31
70	-3.912023	215.65	170.49	45.16
80	-3.778494	208.29	169.13	39.16
90	-3.660712	201.80	167.78	34.02
100	-3.55535	195.99	166.44	29.55
200	-2.862201	157.78	153.19	4.59
300	-2.456736	135.43	140.50	-5.07
400	-2.169054	119.57	128.59	-9.02
500	-1.945911	107.27	117.54	-10.27
600	-1.763589	97.22	101.84	-4.62
700	-1.609438	88.72	98.21	-9.49
800	-1.475907	81.36	89.85	-8.49
900	-1.358124	74.86	82.28	-7.42
1000	-1.252764	69.06	75.42	-6.36
2000	-0.559616	30.84	31.65	-0.81
3000	-0.154151	8.49	8.51	-0.02
4000	0.133531	-7.36	-7.37	0.01
5000	0.356675	-19.66	-19.88	+0.22
6000	0.538996	-29.71	-30.43	+0.72
7000	0.693247	-38.21	-39.68	+1.47
8000	0.826678	-45.57	-47.94	+2.37
9000	0.944461	-52.06	-55.40	+3.34
10000	1.049821	-57.87	-62.19	+4.32
20000	1.742969	-96.08	-106.22	+10.14

Angles are in degrees * f_{o2} = 3500 Hz , Q = 0.2405612

APPENDIX B

The Reverberation Time Data.

Reverberation Time

Reverberation time is defined as the time that would be required for the root mean square sound pressure level of an enclosure, originally in a steady state, to decrease 60 dB after the source is shut off, the reverberation time can be calculated by Sabine's formula [1]

$$T_{60} = \frac{0.05\ Vol}{SA}$$

T_{60} is the reverberation time in seconds at 512 Hz

Vol is the room volume in cu. ft,

S is the total surface area in sq ft

A is the average absorption coefficient

The reverberation time will increase as the frequency decrease with the percentage shown in the data.

Reverberation Time of Room I

Place The Siam Film Development Recording Studio

Volume $Vol = 12900$ ft^3

Surface areas $S = 4000$ ft^2

Absorption Coefficient $A = 0.24$

The reverberation time $T_{60} = \frac{0.05\ Vol}{SA}$

$= 0.66$ second at 512 Hz

f Hz	% T_{60}	T_{60} second
200	124	0.81
300	112	0.73
400	106	0.69
500	100	0.66
600	97	0.64
700	96	0.63
800	94.5	0.62
900	94	0.62
1000	93.5	0.61
2000	93	0.61
3000	92	0.60
4000	91	0.60
5000	90	0.59
6000	88	0.58
7000	84	0.55
8000	82	0.54
9000	78	0.51
10000	73	0.48

Reverberation Time of Room II

Place — The Lecture Room in the Electrical Engineering Department

Volume — $Vol = 8500$ ft^3

Surface areas — $S = 2800$ ft^2

Absorption Coefficient — $A = 0.08$

The reverberation time — $T_{60} = \frac{0.05\ Vol}{SA}$

$= 1.91$ second at 512 Hz

f Hz	% T_{60}	T_{60} . second
200	124	2.36
300	112	2.13
400	106	2.02
500	100	1.91
600	97	1.85
700	96	1.83
800	94.5	1.80
900	94	1.79
1000	93.5	1.78
2000	93	1.77
3000	92	1.75
4000	91	1.73
5000	90	1.71
6000	88	1.68
7000	84	1.60
8000	82	1.56
9000	78	1.48
10000	73	1.39

APPENDIX C.

The Detail of Calculation

of The Phase Angle

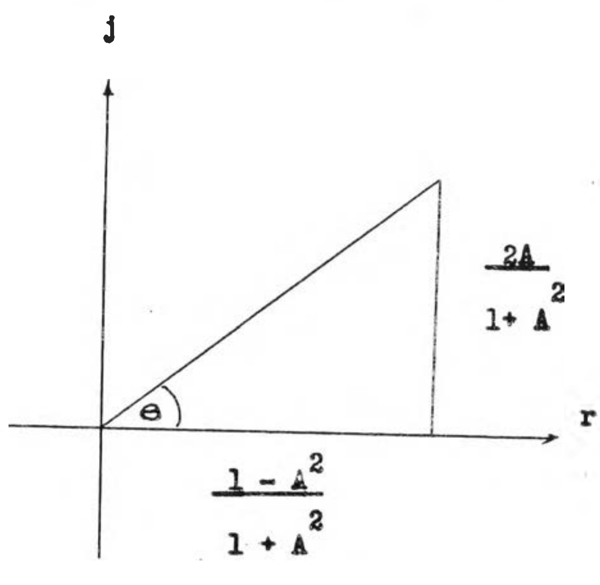
The Phase Angle When The Transfer Function Is in The Form $\frac{1+jA}{1-jA}$

$$\frac{Vo}{Vi} = \frac{1 + jA}{1 - jA}$$

$$\frac{Vo}{Vi} = \frac{1 + jA}{1 - jA} \cdot \frac{1 + jA}{1 + jA}$$

$$\frac{Vo}{Vi} = \frac{1 - A^2 + j2A}{1 + A^2}$$

$$\frac{Vo}{Vi} = \frac{1 - A^2}{1 + A^2} + j\,\frac{2A}{1 + A^2}$$



then $\tan\theta = \frac{2A}{1 - A^2} = \frac{2\tan\frac{\theta}{2}}{1 - \tan^2\frac{\theta}{2}}$

$$\tan\frac{\theta}{2} = A$$

VITA

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