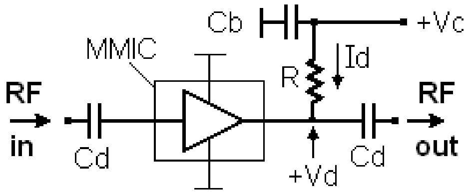
M.M.I.C. , Wide Band Amplifiers

The MMIC (Microwave Monolithic Integrated Circuits) are wide band integrated circuits often used as simple amplifiers, they are designed to replace the transistor and help the designer to build RF amplifiers. Loosely but realistically MMICs are the evolution of thick film ICs (in fact in this section are listed also some old thick film amplifiers).
Without going into technical detail, because it is available a very big quantity of documentation, in few words we can say that the MMIC is used to simplify an amplification chain without worrying about possible self oscillations, instability, impedance mismatching or the bias, the MMIC can solve all these problems. With MMICs design is made easier, securer and more repeatable, all models are matched nearly at 50 / 75 Ω of input impedance.

MMICs are used to ease design process and improve the RF circuits repeatability, their implementation is very easy so the Ohm's law only is needed to calculate the other components of the circuits. Here are explained the 3 classical circuits for power supply and decuopling.

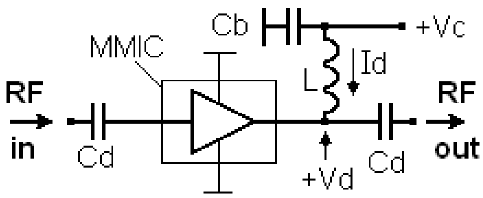
A) MMICs normally use the 4 leads configuration, input, output with power supply and two gound connections. Rarely some types have a separate power supply lead, some others have the bias lead to adjust the current.
B) The decoupling capacitors are used only to block the DC power supply, the value must be a short circuit at the desired frequency. Cb bypass capacitor is used only to short circuit the RF to avoid self oscillations of the MMIC and to avoid that possible noise can enter in the MMIC, the choice of this capacitor is very important if the MMIC has a high gain or there are more than one amplification stage.
C) The bias resistor has the purpose of lowering the power supply voltage from the available value to the right power supply value of the MMIC (for example from Vc 12V to Vd 5V)
D) It is always suggested to use an inductance, in this case the decoupling is increased on the power supply, it can be avoided in the case that the calculated R is so high that it is enough to obtain a good decoupling (for example R > 150 / 200 Ω). Instead the inductance must be inserted when the power supply voltage is similar to the working voltage of the MMIC (that is if Vd = Vc), in fact in this case it is not possible to insert the bias resistor on power supply and the decoupling is made by the inductance itself. The same if the power supply resistor has a too low value (up to 80 / 100 Ω).
E) To improve performaces of these devices, especially at higher frequencies, it is suggested to use SMD or with very short leads components in particular for all ground connections



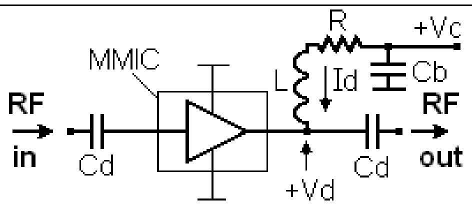
Example of calculation for the famous MAR6, assume to have 6V (Vc) of power supply, from the MAR6 specifications we see that it works with 3.5V of power supply (Vd) and a current of 16mA **{ Vc and Vd in V - Id in** A }
R calculation = (Vc - Vd) : Id (6-3,5) : 0,016 = 150Ω
In this case being R quite high we can avoid to put the decoupling inductance.

	Cd examples	Cb examples
min freq. = 1 MHz	about 47 nF	≥ 470 nF
min freq. = 10 MHz	about 4,7 nF	≥ 47 nF
min freq. = 100 MHz	about 470 pF	≥ 4.7 nF
min freq. = 1 GHz	about 47 pF	470 pF + 10 nF

We suggest to use Cd input and output without exceding the capacity because it is better that the circuit tends to attenuate at lower frequencies. (A capacitor in series behaves as a bland high pass filter).



In case the power supply voltage is very close or equal to that of MMIC (Vc = Vd) it is not possible to use a bias resistor, in this case it is mandatory to use an inductance to separate the RF between the MMIC and the power supply, examples of L values:
min freq. = 1 MHz about 27 µH - min freq. = 10 MHz about 2.7µH
min freq. = 100 MHz about 270nH - min freq. = 1 GHz about 27 nH



This is the optimal circuit configuration because it is obtained the maximum possible decoupling, in fact it is summed the resistance value to the inductance reactance.
The limiter resistor is useful also to permit a sort of limitation on the bias current and accordingly a higher tolerance in power supply voltage.

NOTE : in case of high value inductances (> 10 µH) should be considered a little residual resistance due to the wire of the inductance itself.

Given the huge variety of MMIC devices, but especially the wide variety of performances and technical specifications, we decided to group all these devices in a table of 3 pages. To facilitate the search we have divided them according to their main characteristics:

Low cost and general purpose	low cost
Low noise	NF < 3 dB
High dynamic	medium output power +10 / +17 dBm
High output power	> 17 dBm > 50 mW
Very flat gain	it can be used on instrumentation to have flat gain on wide band
High reverse insulation	high S_{12} , ie high reverse insulation between output and input, for example as buffer for VCOs and oscillators
Variable gain	with pin for gain control
Differential amplifier	
Low voltage power supply	< 3.5 V
Other special feateures	see table below

This table is used for a fast search of the device, other features will be then shown on following pages with prices and eventually a test report for MMICs considered more interesting.

MMICs selection guide

function	cod.	CASE	FREQ. GHz		gain		out power		NF		3° order IP		pwr sup.	
			min	max	max dB	min	dBm	at GHz	dB	at GHz	dBm	at GHz	V	mA
GENERAL PURPOSE and LOW COST	**AG101**	S M D	60MHz-3GHz		15	11	+15	1	2.4	2	+28/+32	1	4.5	50
	ERA 1	plastic	up to 8 GHz		12	10	+11.5	2			+26	2	3.6	40
	ERA 2	plastic	up to 8 GHz		16	12	+12.4	2			+26	2	3.6	40
	SNA 286	plastic	DC	6	15	11	+14	2	5.7	2	+29	2	3.8	50
	INA 34063	S M D	DC	3	± 20 dB		+8	2	4.5	2	+18	2	3	30
	INA 52063	S M D	DC	2.5	23	16	+8	1	3.5	0.1	+20	1	5	30
	LMX 2119	S M D	1.5	2.5	20		+23,5	2					3.6	350
	MAR 1-MSA0186	plas-cer	DC	2.5	18	9	+2	0.5	5.5	0.5	+14	0.5	5	17
	MAR 2 - RAM2	plas-cer	DC	3.5	12.5	8	+5	1			+17	1	5	25
	MAR 3	plas-cer	DC	3	12.5	8	+10	1			+23	1	5	35
	MAR 4	plast.cer	DC	2	9	8	+12.5	1			+25.5	1	5.2	50
	MAR 6	plas-cer	DC	1.5	20	13	+2	1	3	0.5	+14	0.5	3.5	16
	MAR 8	plast-cer	DC	2	27	16	+12.5	1	3.3	1	+27	1	7.8	36
	MAV 11	plastic	DC	2	13	7.5	+17.5	0.5	3.6	0.5	+30	0.5	5.5	60
	MGA 72543	S M D	up to	6 GHz	17	9	+12	5	1.5	4	+10	2	3	20
	MGA 85563	S M D	0,8	6	19	15	+1	3	1.6 on all bandwidth		+12	3	3	20-30
	MSA 0711 e 0735	S M D	DC	3	13	8	+5.5	1	5	1	+18	1	4	22
	RF 2472	S M D	DC	6	21	9	+2	2	1.4 2	1.5 5	+18		3	6
	SGA 2186	plastic	DC	5	10	7.5	+7	1.5	4.4	2	+19.5	2	2.2	20
	SGA 2286	plastic	DC	5	15	10	+7	2	3.5	2	+19	2	2.2	20
	SGA 2386	plastic	DC	5	18	10	+7.5	2	3.3	2	+20	1.5	2.7	20
	SGA 2486	plastic	DC	5	21	11	+7.5	2	3.3	2	+20	2	2.7	20
	SGA 3286	plastic	DC	5	15	10.5	+11.5	1.5	3.8	2	+24	2	2.6	35
	SH 225	special	1 - 900 MHz		21	19	+2	0.5	5.5	0.5			24	23
	µPC 2709T	S M D	DC	2.5	22	19	+8	0.5	5	1			5	25
	µPC 2771T	S M D	DC	2.5	21	18	+11.5	1	6	1			3	35

function		cod.	CASE	FREQ. GHz		gain		out power		NF		3° order IP		pwr sup.	
				min	max	max dB	min	dBm	at GHz	dB	at GHz	dBm	at GHz	V	mA
LOW NOISE NF ≤ 3 dB # = high dynamic	#	**AG101**	S M D	60MHz-3GHz		15	11	+15	1	2.4	2	+28/+32	1	4.5	50
	#	**AM1 - AG102**	S M D	60MHz-3GHz		15	11	+18	2	2.4	2	+33/+36	1	4.4	60-80
	#	**AM50-0003**	S M D	800-1000MHz		15		+18		1.2				3-8	20-60
	#	**AM50-0004**	S M D	1.4 -2 GHz		14		+18		1.4				3-8	20-45
		INA03184	plas-cer	DC	4	25	12	-1	1	2.5	1.5	+7	1.5	3-5	10
	#	**MAALSS0034**	S M D	70MHz-3GHz		15	9	+23	2	1.6	2	+36	2	5	88
		MAAM12031 + 032	S M D	1.7 - 2 GHz		20	13	+2 / +7		1.7 / 1.8		+2 / +7		5	5 / 8
	#	**MGA 62563**	S M D	up to 2.5GHz		23	13	+ 17		0.9	1	+32.5		3-5	60
	#	**MGA 72543**	S M D	up to	6 GHz	17	9	+12	5	1.5	4	+10	2	3	20
	#	**MGA 81563**	S M D	0.5	6	12.5	10	+14.8	3	2.7	3	+27	2	3	42
		MGA 85563	S M D	0,8	6	19	15	+1	3	1.6 on all bandwidth		+12	3	3	20-30
		MGA 86563	S M D	0.5	6 (8)	22	15	+4.3	4	1.7	4	+15	2.4	5	14
		MGA 86576	ceramic	0.5	10	23	12	+7	2.5	1.8	6	+16	4	4-10	16
		MAR 6	plas-cer	DC	1.5	20	13	+2	1	3	0.5	+14	0.5	3.5	16
	#	**MGF 7002**	metallic	0.8	1.9	18	16	+10	1.6	2.5		+22	1	10/-6	90
	#	**MGF 7003**	ceram	0.1	1.9	12	10	+10	1.8	<2.5		+24	1	3	30
		RF 2472	S M D	DC	6	21	9	+2	2	1.4 2	1.5 5	+18		3	6
	#	**SGA 3586**	plastic	DC	5	26	13	+ 13.5	1.5	2.5	2	+25.5	1.5	3.3	35
	#	**SGA 4586**	plastic	DC	5	26	10	+16 / +13		1,8	1	+27	2	3.6	45
	#	**SGA 5586**	plastic	DC	4	26	14	+18 / +15		2.6	2	+30	1.5	3.9	60
	#	**UTO 1043**	metallic	5-1300 MHz		11	8.7	+9	1	2.5	0.5	+22	0.5	12-15	25
HIGH DYNAMIC and MEDIUM POWER ≥ + 10dBm (≥ 10 mW)		**ERA 1**	plastic	up to 8 GHz		12	10	+11.5	2	--		+26	2	3.6	40
		ERA 2	plastic	up to 8 GHz		16	12	+12.4	2	--		+26	2	3.6	40
		ERA 3	plastic	up to 8 GHz		22	12	+11.5	2	--		+23	2	3.5	35
		ERA 4	plastic	up to 8 GHz		14	12	+16.8	2	--		+32	2	5	65
		INA 10386	plastic	DC	4	26	14	from +12 to +14		3.8	1.5	+23	1.5	6	45
		MGA 64135	ceramic	0.5	10	14	8.6	+12 upto 8GHz		--		--		8-11	50
		MGA 72543	S M D	up to	6 GHz	17	9	+12	5	1.5	4	+10	2	3	20
		MGA 81563	S M D	0.5	6	12.5	10	+14.8	3	2.7	3	+27	2	3	42
		MAR 3 - VAM3	plas-cer	DC	3	12.5	8	+10	1	--		+23	1	4-6	35
		MSA 0311-RAM3	S M D	DC	2.5	11.5	8	+10	0.5	--		+22	1	4-5.6	35
		MAR4-MSA0436	ceramic	DC	3	8.5	6	+13	0.5	--		25.5	1	4-6	50
		MAR8-MSA0870	plas-cer	DC	3	32	12	+13	0.5	3.3	1	+27	1	6-9	36
		NGA 286	plastic	DC	6	16	11	+15	2	3.4	2	+31	2	4	50
		SGA 3286	plastic	DC	5	15	10.5	+11.5	1.5	3.8	2	+24	2	2.6	35
		SGA 3386	plastic	DC	5	18	11	+11.5	1.5	3.5	2	+24	1.5	2.6	35
		SGA 3486	plastic	DC	5	23	12	+12.5	2	3.2	2	+25	1.5	2.9	35
		SGA 3586	plastic	DC	5	28	13	+ 13.5	1.5	2.5	2	+25.5	1.5	3.3	35
		SGA 4186	plastic	DC	5	10	8	+ 13.5	1.5	--		+28 / +25		3.2	45
		SGA 4586	plastic	DC	5	26	10	+16 / +13		1,8	1	+27	2	3.6	45
		SGA 5586	plastic	DC	4	26	14	+18 / +15		2.6	2	+30	1.5	3.9	60
		SNA 286	plastic	DC	6	15	11	+14	2	--		+29	2	3.8	50
		SNA 386	plastic	DC	4	22	15	+11	2	4.5	2	+23	2	3.8	35

continue , MMIC selection guide

function	#	cod.	CASE	FREQ. GHz min - max	gain max dB min	out power dBm at GHz	NF dB at GHz	3° order IP dBm at GHz	pwr sup. V mA
HIGH POWER ≥ +17 dBm (≥ 50 mW) # = low noise	#	AM1 - AG102	S M D	60MHz-3GHz	15 11	+18 2	2.4 2	+33/+36	4.4 60-80
		CGY 2014	S M D	power MMIC, cellular dual band 900 + 1800 MHz +35 / +32 dBm out power					
	#	CGY 21	metallic	20-1100MHz	20 15	+19/+20 0.9	4 0.8	+32.5 0.8	5 160
	#	ERA 5	plastic	DC 6 (10)	20 12	+18 2	4.5 1	+33 2	5 65
		ERA 6	plastic	DC 6 (10)	11,5 10,5	+18 2	--	+36 2	5.5 70
		GPD 405	metallic	10 - 500 MHz	15 12	+23 0.4	6 0.1	+29 0.1	15 90
		CGY 52	S M D	100 2.500	13 15	+19 200-1800	4.8 1.8	+32 1	4.5 160
		LMX 2119	S M D	1.5 2.5	20	+23,5 2	-- --		3.6 350
	#	MAALSS0034	S M D	70MHz-3GHz	15 9	+23 2	1.6 2	+36 2	5 88
	#	MAAMSS0049	S M D	250 MHz 4000	20 11	+28.5 2.4	3.5 2	+43 2	5 250
	#	MAV 11	plastic	DC 2	13 7.5	+17.5 0.5	3.6 0.5	+30 0.5	4.5-6 60
	#	MGA 62563	S M D	up to 2.5GHz	23 13	+ 17	0.9 1	+32.5	3-5 60
		MGA 82563	S M D	0.4 6	14 9	+17 2	2.2 2	+31 2	3 84
		MGA 83563	S M D	0.5 6	21 17	+19 1 - 3	-- --	+29 1 - 6	3 150
		MRFIC 1859	S M D	power MMIC, cellular dual band 900 + 1800 MHz +34 / +32 dBm out power					
		NGA 486	plastic	DC 5	15 10	+19/+18 0.5/2	4 2	+38/+34	4.8 80
		PM 2107	plas smd	2 2.6	26 20	+26/30pk 2.4	-- --	-- --	+5V -1.2V
		RF 2145	S M D	1 2	25 20	+26 1.8	-- --		4.5 400
		RF 2174 - 2175	S M D	power MMIC, cellular dual band 900 and 1800 MHz + 36 / + 33 dBm					
		SNA 676	ceramic	dc 7	11 7	+18 2		+36 0.1-2	5.7 70
		UTO 2013	metallic	500-2000MHz	10	+ 21	4.5	+33	15 100
		VNA 25	S M D	0.5 2.5	18 14	+18.2	5.5	+27	5 85
VERY FLAT GAIN		ERA 1	plastic	DC 9-11	12-16 --	+12 2	--	+26 2	3.8 50
		ERA 6	plastic	DC 6	11,5 10,5	+18 2	--	+36 2	5.5 70
		INA 03184	plas-cer	DC 4	25 12	-1 1	2.5 1.5	+7 1.5	3-5 10
		INA 10386	plastic	DC 4	26 14	+12 to +14	3.8 1.5	+23 1.5	6 45
		MGA 81563	S M D	0.5 6	very flat gain up to about 2 GHz				3 42
		MSA 0910	ceramic						
		MWA ….	metallic case, particular use for instrumentation and professional, various types						
		GPA…. GPD….	available: low noise, high power, etc... dc - 2 GHz						
		SH 225	special	2 900 MHz	21	+2			24 23
		SNA 286	plastic	quite flat form100 MHz to 1.5 GHz					
		µPC 2709T	S M D	DC 2.5	22 19	+8 0.5	5 1		5 25
		µPC 2771T	S M D	DC 2.5	21 18	+11.5 1	6 1		3 35
HIGH REVERSE INSULATION		INA 34063	S M D	DC 3	± 20 dB	reverse insulation > 30 dB			3 30
		µPC 2709T	S M D	DC 2.5	22 19	rev. insulation > 30dB low cost			5 25
		MAX 2470 - 2175	S M D	10-500 MHz	13 15	rev. insul. >50dB VCO buffer			3-5.5 6
		MGA 83563	S M D	0.5 6	21 17	insul. < 2GHz >35dB - >2GHz 30dB			3.3 150
		SH 225	1- 900 MHz very flat amplifier with 40dB of reverse insulation						24 23
VARIABLE GAIN		CGY 120	gain control range = 50 dB, bandwidth up to 2.5 GHz						
		IVA05208-14208	gain control range = 30 dB (IVA05208) -- 34 dB (IVA14208) more spec. see below						
		RF 2145	high power, gain control range = 40 dB						
DIFFERENTIAL amplifier		IVA 05208	S M D	DC 2	30 20	group delay is within 400 pSec			4-6.5 35
		IVA 14208	S M D	DC 3	25 18				5-8 38
LOW VOLTAGE < 3.5 V		GPD 110 - INA34063 - INA03184 - MAR 6 - MAX... - µPC 2771					see more detailed specifications in the next pages		
		MGA 62563 + 7254 + 82563 + 83563 + 85563 - MGF 7003 - MSA 07...							
		SGA 2186 + 2286 + 2386 + 3286 + 3386 + 3486							
with special features		GPD 110	for very low frequencies starting from 50 - 100 KHz up to 1.1 GHz , Vmin 2.5 V						
		MGA 64135	high performances up to10 GHz, high output level, HI-REL professional ceramic case						
		MGA 72543	it has a switch inside to exclude it from the circuit						
		MGA 86576	for microwave, ceramic case, works up to 10 GHz, low noise						
		MSA 0910	for instrumentation, limited but ultra-flat gain 0.1-4 GHz HI- REL special case						
		IDA 07318	1.5 Gbit driver for laser or led, TX datas on fiber optic						
		MAR1-MSA 0185	very low VSWR up to 3 GHz on both input and output ports						
		VNA 25	it has already inside two dc block capacitors and the bias network						

The following products AM-1, AG-101G, AG-102 and MAALSS0034 are MMICs from the prestigious Watkins Johanson and MaCom brand for high dynamic range applications (+16 to +22 dBm), but with a very low noise (1,6 to 2,5 dBNF).
The case is the consolidated SOT89 that guaratees a good dissipation even when it is used with a fair current. These MMICs implement GaAs-FET technology and they are suitable for many applications, especially as post-amplifier after very low noise stages.
For example, suppose to use them after a MGA-62563 MMIC or a MAR6, you will get some more decibel of gain greatly increasing the dynamic with an output level up to +16 / +22 dBm. Another interesting application is as a driver for a broadband power module like BGD802, in fact the BGD802 to give the output power of 1 W it requires about 30 mW of input, so these MMICs are the right choice also as TX driver. The application diagram is extremely simple, just the usual dc-block capacitor and a choke for power supply are needed.
In conclusion, the AM-1, AG-102, AG101G and MAALSS0034 MMICs can be used for all applications requiring good dynamic associated with a low noise, as drivers for a higher power stage but also as a buffer stage with medium gain suitable for any need.

MMIC: AM-1 AG-102 AG-101G MAALSS0034, some applications

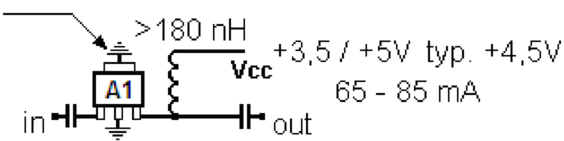
MGA-62563	+	AM-1 AG-102 AG-101G MAALSS0034	=	**ultra low noise high dynamic aplifier** 100MHz - 2.5 GHz NF 1.1 - 1.5 dB gain 20 - 30 dB output +16 / +22 dBm , OIP3 +33 / +36dBm
MAR-6	+	AM-1 AG-102 AG-101G MAALSS0034	=	**low noise amplifier** 50 / 70MHz - 1.5 GHz NF 2.5 - 3.5 dB gain 22 - 35 dB output + 18 dBm , OIP3 +26dBm
AM-1 AG-102 AG-101G MAALSS0034	+	wide band power module, example BGD-802  	=	**wide band power amplifier** 50 / 70 MHz - 1 GHz # output 0,5 - 1 W # gain about 30 dB # # depending on the used power module
AM-1 AG-102 AG-101G MAALSS0034	+	-- power transistor or -- power module or -- power MMIC	=	**medium-high power amplifier** **Depending on the used final**

MMIC AM-1 AG-102

AG-101G MAALSS0034

typical application diagram

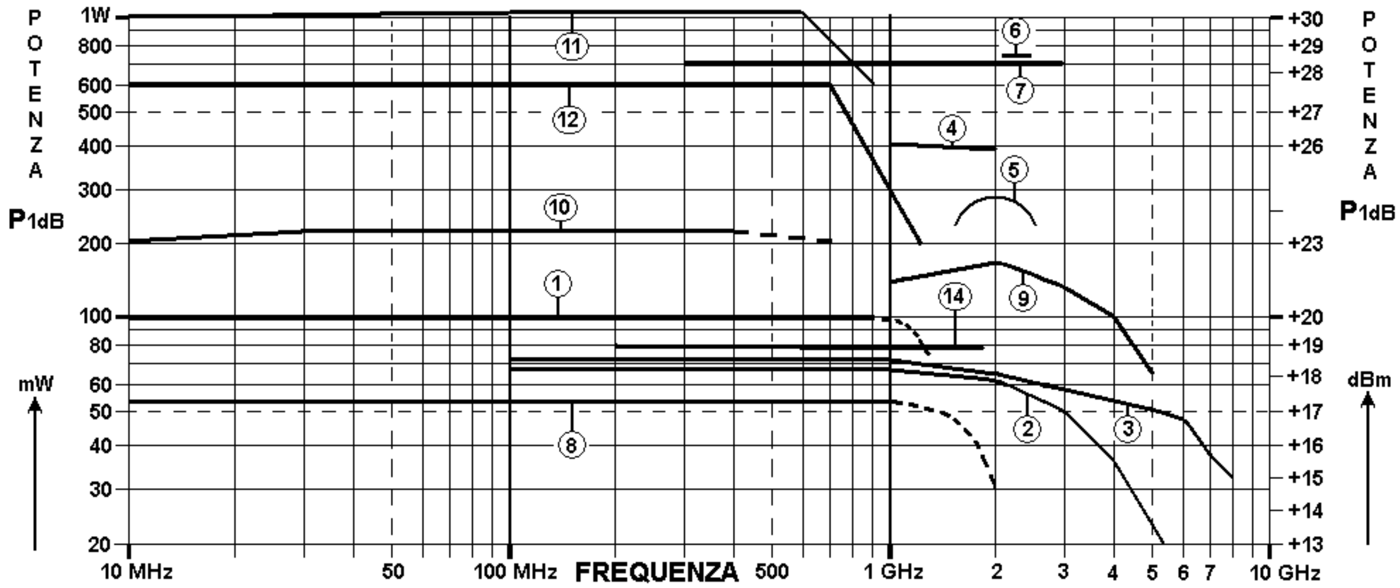
Solder to a little copper ground plain for dissipation



	MMIC : AM-1 AG-102 AG-101G MAALSS0034
Frequency range	60 – 3000 MHz
Gain	10 – 15 dB
Ouput P1dB	from + 16 dBm to + 22 dBm (depending on model)
Output IP3	+39 dBm / +33 dBm (depending on model)
Noise Figure	1,6 – 2.6 dB

medium power broadband MMICs and Modules

The table indicates the continuous output power (P1dB), expressed in dBm and in mW, and the frequency range



From the diagram it is possible to get the device number, below the comparison chart "**NUMBER** = **MMIC**"

1 = CGY 21 over 50 MHz + GPA 505 dc - 500 MHz (max 1 GHz) ---- **2** = ERA 5 up to 5.5 GHz + VNA 25 up to 2.5 GHz

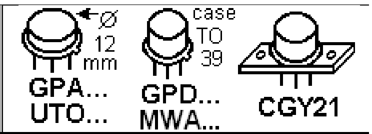
3 = SNA 676 ---- **4** = RF 2145 ---- **5** = LMX 2119M ---- **6** = PM 2107 ---- **7** = MAAMSS0049 ---- **8** = MAV 11

9 = MGA 83563 ---- **10** = GPD 405 ---- **11** = BGD 802 # ---- **12** = MHW 9242 # ---- **14** = CGY 52

they are power modules, the others are MMICs listed in this section

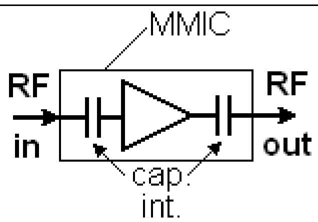
high performances professional MMICs

These particular ICs are used in professional field, such as final stage or driver in laboratory RF signal generators, military RF-VHF front-end receivers for example Watkins - Johnson, Rohde & Schwarz, A class amplifiers, and laboratory and so on. They have better features than common MMICs, such as a low input-output VSWR, constant phase throughout the whole band with a fair group delay, P1dB, IP3 and IP2 specified and guaranteed, etc... They are typically used in wide band circuits and also where is the need of a very fast response as recovery time.
Some have the two dc-block capacitors already inside which greatly facilitates their use, other models have not the capacitors inside (which have to be added externally) this is an advantage especially for use at low frequencies and / or for applications that must be customized considering that they can virtually operate starting by dc.

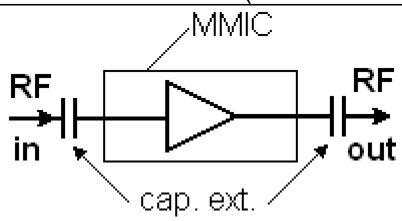
gain - frequency		NF	P 1dB	IP3	IP2	reverse insul.	pwr. supply	cod.	
optimal	max								
dB MHz	dB MHz	dB MHz	dBm	dBm	dBm	dB	V mA		
20 100 - 900	15 30 - 2000	3.9 100 - 900	+ 19	+ 32			4.5 160	**CGY 21**	TO39 case with small heat sink 9 x 21 mm
15 0.1 - 400	12 01 - 850	4 0.1 - 400	- 2	+ 12	+ 14		2.5 10	**GPD 110**	group delay 0.3 nS
15 5 - 400	12 3 - 800	4 - 4.5 5 - 400	- 2	+ 10		> 20	15 10	**GPD 401** **GPD 461 #**	low noise RX stage or driver
14 5 - 400	12 - 800	5.5 - 6 5 - 400	+ 7	+ 19	+ 25	> 20	15 24	**GDP 402** **GPD 462 #**	intermediate stage
15 10 - 400	13 - 900	5.5 5 - 400	+ 23	+35 / +30	+ 34	> 20	15 90	**GPD 405**	high power with still fair NF
8 dc - 1000		6.7	+11.5	+ 17	+ 27		3 30	**MWA 320 #**	group delay < 0.6 ns Imd - 58dB out 1 mW, In+Out VSWR typ. 1.5:1
6.2 dc - 1000		9	+15.2	+ 25	+31		4-5 60-80	**MWA 330 #**	group delay < 0.6 ns Imd - 62dB out 5 mW, In+Out VSWR typ. 1.5:1
10.5 10 - 1000	8.5 - 1300	2 - 3 10 - 1000	+ 8	+ 20	+ 28	16 - 17	15 25	**UTO 1043R**	High Reliability version
10 500 - 2000	9.5 400 - 2100	4.5 500-2000	+ 21	+ 33		16 - 17	15 100	**UTO 2013**	typical group delay 0.5 nS

MMICs with dc-block capacitors already inside

CGY 21
GPD 110
GPD 401
GPD 402
GPD 405
UTO 1043R
UTO 2013



NOTE #
MMICs without dc-block capacitors already inside
(to add externally)



GPD 461
GPD 462
MWA 320
MWA 330