Second Semester Examination
2018/2019 Academic Session

June 2019

EEE322 – RF & Microwave Engineering
(Kejuruteraan Gelombang Mikro & RF)

Duration : 2 hours
(Masa : 2 jam)

Please ensure that this examination paper consists of TEN (10) pages and NINE (9) pages of printed appendix material before you begin the examination.

[Sila pastikan bahawa kertas peperiksaan ini mengandungi SEPULUH (10) muka surat dan SEMBILAN (9) muka surat lampiran yang bercetak sebelum anda memulakan peperiksaan ini.]

Instruction: This question paper consists of **FOUR (4)** questions. Answer **ALL** questions. All questions carry the same marks.

[Arahan: *Kertas soalan ini mengandungi* ***EMPAT (4)*** *soalan. Jawab* ***SEMUA*** *soalan. Semua soalan membawa jumlah Markah yang sama.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. A lossless microstrip line has resistance with a capacitance of 20 pF/m, inductance 100 nH/m, relative permittivity of 3.9 and operating frequency at 2 GHz. The line is terminated with an antenna that has a reflection coefficient of $0.3207 + j0.3183$.
(Note: Only one Smith chart is required for this question. Smith Chart is attached in Appendix 1. For Smith chart solutions, write down the steps clearly in the answer sheet and marks the label in the Smith chart).

Satu talian mikrojalur tanpa kehilangan dengan kapasitan sebanyak 20 pF/m, kearuhan = 100 nH/m, kebolehtelapan kebertelusan 3.9 dan beroperasi pada frekuensi 2 GHz. Talian ditamatkan dengan antena yang mempunyai nilai pantulan pekali sebanyak $0.3207 + j0.3183$
(Nota: Soalan ini hanya memerlukan hanya satu carta Smith. Carta Smith dikepilkan di Lampiran 1. Untuk penyelesaian menggunakan carta Smith, catatkan cara-cara penyelesaian dengan jelas didalam kertas jawapan dan labelkan dalam carta Smith).

(a) Determine,
Hitungkan,

(i) Characteristic impedance for microstrip line.

Galangan kecirian untuk talian mikrojalur.

(5 marks/*markah*)

(ii) The load antenna impedance, standing wave ratio and admittance by using Smith chart.

Galangan beban antena, nisbah gelombang pegun dan beban menggunakan carta Smith.

(20 marks/*markah*)

(iii) The return loss.
Kehilangan pantulan.

(5 marks/*markah*)

(b) Design two lumped element matching network to match between microstrip line and antenna at 2 GHz frequency using Smith Chart method.

Rekabentuk dua jenis rangkaian padanan unsur tergumpal untuk pemadanan antara talian mikrojalur dan antena pada frekuensi 2 GHz menggunakan cara carta Smith.

(i) Draw and determine the actual lumped components in the matching network operating at 2 GHz for both design.

Lukiskan dan hitungkan nilai sebenar unsur tergumpal untuk rangkaian padanan beroperasi pada 2 GHz untuk kedua-dua rekabentuk.

(50 marks/*markah*)

(ii) Based on two matching circuit networks, propose the best design and state the reasons.

Berdasarkan dua jenis rekabentuk padanan rangkaian, cadangkan rekabentuk terbaik dan nyatakan sebab-sebabnya.

(20 marks/*markah*)

2. Each stage in a RF Receiver Front End comes with challenges of its own. For example, design limits imposed by additional fringing field capacitances and PCB manufacturing tolerance on specific transmission line can degrade its performance.

   Setiap peringkat dalam mereka bentuk seni bina penerima akhir depan RF mempunyai cabarannya. Sebagai contoh, kekangan dalam mereka bentuk adalah bebanan penambahan nilai kapasitan medan terpinggir dan toleran dalam pembuatan PCB mampu menghadkan dan menurunkan prestasi sesebuah talian penghantar.

   (a) Microwave filter functions to selectively pass or attenuate a particular band of frequencies and is a crucial element of the receiver front end architecture.

   Penyaring gelombang mikro berfungsi untuk membenarkan atau melemahkan suatu jalur atau frekuensi-frekuensi secara selektif dan adalah elemen penting dalam seni bina penerima akhir depan.

   (i) Design a 5-element low-pass filter with a 3 dB point at 900 MHz using inductor (L) and capacitor (C) component. The filter is to have a Butterworth response, and is to work between terminating impedances of 50 Ω.

   Reka bentuk satu penapis lulus rendah 5-elemen dengan titik 3 dB pada 900 MHz menggunakan komponen L dan C. Penapis perlu mempunyai tindak balas Butterworth dan dipadankan pada galangan 50 Ω.

   (30 marks/*markah*)

   (ii) Design a 5-element high-pass filter with a 3 dB point at 900 MHz using inductor (L) and capacitor (C) component. The filter is to have a Butterworth response, and is to work between terminating impedances of 50 Ω.

   Reka bentuk satu penapis lulus tinggi 5-elemen dengan titik 3 dB pada 900 MHz menggunakan komponen L dan C. Penapis perlu mempunyai tindak balas Butterworth dan dipadankan pada galangan 50 Ω.

   (30 marks/*markah*)

...5/-

(b) Directional coupler is normally used to split the input signal and distributed power by isolating, eliminating or combining signals in microwave signal routing and radio frequency.

Pengganding berarah biasanya digunakan untuk membahagikan isyarat input dan kuasa edaran dengan kaedah pengasingan, penyingkiran atau penggabungan isyarat di dalam penghalaan isyarat gelombang mikro dan frekuensi radio.

(i) Describe, using illustrations, a hybrid ring coupler showing all 4 ports and relevant information.

Terangkan, menggunakan gambarajah, penganding lingkaran hibrid dengan menunjukkan kesemua 4 port dan informasi yang berkaitan.

(20 marks/*markah*)

(ii) Define the Scattering Parameter (S-parameter) of a reciprocal 20 dB hybrid ring coupler.

Takrifkan parameter berselerak (S-parameter) untuk 20 dB penganding lingkaran hibrid yang bertimbal balik.

(20 marks/*markah*)

3. (a) A transmission line is often represented as two-wired line as illustrated in Figure 1. Draw the lumped equivalent circuit based on Figure 1. Label the components clearly.

Talian penghantaran sering digambarkan sebagai dua wayar talian seperti yang ditunjukkan dalam Rajah 1. Lukiskan litar setara tergumpal berdasarkan Rajah 1. Label semua komponen dengan jelas.

(10 marks/*markah*)

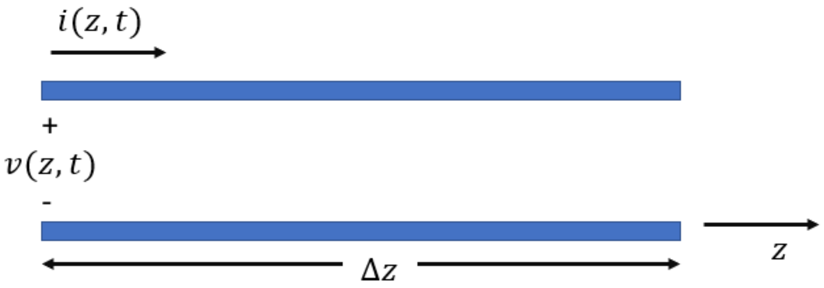


Figure 1: Voltage and current definition for an incremental length of transmission line.

Rajah 1: Definisi voltage dan arus dengan tokokan panjang untuk penghantaran talian.

(b) A four-port network has scattering parameters as shown below.

Di bawah ialah rangkaian empat liang serakan.

$$S = \begin{bmatrix} 0.6\angle 45° & 0.43 + j0.43 & 0.3\angle 45° & 0.14e^{j45} \\ 0.6\angle 45° & 0 & 0 & 0.4\angle 45° \\ 0.3e^{j45} & 0 & 0 & 0.7\angle 45° \\ 0.14\angle 45° & 0.4e^{j45} & 0.5 + j0.5 & 0 \end{bmatrix}$$

(i) Is the network reciprocal?

Adakah rangkaian ini salingan?

(10 marks/*markah*)

(ii) Is the network lossless?

Adakah rangkaian ini tanpa kehilangan?

(10 marks/*markah*)

(iii) Determine the reflection coefficient seen at port 1 if a short circuit is placed at port 4 and all other ports are terminated with matched loads?

Hitung pantulan pekali yang dilihat dari port 1 jika litar tertutup ditempatkan pada port 4 dan port-port yang lain ditamatkan dengan padanan beban.

(20 marks/*markah*)

(c) Explain the concept of microwave diode mixer.

Terangkan konsep pencampur diod gelombang mikro.

(10 marks/*markah*)

(d) A superheterodyne receiver must cover the range from 220 to 224 MHz. The first IF is 10.7 MHz; the second IF is 1.5 MHz. Assuming a local oscillator frequency higher than the input RF frequency, find:

Penerima superheterodin perlu beroperasi pada 220 hingga 224 MHz. Frekuensi IF pertama adalah 10.7 MHz manakala frekuensi kedua adalah 1.5 MHz. Andaikan frekuensi pengayun tempatan adalah lebih tinggi daripada masukan frekuensi RF, cari:

(i) The LO tuning range

Julat Penalaan Pengayun tempatan

(ii) The frequency of the second oscillator

Frekuensi pengayun kedua

(iii) The first IF image frequency range

Julat Frekuensi IF pertama

(15 marks/*markah*)

(e) Design the 2.4 GHz microwave mixer using branch line coupler topology or rat-race coupler on Duroid 4003C with the thickness of 0.813 mm and ε_r of 3.38.

Reka bentuk pencampur gelombang mikro pada 2.4 GHz menggunakan topologi pengganding talian cabang atau pengganding larian tikus pada Duroid 4003C dengan ketebalan sebanyak 0.813 mm dan ε_r sebanyak 3.38.

(25 marks/*markah*)

4. Referring to a block diagram in Figure 2, design a 2.5 GHz wireless transmitter having the specifications as in Table 1. The information for the components that is required for the design is attached in Appendix 2 to Appendix 7.

Merujuk kepada gambarajah blok dalam Rajah 2, reka bentuk pemancar wayarles 2.5 GHz mempunyai spesifikasi seperti dalam Jadual 1. Informasi rekabentuk untuk komponen ini dikepilkan di Lampiran 2 sehingga Lampiran 7.

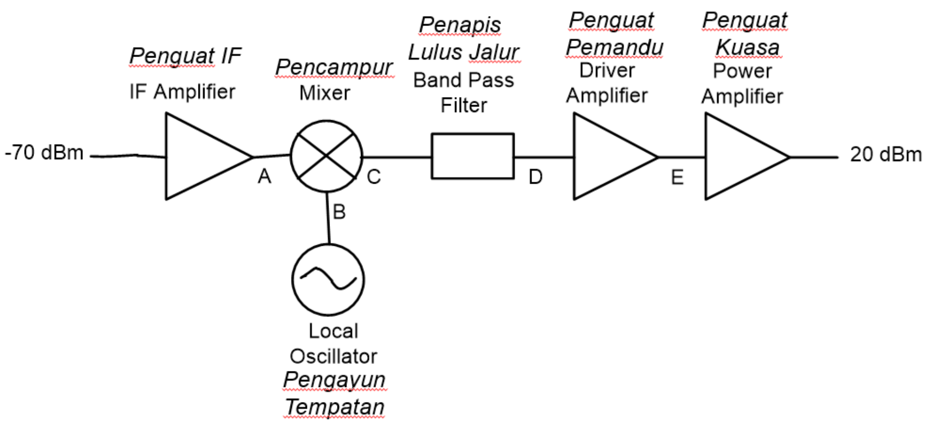


Figure 2: Block diagram of the 2.5 GHz wireless transmitter
Rajah 2: Gambarajah blok pemancar wayarles 2.5 GHz

Table 1: Specification for 2.5 GHz wireless transmitter
Jadual 1: Spesifikasi pemancar wayarles pada 2.5 GHz

TX Frequency Frekuensi TX	IF Frequency Frekuensi IF	Bandwidth Lebarjalur	TX Power Kuasa TX
2.5 GHz	140 MHz	40 MHz	20 dBm

(a) Determine the gain of the IF amplifier and power level at point A (assume minimum input power to the mixer RF port is -30 dBm?

Tentukan gandaan penguat IF dan aras kuasa pada titik A (anggapkan kuasa masukan minima pada liang RF pencampur adalah -30 dBm)

(20 marks/markah)

(b) What is the frequency of the Local Oscillator and minimum output power at point B?

Apakah frekuensi Pengayun Tempatan dan kuasa keluaran minima pada titik B?

(20 marks/*markah*)

(c) Based on the mixer specification and minimum Local Oscillator drive power, what is the mixer output power at point C.

Berdasarkan spesifikasi pencampur dan kuasa pandu minima Pengayun Tempatan, apakah kuasa keluaran pencampur pada titik C.

(20 marks/*markah*)

(d) Referring to the datasheet of the Band Pass Filter, what is the power level at point D?

Merujuk kepada helaian data Penapis Lulus Jalur, apakah aras kuasa pada titik D?

(15 marks/*markah*)

(e) How many Driver Amplifier are required to drive the power amplifier to deliver 20 dBm?

Berapakah bilangan Penguat Pemandu yang diperlukan untuk memandu Penguat Kuasa untuk memberikan 20 dBm?

(15 marks/*markah*)

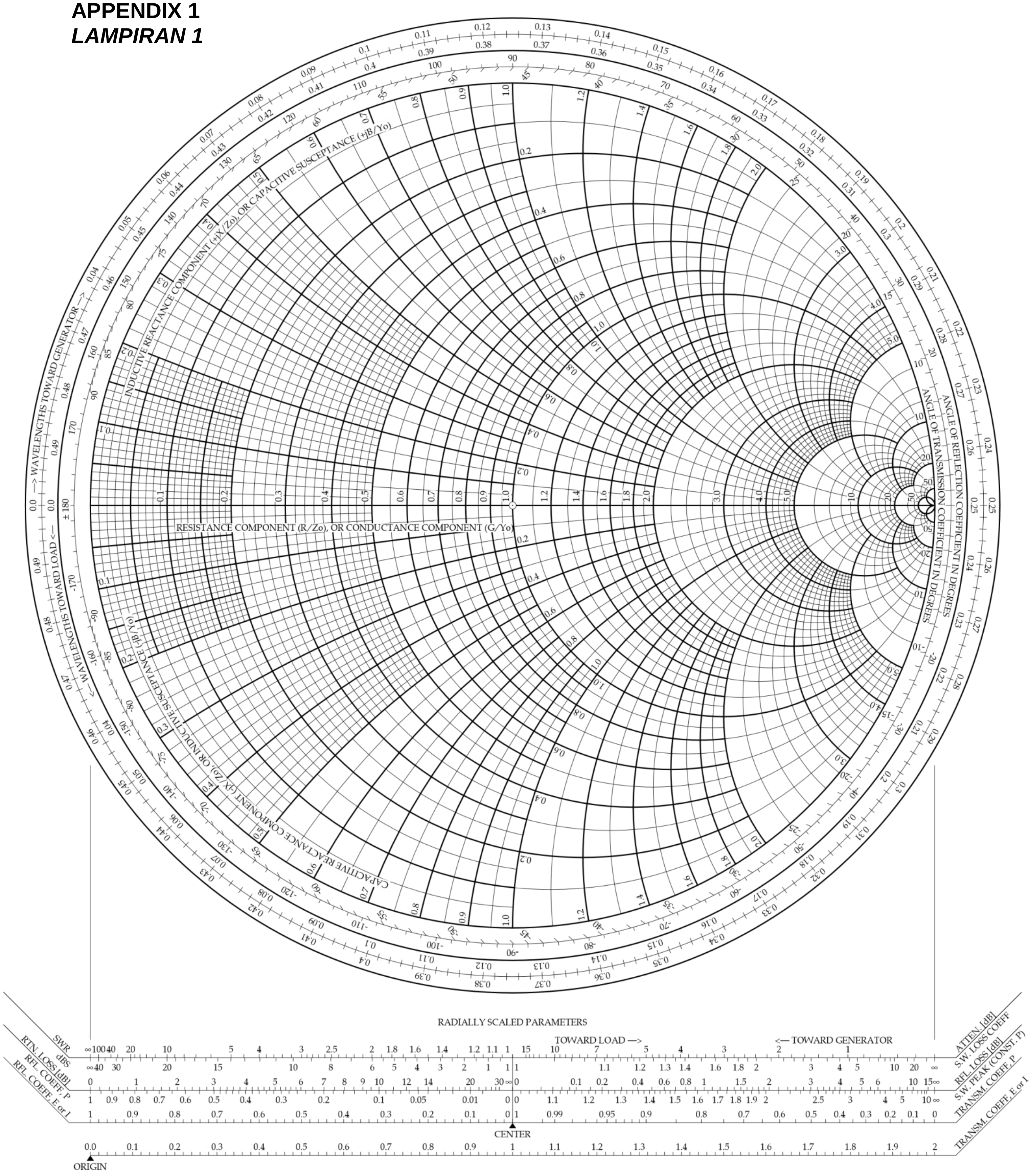
(f) How much gain is required for the Power Amplifier?

Berapakah gandaan yang diperlukan untuk Penguat Kuasa.

(10 marks/*markah*)

-oooOooo-

APPENDIX 1
LAMPIRAN 1



APPENDIX 2
LAMPIRAN 2

MIXER
PENCAMPUR

Data Sheet **ADL5363**

SPECIFICATIONS

V_S = 5 V, I_S = 100 mA, T_A = 25°C, f_{RF} = 2535 MHz, f_{LO} = 2738 MHz, LO power = 0 dBm, Z_O = 50 Ω, unless otherwise noted.

Table 2.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
RF INPUT INTERFACE					
Return Loss	Tunable to >20 dB over a limited bandwidth		16		dB
Input Impedance			50		Ω
RF Frequency Range		2300		2900	MHz
OUTPUT INTERFACE					
Output Impedance	Differential impedance, f = 200 MHz		33||-0.3		Ω||pF
IF Frequency Range		dc		450	MHz
DC Bias Voltage[1]	Externally generated	3.3	5.0	5.5	V
LO INTERFACE					
LO Power		−6	0	+10	dBm
Return Loss			15		dB
Input Impedance			50		Ω
LO Frequency Range		2330		3350	MHz
POWER-DOWN (PWDN) INTERFACE[2]					
PWDN Threshold			1.0		V
Logic 0 Level				0.4	V
Logic 1 Level		1.4			V
PWDN Response Time	Device enabled, IF output to 90% of its final level		160		ns
	Device disabled, supply current <5 mA		220		ns
PWDN Input Bias Current	Device enabled		0.0		μA
	Device disabled		70		μA

[1] Apply the supply voltage from the external circuit through the choke inductors.
[2] The PWDN function is intended for use with $V_S \le 3.6$ V only.

APPENDIX 2 - Continue
LAMPIRAN 2 - Sambungan

5 V PERFORMANCE

V_S = 5 V, I_S = 100 mA, T_A = 25°C, f_{RF} = 2535 MHz, f_{LO} = 2738 MHz, LO power = 0 dBm, VGS0 = VGS1 = 0 V, and Z_O = 50 Ω, unless otherwise noted.

Table 3.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE					
Power Conversion Loss	Including 1:1 IF port transformer and PCB loss		7.7		dB
SSB Noise Figure			7.6		dB
Input Third-Order Intercept (IIP3)	f_{RF1} = 2534.5 MHz, f_{RF2} = 2535.5 MHz, f_{LO} = 2738 MHz, each RF tone at 0 dBm		31		dBm
Input Second-Order Intercept (IIP2)	f_{RF1} = 2535 MHz, f_{RF2} = 2585 MHz, f_{LO} = 2738 MHz, each RF tone at 0 dBm		62		dBm
Input 1 dB Compression Point (IP1dB)[1]	Exceeding 20 dBm RF power results in damage to the device		25		dBm
LO-to-IF Leakage	Unfiltered IF output		−22		dBm
LO-to-RF Leakage			−32		dBm
RF-to-IF Isolation			−44		dBc
IF/2 Spurious	−10 dBm input power		−61		dBc
IF/3 Spurious	−10 dBm input power		−70		dBc
POWER SUPPLY					
Positive Supply Voltage		4.5	5	5.5	V
Quiescent Current	V_S = 5 V		100		mA

[1] Exceeding 20 dBm RF power results in damage to the device.

3.3 V PERFORMANCE

V_S = 3.3 V, I_S = 60 mA, T_A = 25°C, f_{RF} = 2535 MHz, f_{LO} = 2738 MHz, LO power = 0 dBm, R9 = 226 Ω, VGS0 = VGS1 = 0 V, and Z_O = 50 Ω, unless otherwise noted.

Table 4.

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
DYNAMIC PERFORMANCE					
Power Conversion Loss	Including 1:1 IF port transformer and PCB loss		7.4		dB
SSB Noise Figure			6.8		dB
Input Third-Order Intercept (IIP3)	f_{RF1} = 2534.5 MHz, f_{RF2} = 2535.5 MHz, f_{LO} = 2738 MHz, each RF tone at 0 dBm		26		dBm
Input Second-Order Intercept (IIP2)	f_{RF1} = 2535 MHz, f_{RF2} = 2585 MHz, f_{LO} = 2738 MHz, each RF tone at 0 dBm		56		dBm
POWER SUPPLY					
Positive Supply Voltage			3.3		V
Quiescent Current	V_S = 5 V		60		mA

APPENDIX 3
LAMPIRAN 3

OSCILLATOR
PENGAYUN

ANALOG DEVICES

HMC385LP4 / 385LP4E

v02.0705

MMIC VCO w/ BUFFER AMPLIFIER, 2.25 - 2.5 GHz

RoHS✓ EARTH FRIENDLY

Typical Applications

Low noise MMIC VCO w/Buffer Amplifier for:

- Wireless Infrastructure
- Industrial Controls
- Test Equipment
- Military

Features

Pout: +4.5 dBm

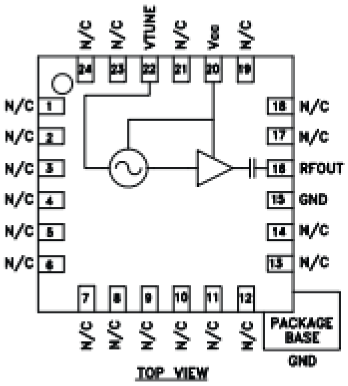
Phase Noise: -115 dBc/Hz @100 KHz

No External Resonator Needed

Single Supply: 3V @ 35 mA

QFN Leadless SMT Package, 16 mm²

Functional Diagram



General Description

The HMC385LP4 & HMC385LP4E are GaAs InGaP Heterojunction Bipolar Transistor (HBT) MMIC VCOs with integrated resonators, negative resistance devices, varactor diodes, and buffer amplifiers. Covering 2.25 to 2.5 GHz, the VCO's phase noise performance is excellent over temperature, shock, vibration and process due to the oscillator's monolithic structure. Power output is 4.5 dBm typical from a single supply of 3V @ 35mA. The voltage controlled oscillator is packaged in a low cost leadless QFN 4x4 mm surface mount package.

Electrical Specifications, T_A = +25° C, Vcc = +3V

Parameter	Min.	Typ.	Max.	Units
Frequency Range		2.25 - 2.5		GHz
Power Output	1.5	4.5		dBm
SSB Phase Noise @ 100 kHz Offset, Vtune= +5V @ RF Output		-115		dBc/Hz
Tune Voltage (Vtune)	0		10	V
Supply Current (Icc) (Vcc = +3.0V)		35		mA
Tune Port Leakage Current			10	µA
Output Return Loss		9		dB
Harmonics 2nd 3rd		 -7 -23		 dBc dBc
Pulling (into a 2.0:1 VSWR)		2.0		MHz pp
Pushing @ Vtune= +5V		-2		MHz/V
Frequency Drift Rate		0.25		MHz/°C

APPENDIX 4
LAMPIRAN 4

AMPLIFIERS
PENGUAT

ANALOG DEVICES

RoHS✓ EARTH FRIENDLY

HMC680LP4 / 680LP4E

v03.0609

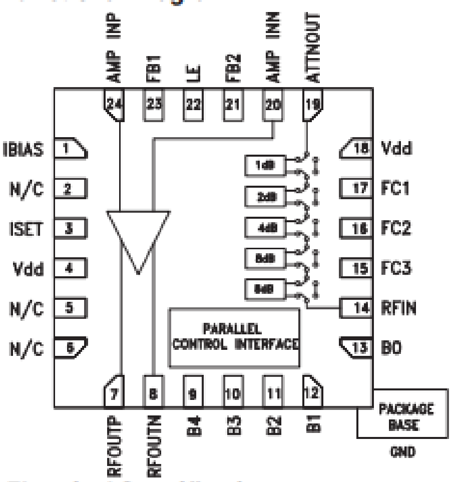
BiCMOS MMIC 5-BIT DIGITAL VARIABLE GAIN AMPLIFIER, 30 - 400 MHz

Typical Applications

The HMC680LP4(E) is ideal for:

- Cellular/3G Infrastructure
- WiBro / WiMAX / 4G
- Microwave Radio & VSAT
- Test Equipment and Sensors
- IF & RF Applications

Functional Diagram



Features

TTL/CMOS compatible parallel or latched parallel control interface

High Output IP3: +40 dBm (At all gain settings)

Low Noise Figure: 5 dB

Wide Gain Control Range: 23 dB

24 Lead 4x4 mm SMT Package: 16 mm²

Excellent State & Step Accuracy (±0.05 dB)

General Description

The HMC680LP4(E) is a digitally controlled variable gain amplifier which operates from 30 to 400 MHz, and can be programmed to provide -4 dB to +19 dB of gain, in 1 dB steps. The HMC680LP4(E) delivers noise figure of 5 dB in its maximum gain state, with output IP3 of up to +40 dBm in any state. This high linearity DVGA also provides a differential RF output which can be used to interface directly with SAW filters in Tx and Rx applications, and with digital to analog converters in Rx chains. The HMC680LP4(E) is housed in a RoHS compliant 4x4 mm QFN leadless package, and is CMOS/ TTL compatible.

Electrical Specifications, T_A = +25° C, 50 Ohm System, Vdd = +5V

Parameter		Min.	Typ.	Max.	Units
Frequency Range			30 - 400		MHz
Gain (Maximum Gain State)		17	19		dB
Gain Control Range			23		dB
Input Return Loss			12		dB
Output Return Loss			13		dB
Gain Accuracy: (Referenced to Maximum Gain State) All Gain States			± (0.15 + 3% of Gain Setting) Max.		dB
Output Power for 1dB Compression		23	25		dBm
Output Third Order Intercept Point (Two-Tone Output Power= +5 dBm Each Tone) [1]			40		dBm
Output Second Order Intercept Point (Two-Tone Output Power= +5 dBm Each Tone) [1]			65		dBm
Harmonics	2nd Order 3rd Order		70 75		dBc dBc
Step Accuracy (Referenced to Maximum Gain State)			±0.2		dB
Noise Figure (max gain state)			5		dB
Switching Characteristics	tRise, tFall (10/90% RF) tON, tOFF (50% CTL to 10/90% RF)		11 13		ns ns
Control Supply Current Idd			4	5	mA
Amp Supply Current (RFOUTP)			122	135	mA
Amp Supply Current (RFOUTN)			122	135	mA

[1] Test frequency 50 MHz

APPENDIX 5
LAMPIRAN 5

ANALOG DEVICES

2.3 GHz to 4.0 GHz ¼ Watt RF Driver Amplifier

Data Sheet **ADL5321**

FEATURES

Operation: 2.3 GHz to 4.0 GHz
Gain of 14.0 dB at 2.6 GHz
OIP3 of 41.0 dBm at 2.6 GHz
P1dB of 25.7 dBm at 2.6 GHz
Noise figure: 4.0 dB at 2.6 GHz
Power supply voltage: 3.3 V to 5 V
Power supply current: 37 mA to 90 mA
Dynamically adjustable bias
No bias resistor required
Thermally efficient, MSL-1 rated SOT-89 package
Operating temperature range: −40°C to +105°C
ESD rating of ±2 kV (Class 3A)

APPLICATIONS

Wireless infrastructure
Automated test equipment
ISM/AMR applications

FUNCTIONAL BLOCK DIAGRAM

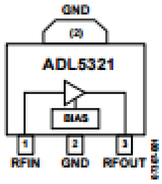


Figure 1.

GENERAL DESCRIPTION

The ADL5321 incorporates a dynamically adjustable biasing circuit that allows for the customization of OIP3 and P1dB performance from 3.3 V to 5 V without the need for an external bias resistor. This feature gives the designer the ability to tailor driver amplifier performance to the specific needs of the design. This feature also creates the opportunity for dynamic biasing of the driver amplifier, where a variable supply is used to allow for full 5 V biasing under large signal conditions and then can reduce the supply voltage when signal levels are smaller and lower power consumption is desirable. This scalability reduces the need to evaluate and inventory multiple driver amplifiers for different output power requirements from 22 dBm to 26 dBm output power levels.

The ADL5321 is also rated to operate across the wide temperature range of −40°C to +105°C for reliable performance in designs that experience higher temperatures, such as power amplifiers. The ¼ watt driver amplifier covers the 2.3 GHz to 4.0 GHz wide frequency range and only requires a few external components to be tuned to a specific band within that wide range. This high performance, broadband RF driver amplifier is well suited for a variety of wired and wireless applications including cellular infrastructure, ISM band power amplifiers, defense equipment, and instrumentation equipment. A fully populated evaluation board is available.

The ADL5321 also delivers excellent adjacent channel leakage ratio (ACLR) vs. P_{OUT}. For output powers up to 10 dBm rms, the ADL5321 adds very little distortion to the output spectrum. At 2.6 GHz, the ACLR is −59 dB and a relative constellation error of −46.6 dB (<0.5% EVM) at an output power of 10 dBm rms.

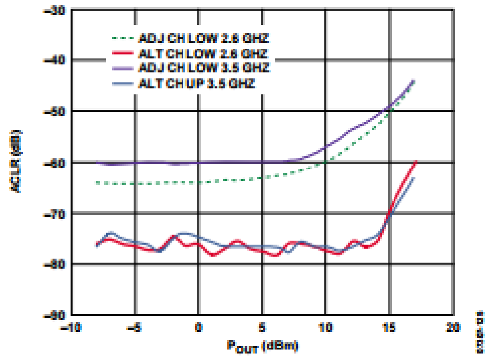


Figure 2. WiMAX 64 QAM, 10 MHz Bandwidth, Single Carrier

APPENDIX 5 - Continue
LAMPIRAN 5 - Sambungan

ADL5321 Data Sheet

TYPICAL SCATTERING PARAMETERS

VCC = 5 V and T_A = 25°C; the effects of the test fixture have been de-embedded up to the pins of the device.

Table 2.

Frequency (MHz)	S11		S21		S12		S22	
	Magnitude (dB)	Angle (°)	Magnitude (dB)	Angle (°)	Magnitude (dB)	Angle (°)	Magnitude (dB)	Angle (°)
2400	−4.54	129.60	11.90	21.92	−26.72	−33.83	−8.18	−166.39
2450	−4.65	126.65	11.89	18.30	-26.63	−36.64	−8.27	−169.02
2500	−4.79	123.62	11.88	14.57	-26.55	−39.62	−8.37	−171.83
2550	−4.92	120.44	11.87	10.68	−26.48	−42.70	−8.45	−175.32
2600	−5.04	117.31	11.85	6.80	−26.42	−45.95	−8.44	−179.11
2650	−5.17	114.43	11.83	2.90	−26.37	−49.25	−8.39	177.31
2700	−5.33	111.78	11.80	−1.06	−26.34	−52.65	−8.33	173.43
2750	−5.50	109.21	11.77	−5.17	−26.31	−56.16	−8.15	169.22
2800	−5.70	106.84	11.74	−9.36	−26.30	−59.84	−7.90	165.46
2850	−5.94	104.85	11.71	−13.64	−26.30	−63.64	−7.63	161.87
2900	−6.25	103.23	11.66	−18.05	−26.31	−67.63	−7.31	158.01
2950	−6.61	101.91	11.62	−22.58	−26.34	−71.77	−6.88	154.58
3000	−7.03	101.06	11.56	−27.18	−26.37	−76.13	−6.44	151.64
3050	−7.53	100.92	11.50	−31.98	−26.44	−80.76	−6.00	148.53
3100	−8.12	101.82	11.40	−36.95	−26.55	−85.61	−5.53	145.65
3150	−8.78	104.04	11.29	−42.09	−26.68	−90.69	−5.03	143.14
3200	−9.47	107.91	11.15	−47.34	−26.85	−95.96	−4.56	140.74
3250	−10.07	113.72	10.97	−52.74	−27.06	−101.50	−4.08	138.36
3300	−10.45	121.55	10.76	−58.29	−27.32	−107.30	−3.61	136.16
3350	−10.45	130.87	10.49	−63.95	−27.65	−113.32	−3.19	133.97
3400	−10.02	140.04	10.17	−69.56	−28.05	−119.45	−2.80	131.77
3450	−9.25	147.61	9.80	−75.16	−28.49	−125.70	−2.43	129.85
3500	−8.28	153.06	9.39	−80.70	−29.00	−132.04	−2.13	128.08
3550	−7.27	156.76	8.92	−86.04	−29.58	−138.45	−1.89	126.22
3600	−6.34	159.01	8.39	−91.20	−30.20	−144.79	−1.66	124.51
3650	−5.51	160.11	7.83	−96.07	−30.88	−151.12	−1.48	123.23
3700	−4.78	160.43	7.26	−100.64	−31.57	−157.36	−1.37	122.16
3750	−4.14	160.36	6.66	−104.97	−32.29	−163.69	−1.27	121.07
3800	−3.60	160.07	6.04	−108.96	−33.02	−170.01	−1.19	120.25
3850	−3.16	159.62	5.43	−112.61	−33.74	−176.34	−1.14	119.79
3900	−2.78	158.95	4.82	−116.07	−34.44	177.21	−1.12	119.31
3950	−2.45	158.24	4.20	−119.27	−35.12	170.60	−1.10	118.94
4000	−2.17	157.64	3.60	−122.18	−35.74	163.89	−1.09	118.86

APPENDIX 6
LAMPIRAN 6

ANALOG DEVICES

HMC414MS8G / 414MS8GE

v04.0607

RoHS✓ EARTH FRIENDLY

GaAs InGaP HBT MMIC POWER AMPLIFIER, 2.2 - 2.8 GHz

Typical Applications

This amplifier is ideal for use as a power amplifier for 2.2 - 2.7 GHz applications:

- BLUETOOTH
- MMDS

Features

Gain: 20 dB

Saturated Power: +30 dBm

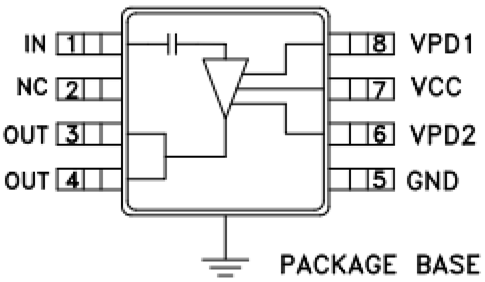
32% PAE

Supply Voltage: +2.75V to +5V

Power Down Capability

Low External Part Count

Functional Diagram



General Description

The HMC414MS8G & HMC414MS8GE are high efficiency GaAs InGaP Heterojunction Bipolar Transistor (HBT) MMIC Power amplifiers which operate between 2.2 and 2.8 GHz. The amplifier is packaged in a low cost, surface mount 8 leaded package with an exposed base for improved RF and thermal performance. With a minimum of external components, the amplifier provides 20 dB of gain, +30 dBm of saturated power at 32% PAE from a +5V supply voltage. The amplifier can also operate with a 3.6V supply. Vpd can be used for full power down or RF output power/current control.

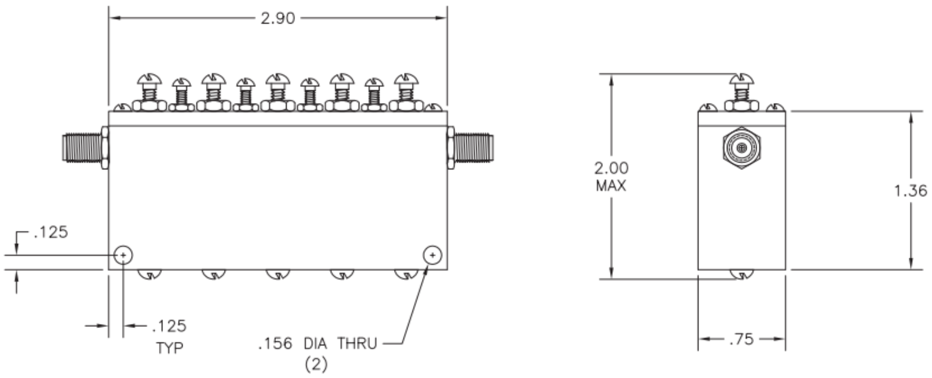
Electrical Specifications, T_A = +25° C, As a Function of Vs, Vpd = 3.6V

Parameter	Vs = 3.6V			Vs = 5V			
	Min.	Typ.	Max.	Min.	Typ.	Max.	Units
Frequency Range		2.2 - 2.8			2.2 - 2.8		GHz
Gain	17	20	25	17	20	25	dB
Gain Variation Over Temperature		0.03	0.04		0.03	0.04	dB/ °C
Input Return Loss		8			8		dB
Output Return Loss		9			9		dB
Output Power for 1 dB Compression (P1dB)	21	25		23	27		dBm
Saturated Output Power (Psat)		27			30		dBm
Output Third Order Intercept (IP3)	30	35		35	39		dBm
Noise Figure		6.5			7.0		dB
Supply Current (Icq) Vpd = 0V / 3.6V		0.002 / 240			0.002 / 300		mA
Control Current (Ipd) Vpd = 3.6V		7			7		mA
Switching Speed tON, tOFF		45			45		ns

APPENDIX 7
LAMPIRAN 7

FILTER
PENAPIS

REVISION			
LTR	ECN	DATE	APPR'D



SPECIFICATIONS

CENTER FREQUENCY (Fo):	2500 MHz
INSERTION LOSS AT Fo:	2 dB TYP
3 dB RELATIVE BANDWIDTH:	44 MHz MIN, 60 MHz MAX
REJECTION:	60 dB TYP @ 2400 MHz
	30 dB TYP @ 2450 MHz
	30 dB TYP @ 2550 MHz
IMPEDANCE:	50 OHMS
CONNECTORS:	SMA FEMALE

UNLESS SPECIFIED
ALL TOLERANCES ±.025

ENVELOPE DRAWING

MICROWAVE FILTER CO. INC. 6743 KINNE ST. E. SYRACUSE, N.Y. 13057	FSCM27834	
DATE 9/10/13	TITLE	
DWN BY MW	FILTER, BANDPASS	
ENGINEER	DRAWING NO.	REV
J. SHAW	18766	–