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PRODUCTION ENGINEERING MEASURE FOR AN INTEGRATED CIRCUIT POWER --ETC(U)
SEP 76 R C DE BLOOIS DAAB05-72-C-5844
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PRODUCTION ENGINEERING MEASURE FOR AN INTEGRATED CIRCUIT POWER AMPLIFIER 600-1000 MHz FOR TACTICAL RADIO EQUIPMENT

QUARTERLY REPORT NO. 13

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Prepared For:

US ARMY ELECTRONICS COMMAND
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PROCUREMENT AND PRODUCTION DIRECTORATE
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During this period the fifty pilot run amplifiers were fabricated at the required production rate. Group A testing was completed within the allotted time establishing that the through-put requirements were met.

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SECTION I - PURPOSE

The objective of this production engineering measure is to establish a production capability to manufacture broadband, highly reliable, integrated circuit amplifiers for use in Army communications equipment.

The work involves transistor design optimization, fabrication of an impedance transformer, and fabrication of a suitable substrate interconnection pattern and package. The program includes actual fabrication of test samples, a production run, and performance of electrical, mechanical, and environmental tests as required.

Reports and other information procured under this requirement will be used for industrial mobilization and preparedness planning to determine what additional planning measures are required, and when necessary, to assist in establishing additional sources.

SECTION II - TECHNICAL NARRATIVE

2.0 INTRODUCTION

This program involves the establishment of production techniques for manufacturing broadband, high-power UHF amplifiers. Successful achievement of the requirements depends on the ability to produce optimized transistors and associated matching circuits for the required frequency band in an economical manner. The 30 watt amplifier module will consist of two 18 watt unit amplifiers that are power-combined using 90 degree interdigitated couplers. Batch processing techniques will be utilized to the maximum extent possible to reduce production costs for this amplifier.

2.1 QUARTERLY PROGRESS

The 50 pilot run amplifiers were fabricated, production rates established, and electrically tuned and tested (Group A) during this period. Steady state life testing, intermittent life testing, and high temperature storage were begun. All qualification testing will be completed during the next period. Construction of the sweep driver and four way combiners were also initiated with completion expected during the next period.

All process and testing measures developed during the quarter were directed towards achieving the goal of utilizing batch processing to produce highly reliable amplifiers. The four major programs (2.2 - 2.5) of the quarter have shown satisfactory results in attaining the aforementioned goal.

2.2 PRE-PRODUCTION PILOT RUN

2.2.1 Lot Formation

A pre-production lot was formed to produce three test units to prove out production techniques. All piece parts were inspected as per QCP 21K60003. No rejects were found among purchased parts. One of the three bright nickel plated boxes blistered during testing at 275°C for 30 min. As a result of this activity, all boxes and lids were blister tested.

Six boxes out of a total lot of seventy were shown to be defective in this respect. In addition, thirty-two out of seventy lids exhibited blistering under the same test conditions. An investigation at the plating vendor resulted in the discovery of the cause of failure. The defective parts were plated to a total of five times the specified plating thickness. Remanufactured parts did not exhibit any blistering due to heat but were pitted from the stripping and replating operation. Units with excessive pits were rejected and were replaced by new parts.

2.2.2 Box Solder-Reflow Assembly

Even though operating at the correct temperature, the heat up on the hot plate caused some discoloration on the first test unit. To remedy the situation, a sheet of lint-free filter paper was used as an interface between the hot plate and part.

Leak testing of the experimental units at this stage of completion verified the assumption that if the solder bond is visibly continuous around the adapters the box is hermetic. Experimental gross leak testing was performed with a metal plate and rubberized gasket that is fastened to the box with C clamps. The box was pressurized to 40psig through a fitting attached to the plate. The assembly was immersed in methanol at 25°C. Any evidence of bubbling constituted a rejection.

2.2.3 Substrate, Component, and Connector Assembly

The high temperature of Box-Solder Reflow Assembly (93D00327) destroyed the glass-to-metal seal of the dc feedthrough when this component was mounted as originally planned. After reviewing the temperature specification of the dc feedthrough, the decision was made to mount the feedthrough with lower melting 60-40 SN/P6 solder at a lower stage temperature during Substrate, Component, and Connector Assembly (93D00325).

Ultrasonic TCM cleaning (93D00325) proved to be a key process. Small amounts of flux and contaminates severly affected electrical performance of the amplifiers. An ultrasonic cleaning time of one minute proved to be very effective at removing any problems along these lines.

2.2.4 Final Inspection

All units passed final inspection. Process was judged proven and documentation finalized.

2.3 PRODUCTION PILOT RUN

2.3.1 Assembly Line Flow

The assembly line was converted from one which produces specialized amplifiers on a one-operator one-part basis to a multiple operator line where the assembly tasks were divided. Three heating stations were set up with the three required temperatures. A component mount and box assembly station was used. A total of 3 1/2 operators were used to assemble the pilot run of 50 units.

2.3.2 Production

Pilot line production of 50 units started on schedule August 16, 1976. The amplifiers were processed as five lots of ten units. ECOM inspection was performed by Mr. Dave Biser with Mr. Skip Karstadt, DCASD, assisting; they determined that production rates and flow met the contract requirements. Fifty amplifiers completed assembly and were serialized for RF test and tune.

2.4 INTERNAL VISUAL PRECAP INSPECTION

2.4.1 Procedure

All units were inspected by production personnel as per MIL-Std. 833 Section 2010 as per contract requirements. On September 7, 1976, Mr. Patriarca, Government source inspector, was called in to witness precap visual inspection.

2.4.2 Inspection Results

All units met the inspection requirements.

2.5 HERMETIC SEALING RESULTS

Four units have been sealed to date. All units pass gross leak testing to 1×10^{-3} CM^3ATM/Sec. Leak tesing using the K85 radioisotope technique for fine leaks is presently being conducted. Results to date are satisfactory.

2.6 RF TEST AND TUNE

All fifty amplifiers were RF tested and tuned during the two-week interval following the production run thus establishing the agreed upon through-put time. The amplifiers were tuned with minimal effort, a result of the consistency of the batch processing techniques used in the manufacturing phase of the program. The transistors used for these amplifiers were taken from several different wafer lots and the variation was accommodated with relative ease. Lot variation accounted for a considerable amount of the gain variation from unit to unit.

2.7 GROUP A TESTING

As required by SCS 409A, all fifty amplifiers were tested for relative phase, input power for 30 watts output, and current drain for 30 watts output. This data is shown in Tables I, II, and III. The data gathered was then used to calculate amplifier gain, efficiency, the phase window, the gain variation and efficiency variations. This data is shown in Tables IV, V, and VI. All data shows that the amplifiers meet the requirements of SCS 409A. The module to module gain variation and the relative phase specifications are just met at certain frequencies. The limit amplifiers could not be improved without great difficulty due to the relatively large bandwidth imposed on the design. It appears that the limits of SCS 409A are at about the extent of practicality with the present state-of-the-art. The efficiency specification was generously exceeded.

TABLE I. INITIAL TEST RELATIVE PHASE ANGLE.

Group A

$P_O = 30W \quad V_{CC} = 28V \quad T_C = 80°C$

UNIT NUMBER	Phase Degrees.								
	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10290	-47	127	-58	127	-49	127	-59	108	-89
10291	-52	125	-56	127	-50	128	-66	101	-89
10292	-45	129	-54	128	-48	129	-59	108	-84
10293	-51	118	-67	118	-57	122	-68	97	-98
10294	-46	127	-56	127	-48	127	-62	107	-96
10295	-50	121	-63	118	-55	124	-61	111	-97
10296	-42	132	-49	132	-42	135	-52	113	-82
10297	-48	127	-58	125	-51	129	-55	108	-83
10298	-47	128	-59	124	-52	127	-62	104	-91
10299	-48	123	-59	121	-54	122	-66	104	-86
10300	-43	126	-58	124	-50	128	-60	108	-94
10301	-51	122	-60	122	-51	128	-60	107	-96
10302	-46	127	-58	124	-50	128	-62	106	-88
10303	-53	122	-60	122	-53	126	-63	102	-88
10304	-50	122	-57	122	-54	124	-65	103	-85
10305	-48	128	-53	128	-48	129	-58	109	-89
10306	-45	128	-56	127	-51	128	-62	104	-92
10307	-47	128	-54	129	-48	128	-65	103	-84
10308	-49	127	-58	123	-51	126	-62	103	-86
10309	-52	123	-58	123	-52	124	-64	102	-93
10310	-52	124	-57	125	-49	128	-59	109	-88
10311	-43	125	-58	123	-53	125	-61	103	-85
10312	-51	121	-58	119	-55	122	-69	98	-95
10313	-49	123	-58	125	-49	122	-70	99	-93
10314	-47	128	-55	127	-48	130	-65	102	-91

TABLE I. INITIAL TEST RELATIVE PHASE ANGLE (CONTINUED).

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	Phase Degrees. f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10315	-48	128	-56	127	-51	124	-63	101	-96
10316	-50	123	-58	126	-50	128	-62	102	-88
10317	-44	128	-54	127	-48	130	-56	111	-90
10318	-48	129	-57	124	-50	130	-61	103	-90
10319	-50	122	-61	121	-52	127	-62	102	-89
10320	-47	127	-58	122	-53	126	-64	100	-95
10321	-51	121	-60	121	-54	122	-63	105	-98
10322	-49	123	-59	122	-52	127	-62	101	-96
10323	-51	122	-61	121	-53	125	-62	103	-92
10324	-47	128	-55	128	-48	128	-62	103	-87
10325	-50	120	-62	118	-57	121	-68	98	-97
10326	-50	124	-58	122	-52	127	-60	104	-98
10327	-48	121	-58	123	-50	123	-62	103	-90
10328	-48	128	-53	129	-46	132	-58	109	-90
10329	-48	123	-60	121	-53	123	-66	102	-89
10330	-52	123	-60	123	-50	129	-63	101	-94
10331	-56	116	-68	113	-60	122	-68	99	-98
10332	-42	129	-58	123	-52	127	-62	105	-88
10333	-54	118	-68	119	-55	121	-68	102	-92
10334	-52	119	-66	118	-56	125	-61	103	-98
10335	-44	126	-58	127	-48	129	-55	112	-87
10336	-58	121	-62	121	-50	126	-63	101	-97
10337	-53	128	-55	128	-47	130	-63	108	-90
10338	-48	128	-56	125	-51	127	-62	106	-82
10339	-48	124	-58	122	-52	124	-66	102	-93

TABLE II. INITIAL TEST R.F. INPUT POWER DATA.

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	P_{IN} (W)								
	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10290	3.71	3.65	3.64	3.77	3.73	3.75	3.70	3.81	3.80
10291	3.83	3.82	3.80	3.85	3.86	3.86	3.75	3.79	3.76
10292	3.81	3.60	3.53	3.59	3.61	3.66	3.48	3.49	3.68
10293	3.40	3.31	3.62	3.83	3.89	3.93	3.70	3.81	4.07
10294	3.98	3.77	3.78	3.93	3.98	3.99	3.92	3.85	3.87
10295	3.67	3.50	3.72	3.82	4.01	3.93	3.72	3.69	3.81
10296	3.87	3.67	3.60	3.55	3.57	3.55	3.41	3.56	3.76
10297	4.22	4.03	4.01	4.09	4.17	4.13	3.90	3.81	3.99
10298	3.80	3.58	3.59	3.72	3.86	3.91	3.90	3.99	4.11
10299	3.60	3.45	3.53	3.67	3.77	3.79	3.82	3.80	3.60
10300	3.56	3.41	3.39	3.59	3.88	3.81	3.67	3.65	3.86
10301	3.76	3.61	3.67	3.91	4.03	4.06	3.80	3.67	3.75
10302	3.82	3.60	3.62	3.71	3.74	3.78	3.73	3.85	3.62
10303	3.80	3.62	3.66	3.85	3.90	4.00	3.80	3.79	3.73
10304	3.61	3.55	3.63	3.64	3.61	3.72	3.62	3.61	3.40
10305	3.76	3.51	3.48	3.62	3.73	3.77	3.64	3.51	3.52
10306	3.69	3.67	3.49	3.58	3.68	3.56	3.54	3.51	3.94
10307	3.37	3.27	3.30	3.40	3.45	3.54	3.55	3.61	3.54
10308	3.77	3.50	3.47	3.52	3.49	3.53	3.42	3.49	3.50
10309	3.46	3.28	3.33	3.51	3.56	3.58	3.48	3.39	3.40
10310	4.01	4.01	4.02	4.05	4.14	4.09	3.95	3.95	3.76
10311	4.15	3.73	3.65	3.87	3.55	3.83	3.83	3.94	3.95
10312	3.80	3.58	3.62	3.72	3.86	3.89	3.69	3.78	3.89
10313	3.64	3.60	3.67	3.57	3.72	3.76	4.00	3.97	3.80
10314	4.01	3.71	3.75	3.81	3.94	3.94	3.80	4.01	4.10

TABLE II. INITIAL TEST R.F. INPUT POWER DATA (CONTINUED)

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	P_{IN} (W)								
	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10315	3.74	3.49	3.48	3.63	3.72	3.78	3.70	3.75	3.74
10316	3.84	3.70	3.72	3.84	3.86	3.80	3.70	3.79	4.12
10317	3.70	3.51	3.60	3.61	3.74	3.70	3.67	3.75	3.79
10318	3.78	3.65	3.60	3.63	3.57	3.57	3.32	3.64	3.68
10319	3.51	3.62	3.63	3.76	3.78	3.78	3.63	3.77	3.94
10320	3.50	3.23	3.20	3.30	3.40	3.54	3.43	3.64	4.01
10321	3.93	3.64	3.65	3.85	3.96	4.11	4.01	4.04	3.99
10322	3.82	3.49	3.46	3.60	3.71	3.78	3.67	3.69	4.19
10323	3.66	3.50	3.64	3.81	3.87	3.92	3.82	3.81	3.72
10324	3.73	3.61	3.58	3.69	3.69	3.70	3.56	3.62	3.53
10325	3.61	3.42	3.51	3.75	3.92	4.00	3.85	3.95	3.90
10326	3.86	3.47	3.46	3.59	3.66	3.81	3.56	3.66	3.66
10327	4.08	3.82	3.91	4.02	4.10	4.00	3.75	3.68	3.86
10328	3.82	3.66	3.65	3.68	3.61	3.59	3.69	3.95	3.73
10329	3.61	3.29	3.28	3.48	3.58	3.70	3.66	3.71	3.74
10330	3.63	3.50	3.55	3.73	3.75	3.72	3.62	3.68	3.92
10331	3.95	3.88	4.01	4.11	4.10	4.06	3.94	4.08	4.10
10332	3.42	3.23	3.22	3.37	3.47	3.56	3.45	3.39	3.34
10333	3.48	3.57	3.70	3.72	3.72	3.74	3.76	3.87	3.75
10334	3.45	3.29	3.48	3.61	3.80	3.78	3.70	3.83	3.72
10335	3.87	3.79	3.75	3.78	3.84	3.80	3.73	3.71	3.78
10336	3.82	3.85	3.80	3.89	3.79	3.70	3.58	3.81	3.74
10337	3.68	3.70	3.77	3.89	3.87	3.71	3.46	3.68	3.61
10338	4.09	3.78	3.60	3.62	3.71	3.69	3.74	3.95	3.94
10339	3.44	3.29	3.35	3.55	3.69	3.61	3.48	3.45	3.52

TABLE III. INITIAL D.C. CURRENT.

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	I (Adc)								
	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10290	1.94	2.00	2.04	2.01	1.95	1.96	1.96	1.98	1.99
10291	2.04	2.10	2.09	2.07	2.03	2.03	2.04	2.06	2.05
10292	2.07	2.09	2.07	2.06	2.03	2.01	1.97	1.94	1.93
10293	2.00	2.04	2.10	2.08	2.05	2.01	1.93	2.00	2.06
10294	1.97	2.00	2.01	1.99	1.95	1.91	1.88	1.92	2.05
10295	1.94	1.97	2.03	2.06	2.05	2.01	1.97	1.90	2.02
10296	2.08	2.07	2.04	1.98	1.94	1.93	1.89	1.95	2.00
10297	2.09	2.10	2.12	2.13	2.11	2.10	2.01	2.02	2.08
10298	2.01	2.02	2.05	2.06	2.09	2.06	2.05	2.09	2.20
10299	2.00	1.98	1.98	2.01	2.04	2.05	2.08	1.99	1.98
10300	2.02	2.00	1.98	1.97	2.04	2.00	1.90	1.94	2.06
10301	2.03	2.03	2.04	2.04	1.98	1.94	1.93	1.92	2.06
10302	2.01	1.93	1.97	1.98	1.97	1.96	1.94	1.93	1.91
10303	2.01	2.02	2.03	2.00	1.97	1.95	1.92	1.94	1.99
10304	1.95	1.95	1.92	1.94	1.93	1.95	1.95	1.96	1.90
10305	1.94	1.94	1.93	1.92	1.93	1.90	1.85	1.87	1.89
10306	2.01	2.01	1.98	1.96	1.97	2.00	2.06	2.00	2.12
10307	2.04	2.05	2.00	1.95	1.96	2.04	2.12	2.14	2.12
10308	2.04	2.02	2.00	1.99	1.98	1.99	1.94	1.97	1.92
10309	2.04	2.03	2.03	1.99	1.98	1.99	1.97	1.98	1.97
10310	2.05	2.03	2.01	2.03	2.03	1.98	1.99	1.87	1.81
10311	1.98	2.01	2.00	1.98	1.96	1.94	1.86	1.87	1.86
10312	1.87	1.88	1.87	1.84	1.90	1.90	1.89	1.90	1.96
10313	1.92	1.93	1.92	1.93	1.96	2.00	2.16	2.02	2.02
10314	2.00	2.03	2.01	1.96	1.91	1.89	1.90	1.92	1.95

TABLE III. INITIAL D.C. CURRENT (CONTINUED).

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	I (Adc)								
	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10315	1.97	1.96	1.94	1.92	1.92	1.92	1.90	1.98	1.99
10316	2.03	2.05	2.05	2.04	2.03	2.01	1.98	1.96	2.01
10317	2.11	2.10	2.08	2.08	2.07	2.06	1.99	2.08	2.12
10318	2.03	2.05	2.12	2.13	2.09	2.04	1.98	2.02	2.02
10319	2.02	2.05	2.13	2.10	2.08	2.03	1.97	2.07	2.10
10320	1.91	1.91	1.92	1.93	1.93	1.98	1.94	1.96	2.02
10321	2.09	2.04	2.05	2.08	2.10	2.12	2.10	2.04	2.05
10322	1.96	1.97	1.98	1.99	1.99	1.96	1.94	1.96	1.99
10323	1.95	1.98	2.04	2.01	1.94	1.94	1.87	1.95	1.98
10324	2.04	2.02	2.01	2.00	1.97	1.95	1.95	1.92	1.90
10325	1.91	1.90	1.91	1.97	1.97	1.96	2.00	2.06	2.02
10326	2.05	2.02	2.04	2.02	1.99	1.97	1.88	2.00	2.04
10327	2.10	2.12	2.14	2.14	2.08	2.03	1.92	1.88	1.91
10328	2.06	2.08	2.06	2.03	1.98	1.91	1.94	2.03	2.02
10329	1.92	1.92	1.96	1.94	1.95	1.95	1.95	1.98	2.01
10330	2.01	2.06	2.07	2.03	2.00	1.99	1.97	1.96	2.00
10331	2.10	2.10	2.14	2.13	2.10	2.07	2.00	2.00	2.00
10332	1.90	1.89	1.87	1.91	1.90	1.88	1.86	1.83	1.93
10333	2.04	2.06	2.10	2.08	2.02	2.01	2.00	1.94	1.89
10334	2.06	2.06	2.08	2.06	2.04	2.01	1.93	2.02	2.04
10335	1.98	1.94	1.93	1.93	1.91	1.90	1.88	1.82	1.82
10336	2.05	2.04	2.04	2.00	1.92	1.90	1.84	1.97	1.93
10337	2.04	2.06	2.02	2.05	1.98	1.91	1.92	1.87	1.94
10338	2.06	2.06	2.06	2.00	2.03	2.02	2.01	2.01	1.94
10339	1.99	1.98	1.97	2.00	2.00	1.97	1.96	1.90	1.93

TABLE IV. INITIAL TEST RF POWER GAIN.

Group A

$P_O = 30W$ $V_{CC} = 28V$ $T_C = 80°C$

G_T (dB)

UNIT NUMBER	f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10290	9.07	9.15	9.16	9.01	9.05	9.03	9.09	8.96	8.97
10291	8.93	8.95	8.97	8.92	8.91	8.90	9.03	8.98	9.02
10292	8.96	9.21	9.29	9.22	9.20	9.14	9.35	9.34	9.11
10293	9.45	9.57	9.18	8.94	8.87	8.83	9.09	8.97	8.67
10294	8.73	8.84	8.87	8.73	8.71	8.72	8.84	8.92	8.85
10295	9.12	9.33	9.06	8.95	8.74	8.83	9.07	9.10	8.96
10296	8.89	9.12	9.21	9.27	9.24	9.27	9.44	9.26	9.02
10297	8.52	8.72	8.74	8.65	8.57	8.61	8.86	8.96	8.76
10298	8.97	9.23	9.22	9.06	8.91	8.85	8.86	8.76	8.63
10299	9.20	9.38	9.29	9.13	9.00	8.99	8.95	8.97	9.20
10300	9.26	9.44	9.45	9.22	8.88	8.96	9.12	9.15	8.91
10301	9.02	9.20	9.12	8.85	8.72	8.69	8.97	9.12	9.03
10302	8.95	9.21	9.18	9.08	9.04	9.00	9.05	8.92	9.18
10303	8.97	9.18	9.14	8.92	8.86	8.75	8.97	8.98	9.05
10304	9.20	9.27	9.17	9.16	9.20	9.07	9.18	9.20	9.46
10305	9.02	9.32	9.35	9.18	9.05	9.00	9.16	9.32	9.31
10306	9.10	9.12	9.34	9.23	9.11	9.25	9.28	9.32	8.82
10307	9.49	9.63	9.59	9.46	9.39	9.28	9.27	9.20	9.28
10308	9.01	9.33	9.37	9.31	9.34	9.29	9.43	9.34	9.33
10309	9.38	9.61	9.55	9.32	9.26	9.23	9.36	9.47	9.46
10310	8.74	8.74	8.73	8.70	8.60	8.65	8.80	8.80	9.02
10311	8.59	9.05	9.15	8.89	9.26	8.94	8.94	8.82	8.81
10312	8.97	9.23	9.18	9.06	8.90	8.87	9.10	8.99	8.87
10313	9.16	9.21	9.21	9.24	9.07	9.02	8.75	8.78	8.97
10314	8.74	9.08	9.03	8.96	8.82	8.82	8.97	8.74	8.64

TABLE IV. INITIAL TEST RF POWER GAIN (CONTINUED).

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	G_T (dB) f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10315	9.04	9.34	9.36	9.17	9.07	8.99	9.09	9.03	9.04
10316	8.93	9.09	9.07	8.93	8.91	8.97	9.09	8.98	8.62
10317	9.09	9.32	9.21	9.20	9.04	9.09	9.12	9.03	8.98
10318	9.00	9.15	9.21	9.17	9.24	9.24	9.56	9.16	9.11
10319	9.32	9.18	9.17	9.02	9.00	9.00	9.17	9.01	8.82
10320	9.33	9.70	9.72	9.59	9.46	9.28	9.42	9.16	8.74
10321	8.83	9.16	9.15	8.92	8.79	8.63	8.74	8.71	8.76
10322	8.95	9.34	9.38	9.21	9.08	9.00	9.12	9.10	8.55
10323	9.13	9.33	9.16	8.96	8.89	8.84	8.95	8.96	9.07
10324	9.05	9.20	9.23	9.10	9.10	9.09	9.26	9.18	9.29
10325	9.20	9.43	9.32	9.03	8.84	8.75	8.92	8.81	8.86
10326	8.91	9.37	9.38	9.22	9.14	8.96	9.25	9.14	9.14
10327	8.66	8.95	8.85	8.73	8.64	8.75	9.03	9.11	8.91
10328	8.95	9.14	9.15	9.11	9.20	9.22	9.10	8.81	9.05
10329	9.20	9.60	9.61	9.36	9.23	9.09	9.14	9.08	9.04
10330	9.17	9.33	9.27	9.05	9.03	9.07	9.18	9.11	8.84
10331	8.80	8.88	8.74	8.63	8.64	8.69	8.82	8.66	8.64
10332	9.43	9.68	9.69	9.49	9.37	9.26	9.39	9.47	9.53
10333	9.36	9.24	9.09	9.07	9.07	9.04	9.02	8.89	9.03
10334	9.39	9.60	9.36	9.20	8.97	9.00	9.09	8.94	9.06
10335	8.89	8.98	9.03	9.00	8.93	8.97	9.05	9.08	9.00
10336	8.89	8.92	8.97	8.87	8.98	9.09	9.23	8.96	9.04
10337	9.11	9.09	9.01	8.87	8.89	9.08	9.38	9.11	9.20
10338	8.66	9.00	9.21	9.18	9.08	9.10	9.04	8.80	8.81
10339	9.41	9.60	9.52	9.27	9.12	9.20	9.35	9.39	9.31

TABLE V. INITIAL TOTAL CIRCUIT EFFICIENCY.

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	η (%) f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10290	55	54	53	53	55	55	55	54	54
10291	53	51	51	52	53	53	52	52	52
10292	52	51	52	52	53	53	54	55	56
10293	53	53	51	52	52	53	56	53	52
10294	54	53	53	54	55	56	57	56	52
10295	55	54	53	52	52	53	55	56	53
10296	52	52	53	54	55	55	57	55	53
10297	51	51	50	50	51	51	53	53	52
10298	53	53	52	52	51	52	52	51	49
10299	53	54	54	53	53	52	52	54	54
10300	53	53	54	54	53	53	52	55	52
10301	53	53	53	53	54	55	55	56	52
10302	53	56	54	54	54	55	55	56	56
10303	53	53	53	54	54	55	56	55	54
10304	55	55	56	55	56	55	55	55	56
10305	55	55	56	56	56	56	58	57	57
10306	53	53	54	55	54	54	52	53	51
13007	53	52	54	55	55	53	51	50	51
10308	53	53	54	54	54	54	55	54	56
10309	53	53	53	54	54	54	54	54	54
10310	52	53	53	53	53	54	54	57	59
10311	54	53	53	54	55	55	58	57	58
10312	57	57	57	58	56	56	57	56	55
10313	56	56	56	56	55	54	50	53	53
10314	54	53	53	55	56	57	56	56	55

TABLE V. INITIAL TOTAL CIRCUIT EFFICIENCY (CONTINUED).

Group A

P_O = 30W V_{CC} = 28V T_C = 80°C

UNIT NUMBER	η (%) f (MHz) 600	f (MHz) 650	f (MHz) 700	f (MHz) 750	f (MHz) 800	f (MHz) 850	f (MHz) 900	f (MHz) 950	f (MHz) 1000
10315	54	55	55	56	56	56	56	54	54
10316	53	52	52	52	53	53	54	55	53
10317	51	51	51	52	52	52	54	52	51
10318	53	52	50	50	51	53	54	53	53
10319	53	52	56	51	52	53	54	52	51
10320	56	56	52	55	55	54	55	55	53
10321	51	52	52	52	51	50	51	53	52
10322	55	54	54	54	54	55	55	55	54
10323	55	54	53	53	55	55	57	55	54
10324	53	53	53	53	54	55	55	56	56
10325	56	56	56	54	54	55	54	52	53
10326	52	53	53	53	54	54	57	54	53
10327	51	51	50	50	52	53	56	57	56
10328	52	52	52	53	54	56	55	53	53
10329	56	56	55	55	55	55	55	54	53
10330	53	52	52	53	53	54	54	55	54
10331	51	51	50	50	51	52	54	54	54
10332	56	57	58	56	56	57	58	50	55
10333	52	52	51	51	53	53	54	55	57
10334	52	52	52	56	53	53	56	53	53
10335	54	55	55	53	56	56	57	59	59
10336	52	53	53	52	56	56	58	54	55
10337	53	52	53	53	54	56	56	57	55
10338	52	52	52	53	53	53	53	53	55
10339	54	54	54	54	53	54	55	56	56

TABLE VI. SUMMARY OF R.F. PERFORMANCE OF PILOT RUN AMPLIFIERS.

F	GAIN (dB)			PHASE (Degrees)			EFFICIENCY (%)		
(MHz)	MIN	MAX	DELTA	MIN	MAX	DELTA	MIN	MAX	DELTA
600	8.52	9.49	0.97	-42	-58	16	51	57	6
650	8.72	9.70	0.98	116	132	16	51	57	6
700	8.73	9.72	0.99	-49	-68	19	50	58	8
750	8.63	9.59	0.96	113	132	19	50	58	8
800	8.57	9.46	0.89	-42	-60	18	51	56	5
850	8.61	9.29	0.68	121	135	14	50	57	7
900	8.74	9.56	0.82	-52	-70	18	50	58	8
950	8.66	9.47	0.81	97	113	16	50	59	9
1000	8.55	9.53	0.98	-82	-98	16	49	59	10

SECTION III - CONCLUSIONS

1. The production rates and through-put times imposed on this program are achievable and practical at this time.

2. Batch processing techniques developed and perfected during this production engineering contract produce a uniform and easily tuned amplifier.

3. The limits of SCS 409A for gain variation and relative phase are realizable with little difficulty but are at the practical limit for production of large numbers of amplifiers.

SECTION IV - PROGRAM FOR THE NEXT INTERVAL

1. Complete the environmental testing (Group B and Group C)

2. Seal the amplifiers

3. Complete the sweep driver

4. Prepare the final report

5. Ship amplifiers, sweep driver, Final Report and General Report on Step II

SECTION V - PUBLICATIONS, REPORTS, AND CONFERENCES

There were no outside publications applicable to the contract during this quarter.

Monthly Narrative Report Nos. 52, 53, and 54 were submitted during this period.

SECTION VI - IDENTIFICATION OF PERSONNEL

Eighteenth Quarter Efforts:

Name	Hours
Roger De Bloois	40
Ron Grassl	480
C. Hewett	180
	620*

*This effort has been expended but is not being charged against the contract.

APPENDIX A

ELECTRONICS COMMAND
TECHNICAL REQUIREMENTS

SCS-409A
19 April 1974

INTEGRATED CIRCUIT POWER AMPLIFIER 600-1000 MHz

1. SCOPE

1.1 This specification covers the detail requirements for addable integrated power amplifier modules.

1.2 Ratings (at T_{case} = 80°C)

	Symbol	Min.	Max.	Unit
Upper cutoff frequency	f_u	1000		MHz
Lower cutoff frequency	f_l		600	MHz
Transducer power gain	G_T	8		dB
Power output	P_o	30		W
Overall efficiency	η	45		%

2. APPLICABLE DOCUMENTS

2.1 The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein:

SPECIFICATIONS

Military

MIL-P-11268	Parts, Materials, and Processes used in Electronic Equipment
MIL-M-38510	Microcircuits, General Specification for Electronics Command
SC-A-46600	Preproduction Sample Approval in Lieu of Qualification Requirements in Specifications for Semiconductor Devices and Electron Tube

STANDARDS

Military

MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-883	Test Methods and Procedures for Microelectronics

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. REQUIREMENTS

3.1 General. Requirements shall be in accordance with MIL-M-38510, Class B and as otherwise specified herein. Integrated circuit techniques shall be used for power amplifier circuit fabrication. Passive network matching structures shall be realized by using either microstrip on alumina or thin/thick film lumped elements formed on a single substrate or a combination of these two approaches. Utilization of batch processing techniques for the fabrication of the amplifier circuit is encouraged. The amplifier shall be designed to work from a 50 ohm source into a 50 ohm load.

3.2 Test fixture. At the time of delivery of sample circuits for evaluation, the contractor shall supply all test jigs necessary for determining electrical characteristics.

3.3 Supply voltage. The supply voltage shall be 28 VDC and the circuit performance shall be optimized for this voltage. The module shall operate within the performance requirements specified in subgroup 2 of the Group A inspection at a 30 VDC supply.

3.4 Thermal resistance. The amplifier module shall have a thermal resistance of no greater than 6° C/watt. (4.5)

3.5 Performance characteristics. Performance characteristics shall conform to the requirements of 1.2 and Tables I and II.

3.6 Markings. The following minimum markings shall apply; type number manufacturer's identification and date code.

3.7 Package. Unless specifically approved by the procuring activity, no lacquers, varnishes, greases or other organic materials shall be used inside the package and no dessicants shall be contained in the package. The overall package shall be hermetically sealed. Metals used for leads, studs and cases shall be corrosion resistant type or shall be placed or treated to resist corrosion.

3.8 Parts, materials, and processes. Unless otherwise specified, all parts, materials and processes shall conform to MIL-P-11268.

3.9 Workmanship. Workmanship shall conform to Requirement 9 of MIL-STD-454.

4. QUALITY ASSURANCE PROVISIONS

4.1 Sampling and inspection. Except as otherwise specified herein, the responsibility for inspection, general procedures for acceptance, classification of inspection and inspection conditions and methods of test should be in accordance with MIL-M-38510.

4.2 Qualification inspection. Qualification inspection shall consist of examinations and tests specified in Tables I, II, and III.

4.2.1 Preproduction sample approval. The preproduction sample approval requirements of SC-A-46600 hereby replace any qualification requirements referable to the product covered herein.

4.3 Quality conformance inspection. Quality conformance inspection shall consist of Groups A, B, and C inspections.

4.3.1 Group A inspection. Group A inspection shall consist of the examinations and tests specified in Table I.

4.3.2 <u>Group B inspection</u>. Group B inspection shall consist of the examinations and tests specified in Table II.

4.3.3 <u>Group C inspection</u>. Group C inspection shall consist of the examinations and tests specified in Table III.

4.4 <u>Methods of examination and test</u>. Methods of examination and test shall be as specified in Tables I, II, and III and as follows: Group C inspection shall be made on six samples selected from each one hundred (100) units produced.

4.4.1 <u>Inspection conditions</u>. All measurements shall be made at a case temperature of 80° C. unless otherwise specified.

Table I - Group A Inspection

Examination or Test	MIL-STD-883 Method	Specific Conditions	LTPD	Max-Acc.	Symbol	Limits Min.	Limits Max.	Unit
<u>Subgroup 1</u>								
Visual and mechanical examination	2008	Note 6.1						
<u>Subgroup 2</u>								
Power output		See 4.4.2.1			P_o	30		watts
Total efficiency		See 4.4.2.2			n	45		%
Transducer power gain		See 4.4.2.3			G_T	8	11	dB
NOTE: Limit on max. gain for over voltage test shall be 12 dB.								
<u>Subgroup 3</u>								
Module to module gain variation		See 4.4.2.4					1	dB
Module to module phase variation		See 4.4.2.5					20°	

Table II - Group B Inspection

Examination or Test	MIL-STD-883 Method	Specific Conditions	LTPD	Max-Acc.	Symbol	Limits Min.	Limits Max.	Unit
<u>Subgroup 1</u>								
Internal visual (precap)	2010	Test Condition C						
<u>Subgroup 2</u>								
Temperature cycling	1010	Test condition B 5 cycles						
Thermal shock	1011	Test condition A 5 cycles						
Seal	1014	Test conditions Fine condition A Gross condition C						
Moisture resistance	1004	Omit initial conditioning						
<u>Subgroup 3</u>								
Shock	2002	Condition A	Pulse length 0.4 msec					
Vibration	2007							
Acceleration	2001							
<u>Subgroup 4</u>								
High temperature storage	1008	T_A = 100°C. 1000 hrs.						

Table II - Group B Inspection Con't.

Examination or Test	MIL-STD-833 Method	Specific Conditions	LTPD	Max-Acc.	Symbol	Limits Min.	Limits Max.	Unit
<u>Subgroup 5</u>								
Intermittent	1006	Condition B See 4.4.2.6						
Steady state	1005	Condition B See 4.4.2.7						
<u>Subgroup 6</u>								
VSWR End points for		See 4.4.2.8						
<u>Subgroups 2 thru 6</u>								
Change in power output		See 4.4.2.1			$\Delta \frac{P_o}{P_o}$	±10		%
Change in transducer power gain		See 4.4.2.3			ΔG_T	± 1		dB

Table III - Group C Inspection

Examination or Test	MIL-STD-833 Method	Specific Conditions	LTPD	Max-acc.	Symbol	Limits Min.	Limits Max.	Unit
Thermal resistance		See 4.5					6	°C/watt
100 watt amplifier		See 4.6						
Operating temperature characteristic		See 4.7						

4.4.2 Electrical test measurements. All units will be subjected to the electrical tests measurements with a supply voltage of 28 VDC. In addition, 20% of the units will be subjected to the electrical test measurements with a supply voltage of 30 VDC.

4.4.2.1 RF power output. The RF power output shall be measured across the frequency band with a supply voltage of 28 VDC. The load and source impedances shall be 50 ohms, resistive. No matching or tuning shall be used between the source and the input of the amplifier and between the load and output of the amplifier.

This measurement shall be performed as a continuous swept frequency across the band or as discrete frequency measurements at 50 MHz frequency intervals.

4.4.2.2 Total circuit efficiency. The total circuit efficiency shall be measured across the band at 50 MHz intervals at P_o equal to 30 watts under the conditions described in 4.4.2.1. The total circuit efficiency (n) is determined by:

$$n = \frac{P_o \times 100\%}{V_{CC}\ I_{CC}}$$

where I_{CC} is the total dc current in amperes being delivered by the supply voltage.

4.4.2.3 RF transducer power gain. The large signal transducer power gain (G_T) shall be measured across the band under the conditions described in 4.4.2.1 at P_o equal to 30 watts. The transducer power gain shall be determined using:

$$G_T\ (dB) = 10 \log \left(\frac{P_o}{P_{avs}} \right)$$

with P_o being held constant for this measurement.

This measurement shall be performed as a continuous swept frequency across the band or as discrete frequency measurements at 50 MHz frequency intervals.

4.4.2.4 Module to module gain variation. At any single frequency within the operating bandwidth the gain variation between any two modules (that is among all modules) shall be measured in accordance with 4.4.2.3.

4.4.2.5 Module to module phase variation. Over the operating bandwidth the amplifier phase shift shall be measured under the operating conditions described in 4.4.2.1 and at P_o equal to 30 watts. The module to module phase variation shall be defined as the amplifier phase shift between any two modules (that is among all modules) measured at 50 MHz increments within the operating bandwidth.

4.4.2.6 Intermittent life test. The intermittent life test shall be performed under the following pulse conditions.

Peak output power	= 30 watts (rms)
Pulse width	= 1 msec
Duty cycle	= 10%
Supply voltage	= 28V (continuous)
Heat sink temperature	= 80°C.
Frequency	= 1000 MHz ± 1%
Test duration	= 1000 hours

4.4.2.6.1 The MTBF for the module shall be calculated based on the results of the above test.

4.4.2.7 Steady state life. An equal number of devices as tested under 4.4.2.6 shall be tested under steady state operation with the following conditions.

P_o	= 30 Watts (rms)
Supply voltage	= 28V
Heat sink temperature	= 80°C.
Frequency	= 1000 MHz ± 1%
Test duration	= 1000 hrs.

4.4.2.7.1 The MTBF for the module shall be calculated based on the results of the above test.

4.4.2.8 VSWR testing. The power amplifier shall withstand output mismatching under a VSWR of 3:1 at all phase angles of the reflection coefficient at the frequencies f_u, and f_1 with a P_{avs} producing P_o equal to 30 watts under matched output conditions.

4.5 Thermal resistance. The amplifier module shall be IR scanned under rated operating conditions to insure that the maximum thermal resistance is no greater than 6°C/watt. The maximum chip temperature found during the scanning shall be used to determine the thermal resistance. (3.4)

4.6 100 watt amplifier. Four amplifier modules shall be used to construct a 100 watts power amplifier. The amplifiers shall be appropriately combined and heat sunk to demonstrate performance. Power gain, efficiency and power output capability shall be measured across the 600 - 1000 MHz band to determine compliance with Section 3.

4.7 Operating temperature characteristics. Three modules shall be characterized for ambient temperatures of -40°C., 0°C., +40°C., +80°C. Power gain, efficiency and output power capability over the frequency range shall be measured to determine compliance with Section 3. Case temperature shall be maintained at the ambient throughout these tests.

5. PREPARATION FOR DELIVERY

5.1 Preparation for delivery. Preparation for delivery shall conform to MIL-M-38510.

6. NOTES

6.1 Dimensions of amplifier module to be determined.

6.2 Abbreviations and symbols.

6.2.1 The following abbreviations and symbols are used herein.

E_g = generator voltage

R_g = generator impedance, R_g = 50 ohms

G_T = transducer power gain

P_o = power output

η = total circuit efficiency

V_{CC} = DC supply voltage

I_{CC} = DC supply current

P_{avs} = power available from source = $E_g{}^2/4R_g$

f_u = upper frequency (1000 MHz)

f_1 = lower frequency (600 MHz)

ΔP_o = change in power output (P_o) in watts

ΔG_T = change in transducer power gain (G_T) in dB.

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