



Will-Semi RFIC Solutions Summary

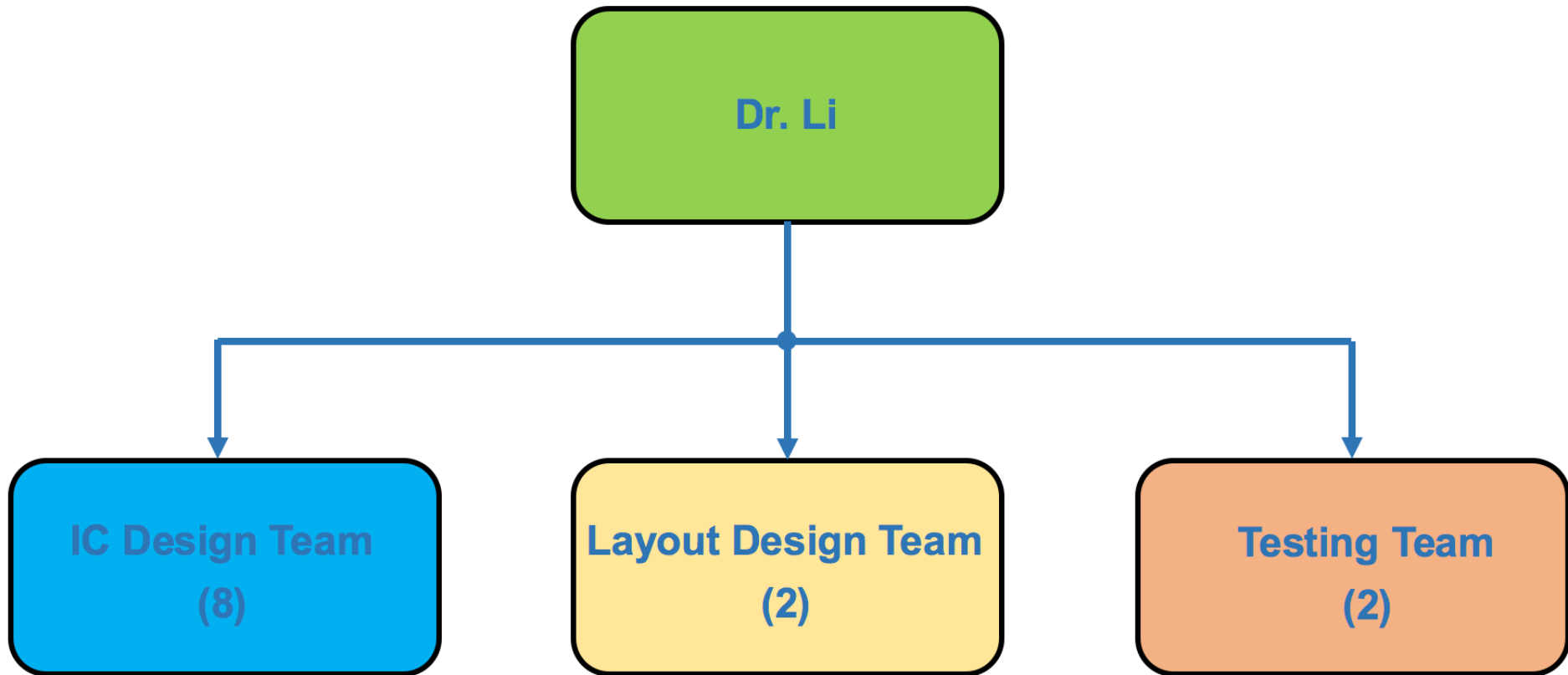
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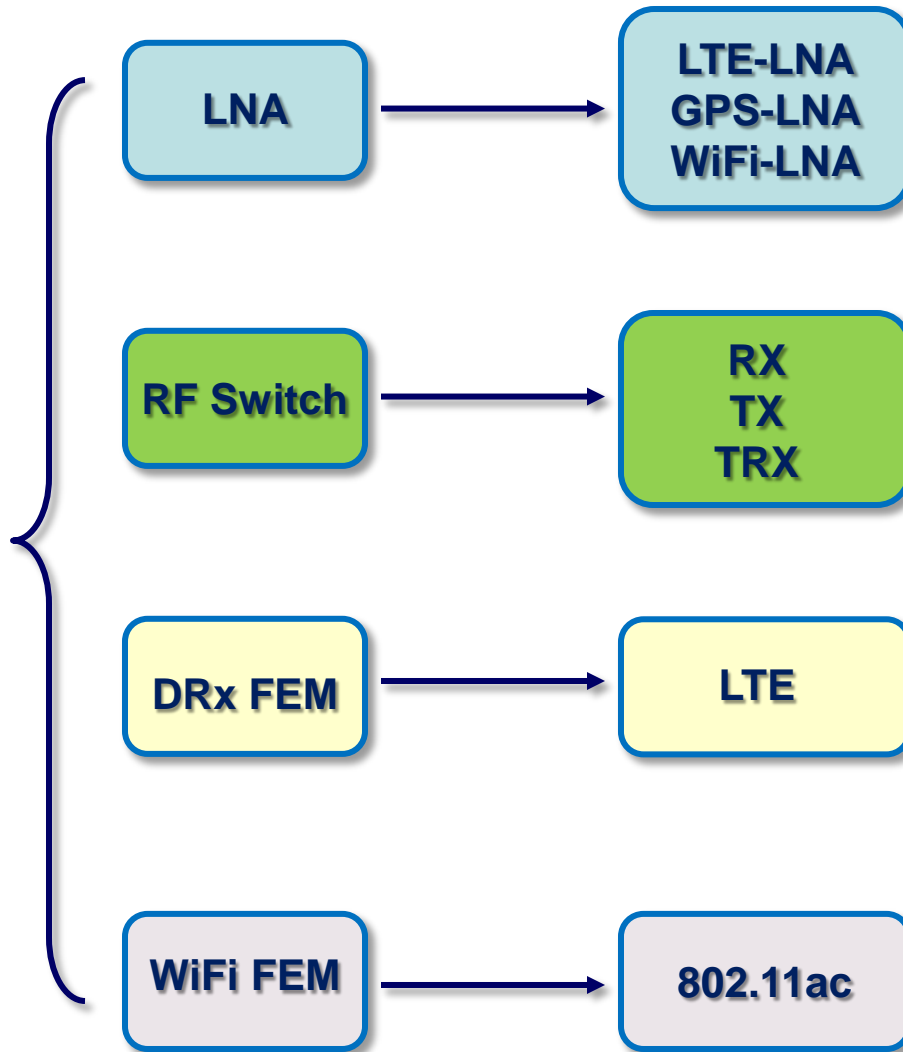
Version :

- **Will-Semi RF/Analog IC team**
 - 2 Ph.D. + 7 M.S. + 4 B.S.
- **Dr. Xiaoyong Li's education background**
 - **Ph.D. – Univ. of Washington, Seattle, WA**
 - GPA – 3.97/4.0
 - **M.S. – Peking Univ., Beijing, China**
 - Exempt from entry exam
 - **B.S. – Peking Univ., Beijing, China**
 - Exempt from entry exam

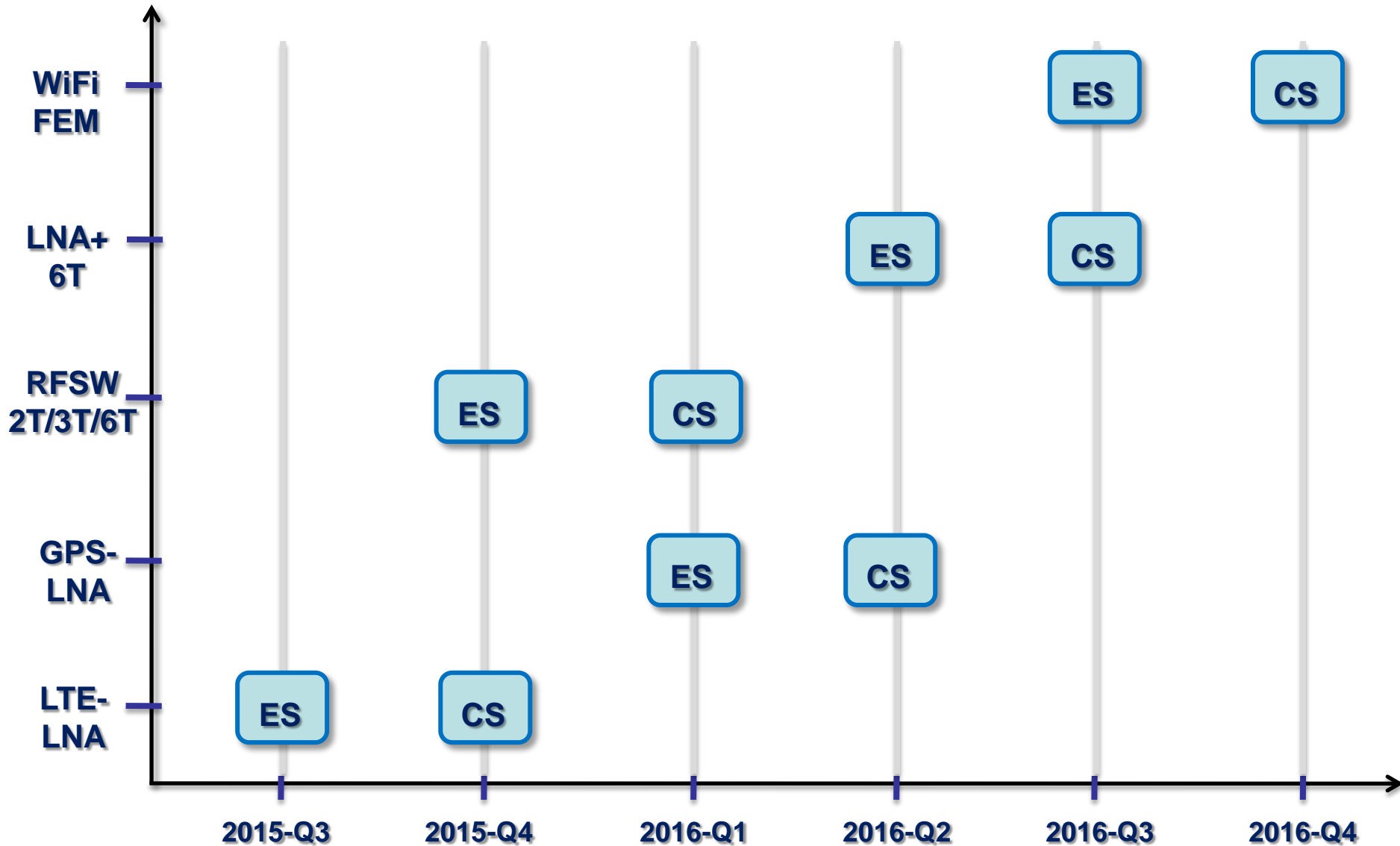
- **Dr. Xiaoyong Li's industry experiences**
 - **Qualcomm Inc. – RF/Analog project lead**
 - **CDMA/GPS receiver**
 - **WCDMA/GSM/Diversity/GPS receiver**
 - **BT/FM SoC**
 - **WLAN/BT/FM combo SoC**
 - **Spreadtrum Inc. – RF/Analog RX design lead**
 - **TDSCDMA/GSM transceiver**
 - **SiBeam Inc. – RF/Analog design engineer**
 - **CMOS 60-GHz MIMO transceiver**



Will-Semi RFIC Products



Will-Semi RFIC Products Roadmap

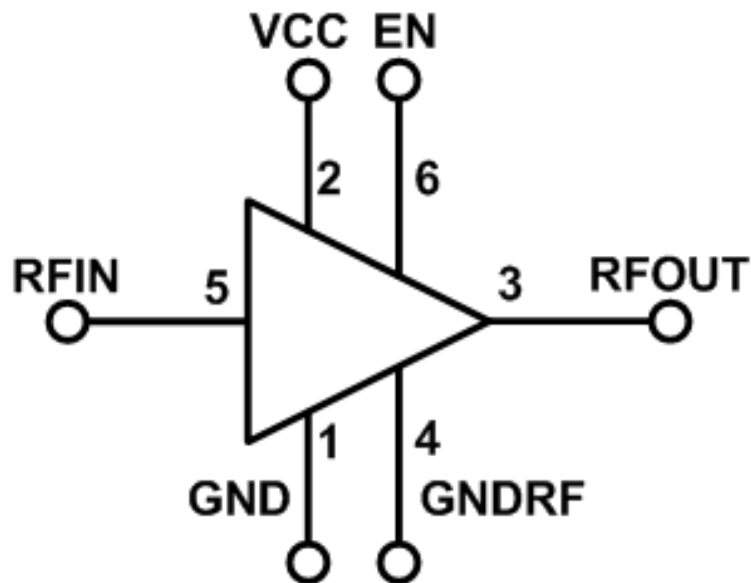
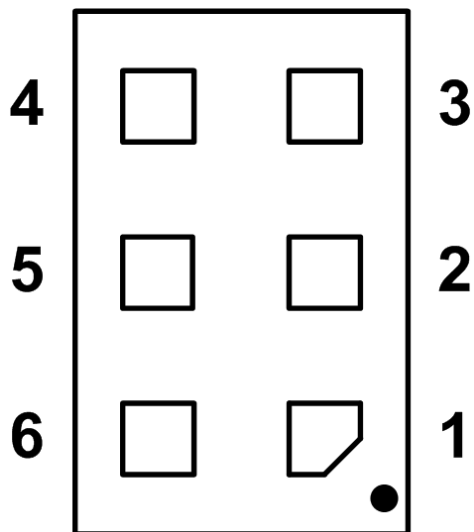


Will-Semi LTE-LNA Solutions

	LNA	Package	Frequency Range	Status
LTE-LNA	WS7932D	DFN1107	2300 ~ 2690 MHz	MP Q4/2015
	WS7931D	DFN1107	1805 ~ 2170 MHz	MP Q4/2015
	WS7938D	DFN1107	1805 ~ 2690 MHz	MP Q4/2015
	WS7930D	DFN1107	728 ~ 960 MHz	MP Q2/2016
GPS-LNA	WS7916S	DFN1510	1550 ~ 1615 MHz	MP Q2/2016
	WS7919S	DFN1107	1550 ~ 1615 MHz	MP Q2/2016

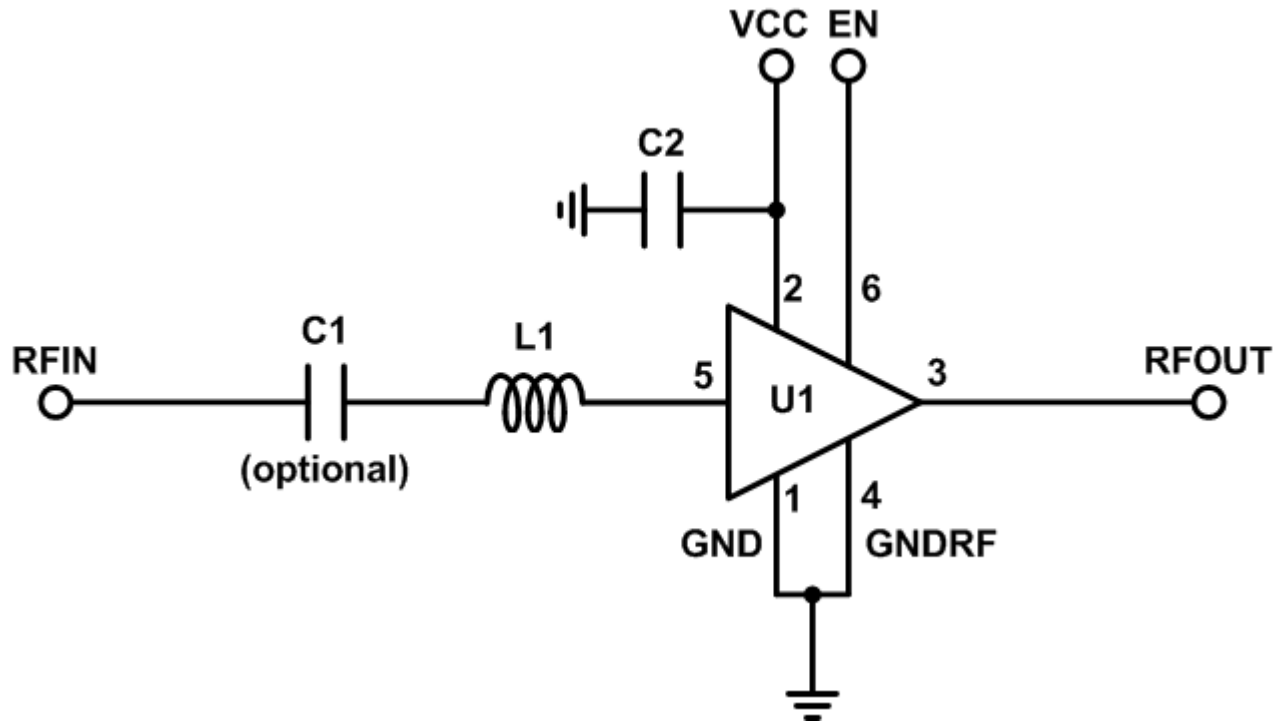
- **Operating frequency**
 - **2300~2690 MHz for high-band, 1805~2170MHz for mid-band and 728~960 MHz for low-band**
- **Noise figure = 1.0 dB**
- **Gain = 12.5 dB**
- **Input 1 dB compression point = -3.0 dBm**
- **In-band input IP3 = +6.0 dBm**
- **Supply voltage: 1.8 V to 3.1 V**
- **Integrated supply decoupling capacitor**
- **Supply current: 5.8 mA**
- **Power-down mode leakage current < 1 μ A**
- **One external matching inductor required**
- **Output decoupled to ground**
- **ESD protection: HBM > 2000V for all pins**
- **Integrated output matching**
- **Package: 6-pin DFN, 1.1 x 0.7 x 0.55 mm³**
- **Process: CMOS RF**

Will-Semi LTE-LNA – Pin Diagram



1	GND
2	VCC
3	RFOUT
4	GNDRF
5	RFIN
6	EN

Will-Semi LTE-LNA – Application Circuit



U1	LNA
L1	Input matching
C1	DC blocking
C2	Supply decoupling

High-Band LTE LNA

	BGA7H1N6	BGU8H1	WS7932D
Chip Provider	Infineon	NXP	Will-Semi
Frequency	2300~2690 MHz	2300~2690 MHz	2300~2690 MHz
Vcc	1.5~3.3V	1.5~3.1V	1.8~3.1V
Power Gain	12.5 dB	13.0 dB	12.5 dB
NF	1.0 dB	1.1 dB	1.0 dB
P1dB	-2.0 dBm	-3.0 dBm	-3.0 dBm
IIP3	+6.0 dBm	+6.0 dBm	+6.0 dBm
Input Return Loss	11 dB	8 dB	8 dB
Output Return Loss	19 dB	20dB	14 dB
Reverse Isolation	20 dB	20 dB	34 dB
Power-on Current	4.9 mA	5.0 mA	5.8 mA
Power-off Current	< 1uA	< 1uA	< 1uA
Process	SiGe	SiGe	CMOS
Package	DFN 1.1x0.7x0.375 mm ³	DFN 1.1x0.7x0.37mm ³	DFN 1.1x0.7x0.55mm ³

Mid-Band LTE LNA

	BGA7M1N6	BGU8M1	WS7931D
Chip Provider	Infineon	NXP	Will-Semi
Frequency	1805~2170 MHz	1805~2170 MHz	1805~2170 MHz
Vcc	1.5~3.3V	1.5~3.1V	1.8~3.1V
Power Gain	12.7 dB	13.5 dB	12.1 dB
NF	0.9 dB	1.0 dB	1.0 dB
P1dB	0 dBm	-2.0 dBm	-3.5 dBm
IIP3	+8.0 dBm	+5.0 dBm	+5.0 dBm
Input Return Loss	10 dB	9 dB	8 dB
Output Return Loss	15 dB	20dB	24 dB
Reverse Isolation	19 dB	20 dB	34 dB
Power-on Current	4.5 mA	5.0 mA	5.6 mA
Power-off Current	< 1uA	< 1uA	< 1uA
Process	SiGe	SiGe	CMOS
Package	DFN 1.1x0.7x0.375 mm ³	DFN 1.1x0.7x0.37mm ³	DFN 1.1x0.7x0.55mm ³

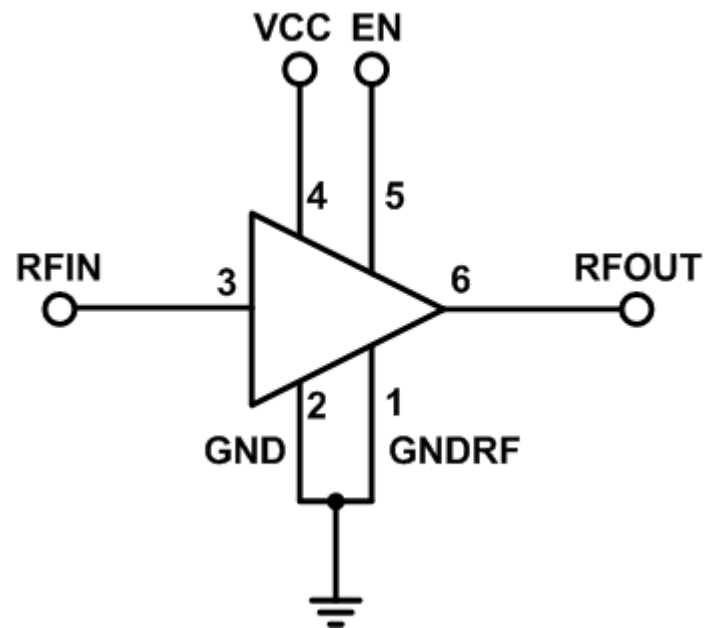
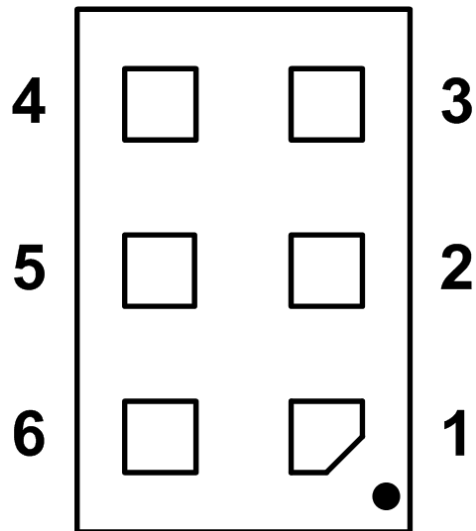
Low-Band LTE LNA

	BGA7L1N6	BGU8L1	WS7930D
Chip Provider	Infineon	NXP	Will-Semi
Frequency	728~960 MHz	728~960 MHz	728~960 MHz
Vcc	1.5~3.3V	1.5~3.1V	1.8~3.1V
Power Gain	13.1 dB	14.0 dB	13.5 dB
NF	0.9 dB	0.8 dB	0.95
P1dB	-2.0 dBm	-3.0 dBm	0 dBm
IIP3	2.0 dBm	2.0 dBm	0.5 dBm
Input Return Loss	17 dB	12 dB	8 dB
Output Return Loss	23 dB	20 dB	14 dB
Reverse Isolation	21 dB	26 dB	34 dB
Power-on Current	4.5 mA	4.6 mA	5.8 mA
Power-off Current	< 1uA	< 1uA	< 1uA
Process	SiGe	SiGe	CMOS
Package	DFN 1.1x0.7x0.375 mm ³	DFN 1.1x0.7x0.37mm ³	DFN 1.1x0.7x0.55mm ³

Will-Semi GPS-LNA Solutions

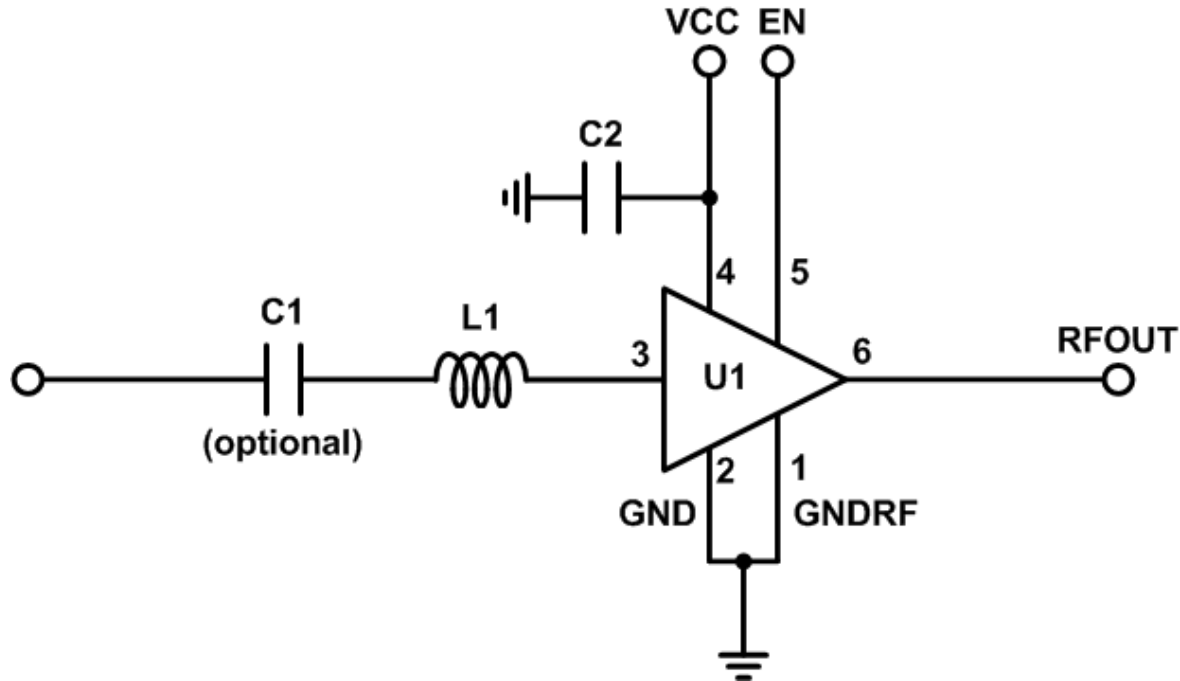
- **Operating frequency**
 - **1550~1615MHz for GNSS**
- **Noise figure = 0.80 dB**
- **Gain = 17.0 dB**
- **Input 1 dB compression point = -8.5 dBm**
- **In-band input IP3 = +8.5 dBm**
- **Supply voltage: 1.5 V to 3.1 V**
- **Integrated supply decoupling capacitor**
- **Supply current: 5.9 mA**
- **Power-down mode leakage current < 1 μ A**
- **One external matching inductor required**
- **Output decoupled to ground**
- **ESD protection: HBM > 2.0 KV for all pins**
- **Integrated output matching**
- **Package: 6-pin DFN, 1.5 x 1.0 x 0.55 mm³ or 1.1 x 0.7 x 0.55 mm³**
- **Process: CMOS RF**

Will-Semi WS7916S – Pin Diagram



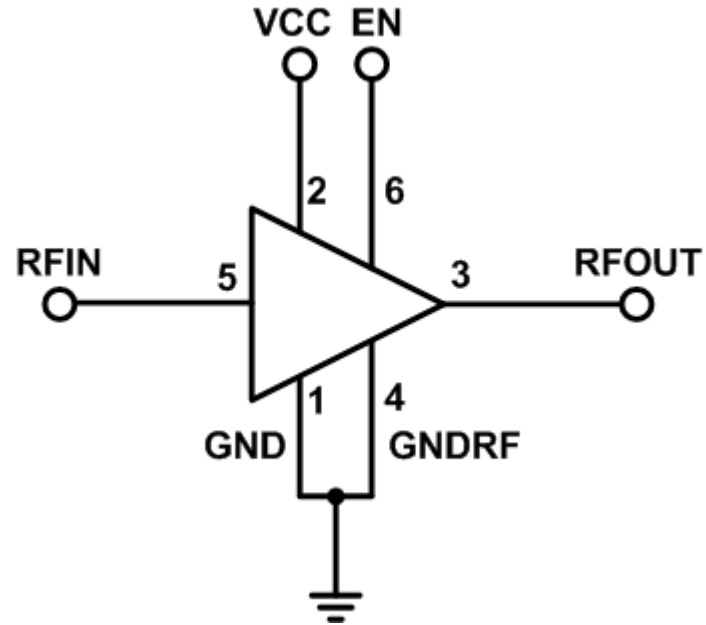
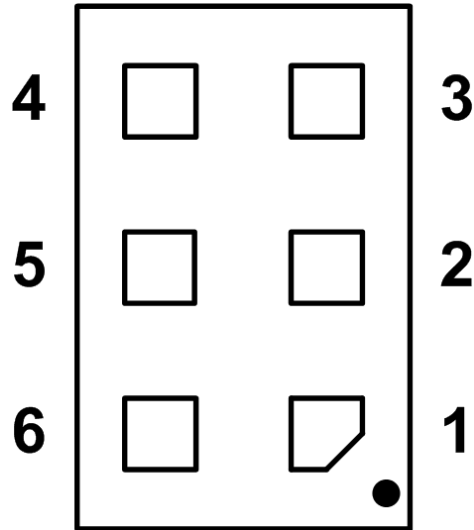
1	GNDRF
2	GND
3	RFIN
4	VCC
5	EN
6	RFOUT

Will-Semi WS7916S – Application Circuit



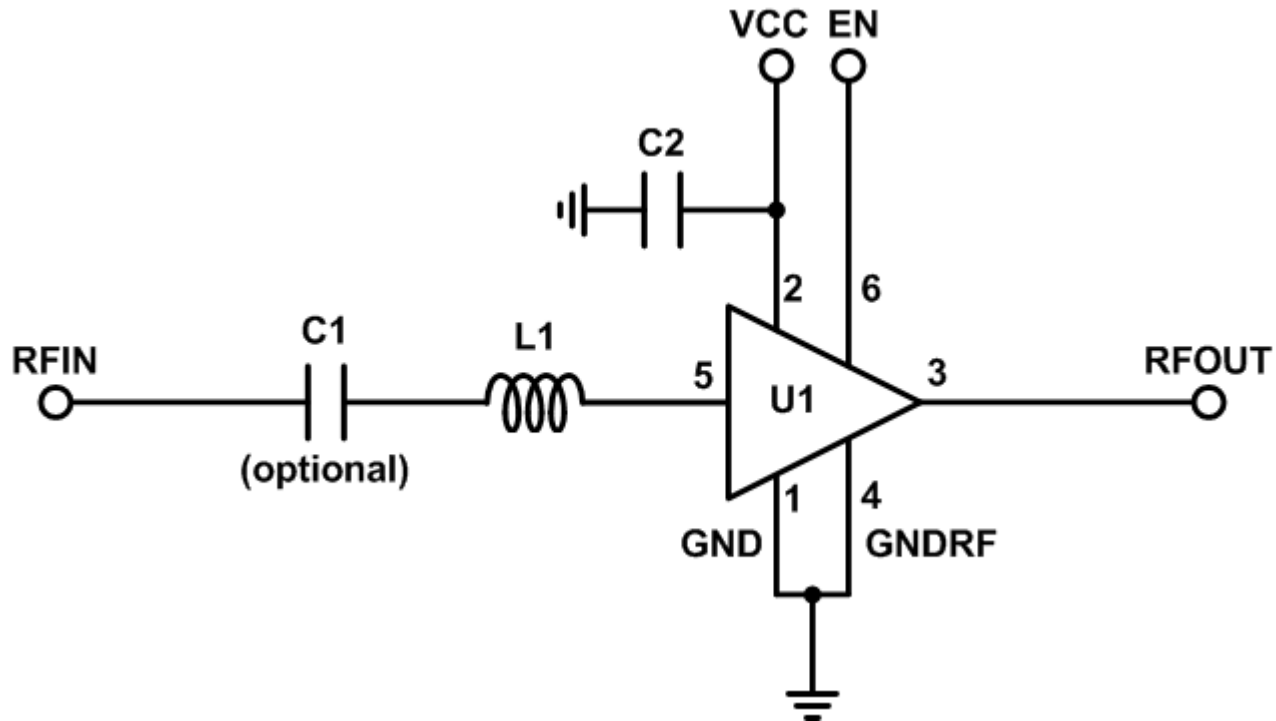
U1	LNA
L1	Input matching
C1	DC blocking
C2	Supply decoupling

Will-Semi WS7919S – Pin Diagram



1	GND
2	VCC
3	RFOUT
4	GNDRF
5	RFIN
6	EN

Will-Semi WS7919S – Application Circuit



U1	LNA
L1	Input matching
C1	DC blocking
C2	Supply decoupling

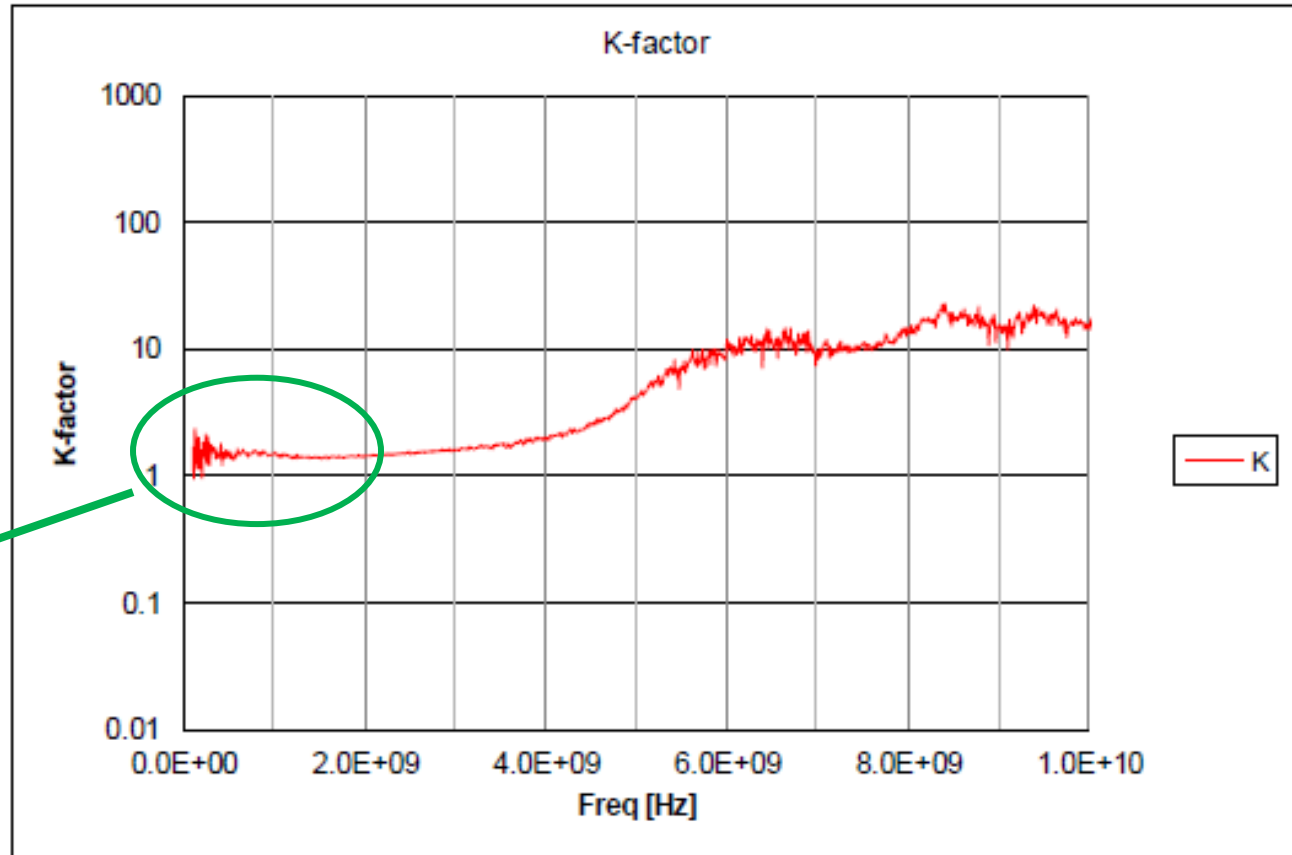
	BGU7005	WS7916S	WS7919S
Chip Provider	NXP	Will-Semi	Will-Semi
Frequency	1559~1610 MHz	1550~1615 MHz	1550~1615 MHz
Vcc	1.5~3.1V	1.5~3.1V	1.5~3.1V
Power Gain	16.5 dB	16.5 dB	17.0 dB
NF	0.85 dB	0.85 dB	0.80 dB
P1dB	-8.0 dBm	-9.5 dBm	-8.5 dBm
IIP3	+12.0 dBm	+9.5 dBm	+8.5 dBm
Input Return Loss	8 dB	8 dB	8 dB
Output Return Loss	14 dB	24 dB	15 dB
Reverse Isolation	23 dB	25 dB	30 dB
Power-on Current	4.5 mA	5.8 mA	5.9 mA
Power-off Current	< 1uA	< 1uA	< 1uA
Process	SiGe	CMOS	CMOS
Package	DFN 1.45x1.0x0.5mm ³	DFN 1.5x1.0x0.55mm ³	DFN 1.1x0.7x0.55mm ³

- **CMOS process**
 - Capacity and cost
 - Turn-around time
- **Better reverse isolation than Infineon and NXP's LNA**
 - Much better stability-factor
 - Much easier simultaneous input and output matching
- **Will-Semi LNAs has excellent ESD performance**
 - HBM > 2000V for all pins
- **Flip-chip package**
 - Less inductance
 - Superior thermal and electrical reliability

SiGe V.S. CMOS

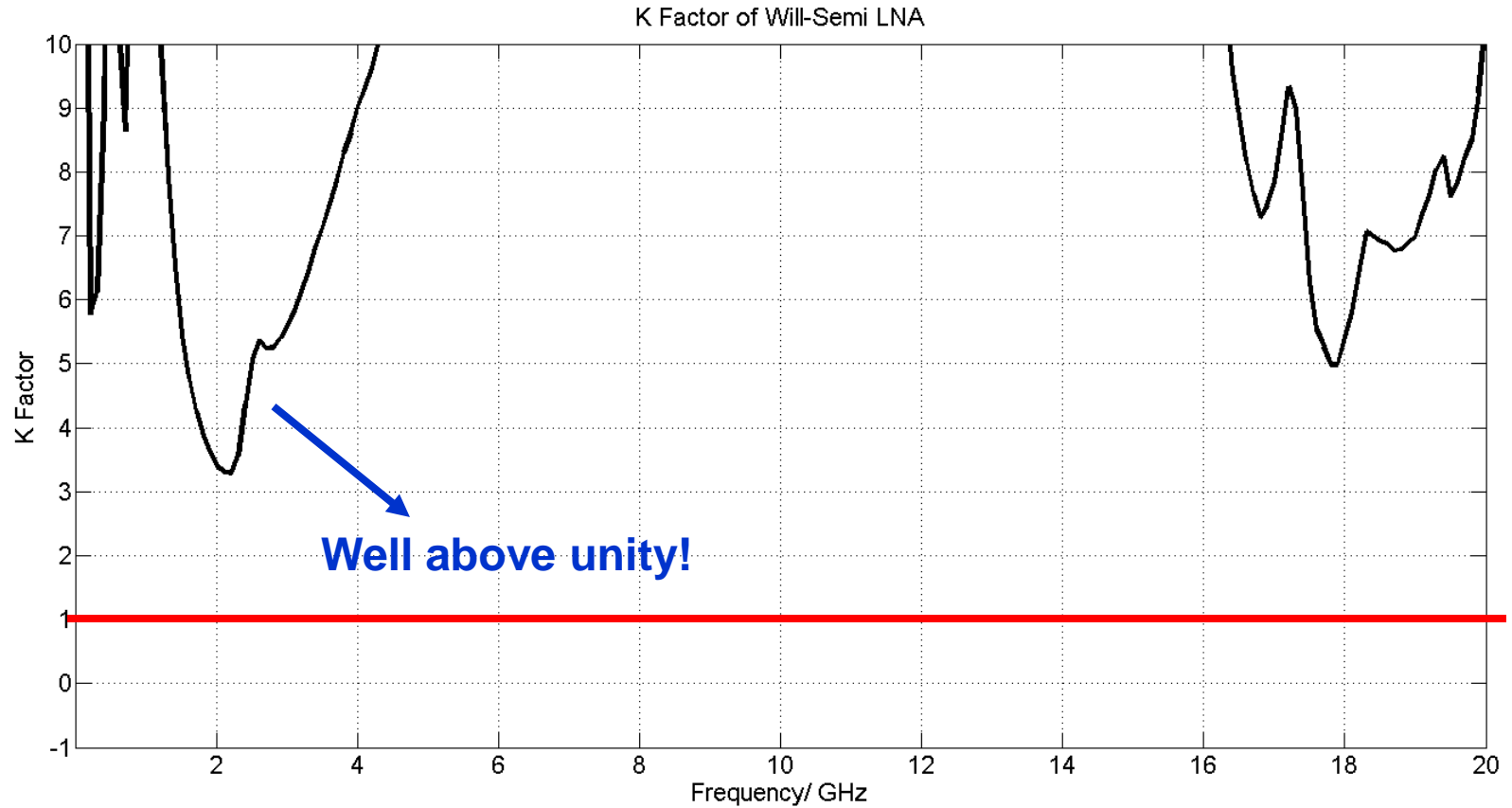
	SiGe	CMOS
gm/l	+	-
Fmin	+	-
BV	+	-
Linearity	-	+
Capacity	-	+
Turn-around time	-	+
Cost	-	+
Integration level	-	+

● NXP



Marginal OK

● Will-Semi



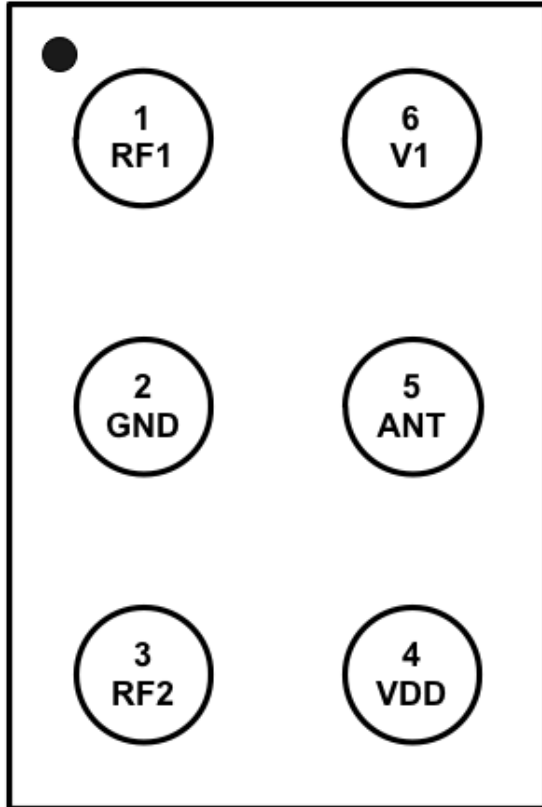
Will-Semi RFSW Solutions

Will-Semi Advanced RFSW Solutions

RFSW	Part #	Frequency Range	Package	Status
SP2T	WS7802Z	700~2700MHz	QFN1.1x1.1	MP
SP3T	WS7803Z	700~2700MHz	QFN1.1x1.1	MP
SP4T	WS7804Z	700~2700MHz	QFN2.0x2.0	MP
SP6T	WS7806Z	700~2700MHz	QFN2.0x2.0	MP
SP8T	WS7808Z	700~2700MHz	QFN2.0x2.0	MP
SP2T	WS7802C WS7812C WS7802F	700~2700MHz	DFN1.1x0.7 QFN1.1x1.1	MP Q3/2016
SP3T	WS7803F	700~2700MHz	QFN1.1x1.1	MP Q3/2016
SP4T	WS7804Q	700~2700MHz	QFN2.0x2.0	MP Q3/2016
SP6T	WS7806Q	700~2700MHz	QFN2.0x2.0	MP Q3/2016
SP8T	WS7808Q	700~2700MHz	QFN2.0x2.0	MP Q3/2016

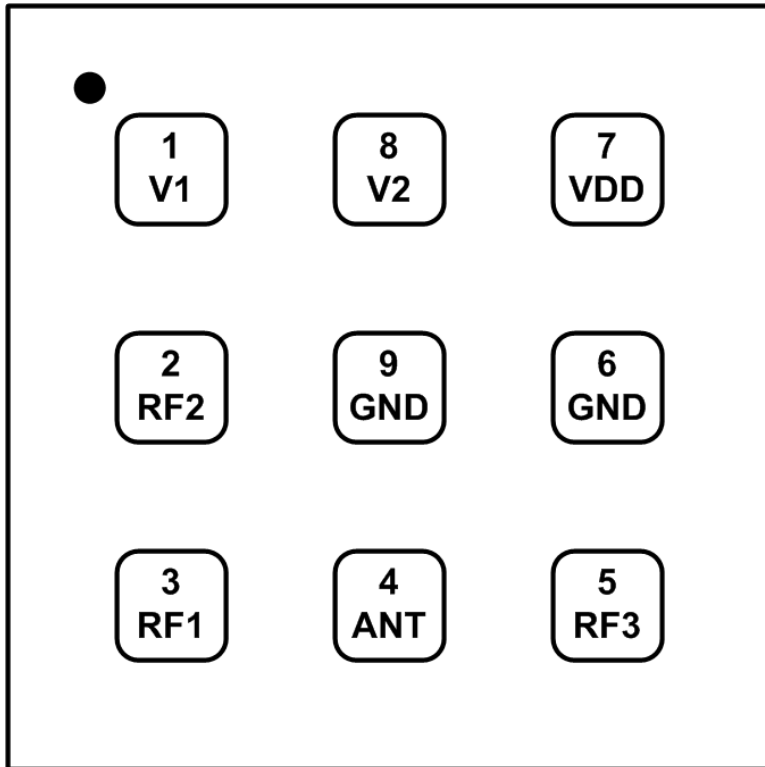
- **Operating frequency**
 - 700~2700 MHz
- **Applications**
 - LTE/WCDMA diversity antenna switches
 - WiFi/Bluetooth
- **Low insertion loss of 0.7 dB at 2.7 GHz**
- **Supply voltage: 2.5 V ~ 3.3 V**
- **Low Supply current: <50 μA**
- **Package**
 - SPDT: DFN, 1.1x0.7x0.45 mm³, 6-pin
 - SP3T / SP2T: QFN, 1.1x1.1x0.45 mm³, 12-pin
 - SP4T / SP6T / SP8T: QFN, 2.0x2.0x0.55 mm³, 14-pin
- **Process: CMOS RF/SOI**

WS7802C – Pin Diagram



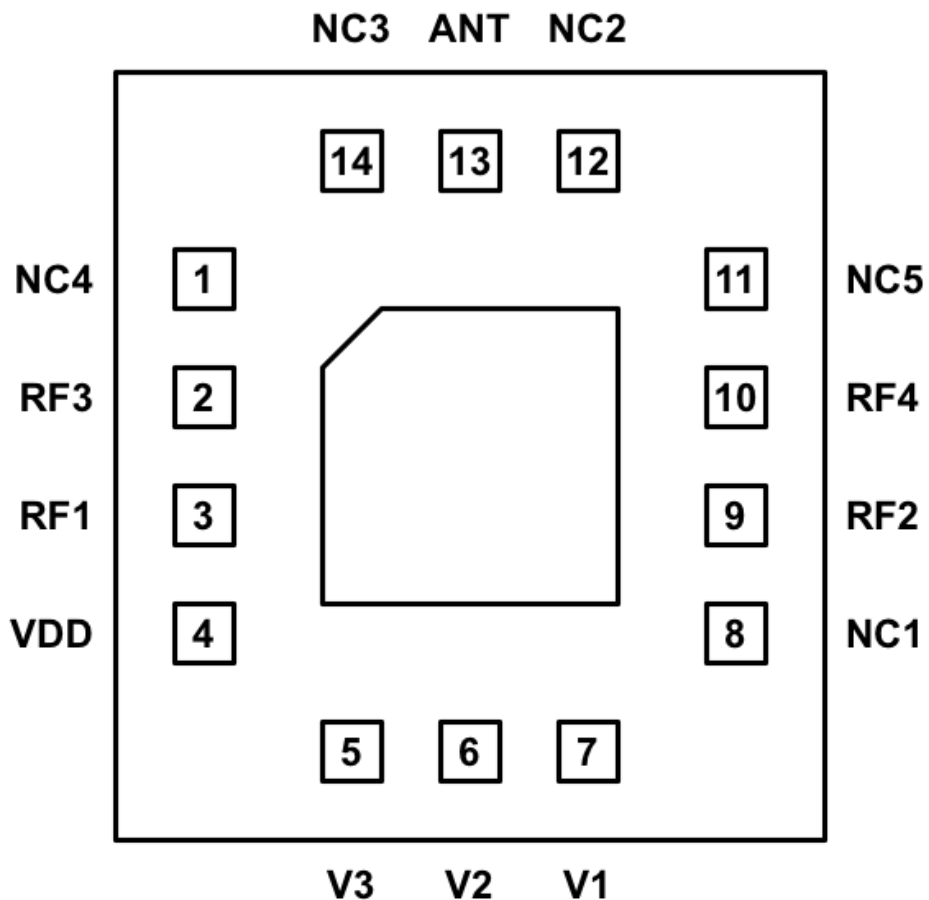
1	RF1
2	ANT
3	RF2
4	VDD
5	GND
6	V1

WS7803F / WS7803Z– Pin Diagram



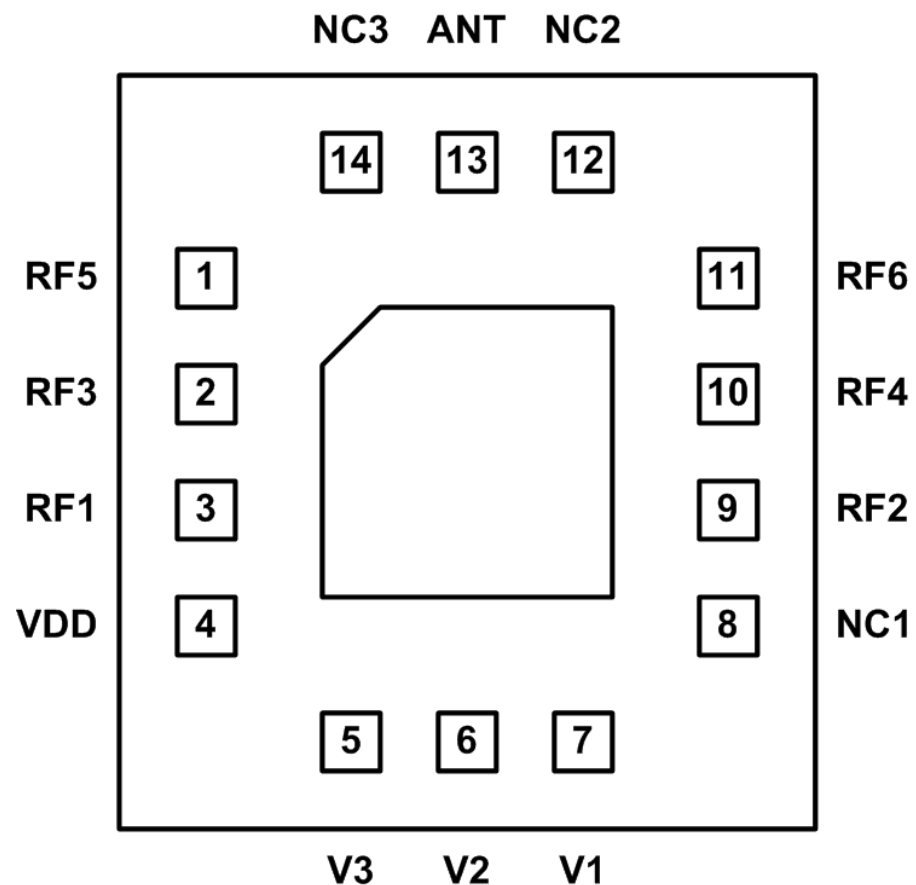
1	V1
2	RF2
3	RF1
4	RFC
5	RF3
6	GND
7	VDD
8	V2
9	GND

WS7804Q / WS7804Z – Pin Diagram



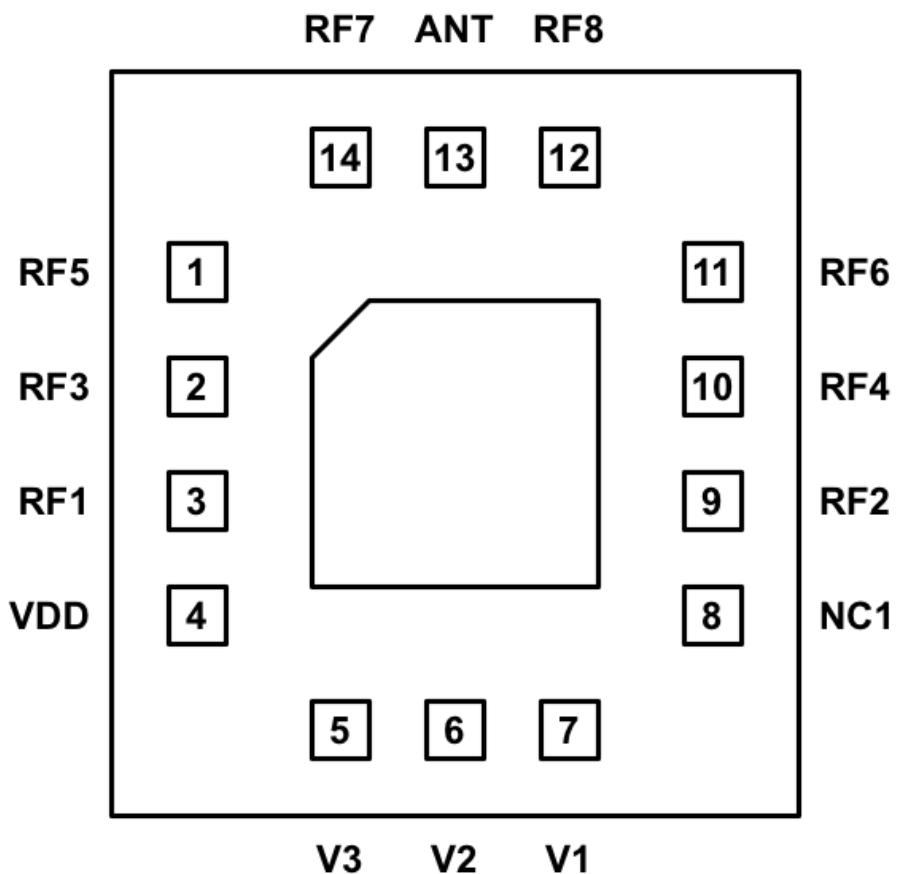
1	NC4
2	RF3
3	RF1
4	VDD
5	V3
6	V2
7	V1
8	NC1
9	RF2
10	RF4
11	NC5
12	NC2
13	ANT
14	NC3

WS7806Q / WS7806Z – Pin Diagram



1	RF5
2	RF3
3	RF1
4	VDD
5	V3
6	V2
7	V1
8	NC1
9	RF2
10	RF4
11	RF6
12	NC2
13	ANT
14	NC3

WS7808Q / WS7808Z – Pin Diagram



1	RF5
2	RF3
3	RF1
4	VDD
5	V3
6	V2
7	V1
8	NC1
9	RF2
10	RF4
11	RF6
12	RF8
13	ANT
14	RF7

Will-Semi RFSW Performance Summary

	WS7802Z	WS7803Z
Chip Provider	Will-Semi	Will-Semi
Frequency	0.1~6.0 GHz	0.1~6.0 GHz
Vcc	2.6~5.0V	2.6~5.0V
Insertion Loss	0.35 dB	0.35 dB
Isolation	33 dB	33 dB
Input Return Loss	22 dB	17 dB
Output Return Loss	23 dB	18 dB
P_{0.1dB}	39 dBm	35 dBm
IIP3	69 dBm	67 dBm
Power-on Current	40 uA	40 uA
Process	CMOS SOI	CMOS SOI
Package	QFN 1.1x0.7x0.55 mm³	QFN 1.1x1.1x0.55mm³

Will-Semi RFSW Performance Summary

	WS7804Z	WS7806Z	WS7808Z
Chip Provider	Will-Semi	Will-Semi	Will-Semi
Frequency	0.1~3.0 GHz	0.1~3.0 GHz	0.1~3.0 GHz
Vcc	2.4~4.2V	2.4~4.2V	2.4~4.2V
Insertion Loss	0.5 dB	0.5 dB	0.65 dB
Isolation	30 dB	28 dB	27dB
Input Return Loss	20 dB	19 dB	17 dB
Output Return Loss	21 dB	20 dB	18 dB
P_{0.1dB}	39 dBm	39 dBm	38 dBm
IIP3	69 dBm	69 dBm	69 dBm
Power-on Current	50 uA	50 uA	50 uA
Process	CMOS SOI	CMOS SOI	CMOS SOI
Package	QFN 2.0x2.0x0.55 mm³	QFN 2.0x2.0x0.55mm³	QFN 2.0x2.0x0.55mm³

Will-Semi RFSW Performance Summary

	WS7802C	WS7802F	WS7803F
Chip Provider	Will-Semi	Will-Semi	Will-Semi
Frequency	0.7~2.7 GHz	0.7~2.7 GHz	0.7~2.7 GHz
Vcc	2.5~3.3V	2.5~3.3V	2.5~3.3V
Insertion Loss	0.44 dB	0.44 dB	0.45 dB
Isolation	40 dB	40 dB	35 dB
Input Return Loss	17 dB	17 dB	20 dB
Output Return Loss	18 dB	18 dB	21 dB
P _{0.1dB}	35 dBm	35 dBm	34 dBm
IIP3	57 dBm	57 dBm	57 dBm
Power-on Current	35 uA	35 uA	37 uA
Process	CMOS SOI	CMOS SOI	CMOS SOI
Package	QFN 1.1x0.7x0.55 mm ³	QFN 1.1x1.1x0.55mm ³	QFN 1.1x1.1x0.55mm ³

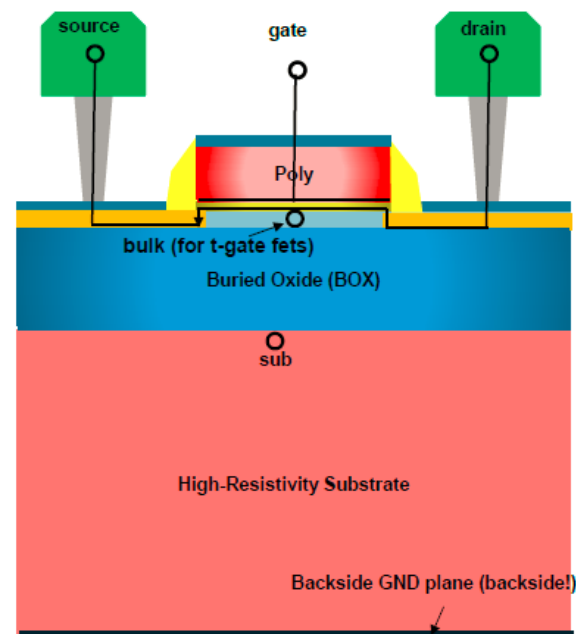
Will-Semi RFSW Performance Summary

	WS7804Q	WS7806Q	WS7808Q
Chip Provider	Will-Semi	Will-Semi	Will-Semi
Frequency	0.7~2.7 GHz	0.7~2.7 GHz	0.7~2.7 GHz
Vcc	2.5~3.3V	2.5~3.3V	2.5~3.3V
Insertion Loss	0.49 dB	0.56 dB	0.73 dB
Isolation	36 dB	35 dB	34 dB
Input Return Loss	23 dB	19 dB	14 dB
Output Return Loss	24 dB	20 dB	15 dB
P _{0.1dB}	35 dBm	34 dBm	33 dBm
IIP3	63 dBm	62 dBm	63 dBm
Power-on Current	46 uA	45 uA	44 uA
Process	CMOS SOI	CMOS SOI	CMOS SOI
Package	QFN 2.0x2.0x0.55 mm ³	QFN 2.0x2.0x0.55mm ³	QFN 2.0x2.0x0.55mm ³

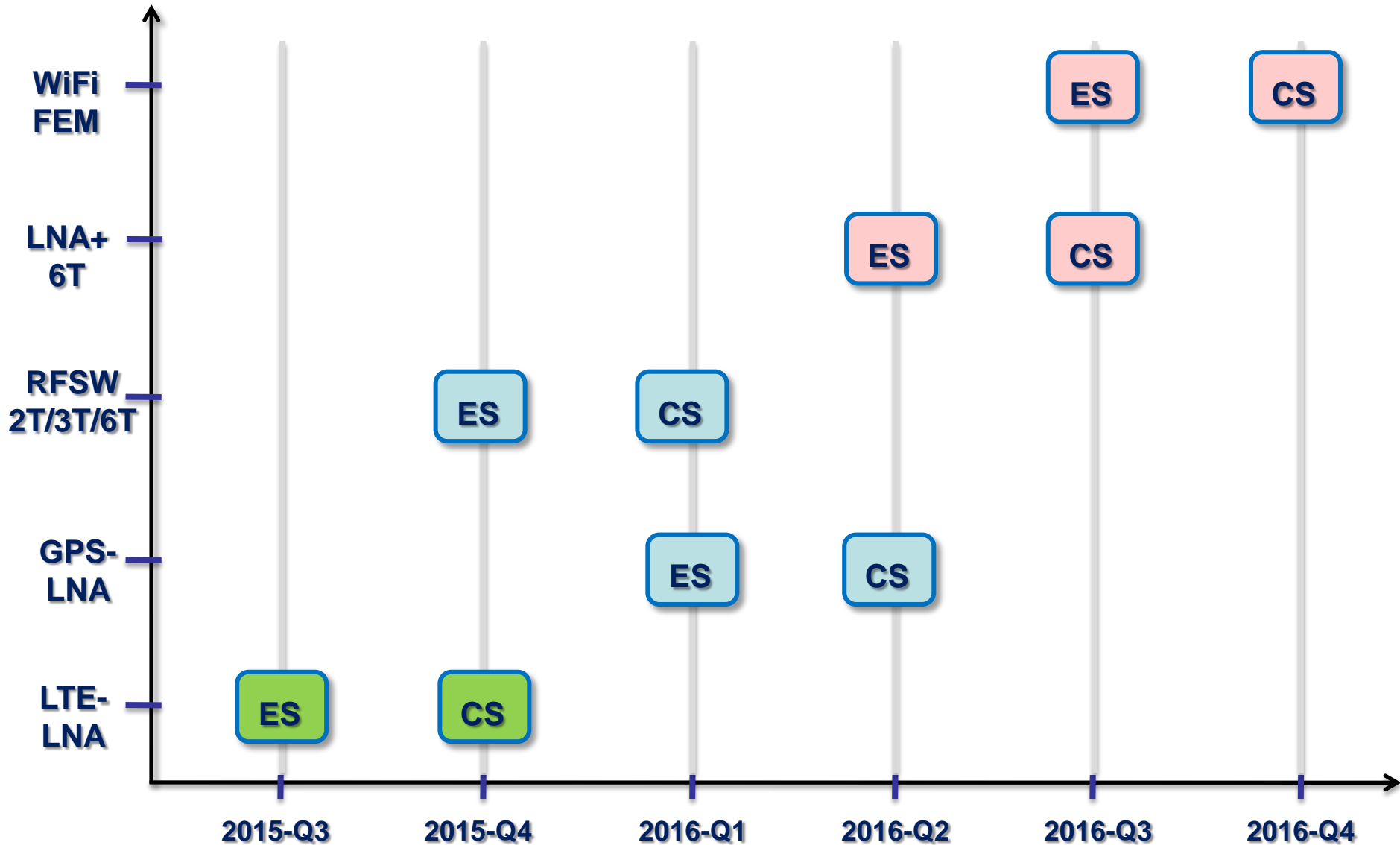
CMOS SOI Process

- **Why CMOS SOI process?**
 - **Significantly smaller $R_{on} \cdot C_{off}$ than CMOS – good for switches!**
 - **Virtually lossless substrate compared to CMOS – high-Q passive devices achievable**
 - **No latch-up issue, therefore no guard-ring needed – less silicon area consumed**
 - **Can short body and source – no body effect**

- **Why CMOS bulk process?**
 - **Less expensive**
 - **Much shorter turn-around time**
 - **Virtually unlimited capacity!**



Will-Semi RFIC Products Roadmap



Will-Semi RF Solution Summary

Will-Semi Part	P2P Part	Comments	Package
WS7930D	BGA7L1N6	Infineon LTE-LNA	DFN1.1x0.7
WS7931D	BGA7M1N6	Infineon LTE-LNA	DFN1.1x0.7
WS7932D	BGA7H1N6	Infineon LTE-LNA	DFN1.1x0.7
WS7938D	NA	NA	DFN1.1x0.7
WS7916S	BGU7005	NXP GPS-LNA	DFN1.5x1.0
WS7919S	BGU8009	NXP GPS-LNA	DFN1.1x0.7
WS7802C	RF1630	RFMD SP2T	DFN1.1x0.7
WS7812C	SKY13489	Skyworks SP2T	DFN1.1x0.7
WS7802F/WS7802Z	RF1628	RFMD SP2T	QFN1.1x1.1
WS7803F/WS7803Z	RF1628A/SKY13582	Skyworks SP3T	QFN1.1x1.1
WS7804Q/WS7804Z	SKY13414	Skyworks SP4T	QFN2.0x2.0
WS7806Q/WS7806Z	SKY13416	Skyworks SP6T	QFN2.0x2.0
WS7808Q/WS7808Z	SKY13418	Skyworks SP8T	QFN2.0x2.0

Thanks!