

## 20 MHz GPSDO PLL

This is a preliminary document describing a GPSDO PLL that is to work with a ublox NEO-7 GPS receiver. Eventually it is desired to incorporate an Arduino uP to manage the startup with a simple display and a buffer board that will supply a suitable signal for reference frequency distribution employing 74HCT1G125 drivers.

The First PCB [1.7" x 1.7"] provides a PLL, an interface to the ublox GPS, an Arduino connection and a level converter for the serial communications. There is provision for a battery backup for the ublox NEO-7 that may be implemented in several different ways.

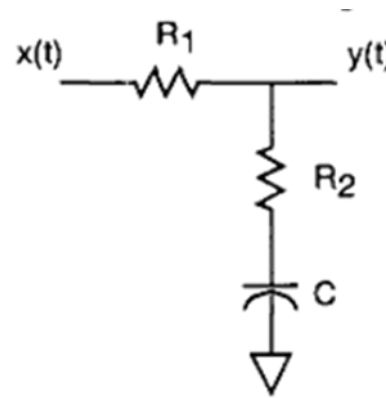
The PLL filter is described by the normal equations found below and exploited in a spreadsheet to be made available later.

### Second Order Passive Lead-Lag Filter

$$\tau_1 = C(R_1 + R_2) \quad \tau_1 = \frac{K_p K_v}{\omega_n^2}$$

$$\tau_2 = CR_2 \quad \tau_2 = \frac{2\zeta}{\omega_n} - \frac{1}{K_p K_v}$$

$$\omega_n = \sqrt{\frac{K_p K_v}{\tau_1}} \quad \zeta = \frac{1}{2\omega_n \tau_1} + \frac{\omega_n \tau_2}{2}$$



Also

$$\omega_n = \sqrt{\frac{K \omega_1}{N}} = \sqrt{\frac{K}{R_1 C N}}$$

$$\zeta = \frac{\omega_n}{2\omega_2} = \frac{R_2}{2} \sqrt{\frac{K C}{R_1 N}}$$

$K_p$  is the phase detector gain in volts per radian

$K_v$  is the VCO gain in radians per volt-second

$\zeta$  is the damping factor [zeta]

$\omega_n$  is the natural frequency of the loop  $= 2 * \pi * f$

$N$  is the loop frequency divisor

$f$  is the loop frequency in Hz

$$[(\text{Power Supply}/2)]/[\pi/2] = (\text{Power Supply}) / \pi$$

$$2 * \pi * (\text{VCO Slope})$$

$$K = \frac{K_v K_p}{N} = [2 * (\text{VCO Slope}) * (\text{Power Supply})] / N$$

NOTE: The PI's cancel

f	$\omega_n$	$\omega_n^2$	C in F	$\tau_1$	$\tau_2$	R2	R1	C in uF
0.16	1.005310	1.010647491	0.000470000	94.988610	2.575851	5,480.53	196,622.89	470
R1	R2	C	$\omega_n$	$\zeta$	f			
196000	6040	0.000470000	1.020842	1.448984	0.162472			

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After some additional reading, I have added another tab to the spreadsheet with the damping factor [zeta],  $\zeta = 0.707$ . As it turns out you can achieve this condition by changing the R1 value to 200.0K and R2 to 3010 Ohms,  $\zeta = 0.7418$ ; C still = 470  $\mu$ F. Keeping the values of R1 = 196.0K and C = 470  $\mu$ F with R2 = 3.020 K by simply putting two of the 6.040K resistors in parallel and  $\zeta = 0.7245$ , if you are interested in this value for  $\zeta$ .

In my opinion, too many of the authors have put far too much emphasis on Floyd Gardner's mathematics and very little on the real world. Gardner shows best performance with  $\zeta = 0.5$  and has a "compromise" value of  $\zeta = 0.707$ . These values reflect loops primarily used for an integer N synthesizer or signal recovery. We are doing neither and overshoot is undesirable, so  $\zeta = 1.3$  is number that I have chosen. Professor Long does differentiate in types of loops and suggests that even higher values of  $\zeta$  may be used.

Another variable, of the few that are available is the loop natural frequency. This design can be considered a high gain loop, because of the VCO slope, the loop divisor N is only 10 and the reference frequency is 2.0MHz. When using reference frequencies of 1pps or up to 10KHz the loop natural frequency needs to be very small and preferably several orders of magnitude less than the reference frequency. I have chosen to keep this value small and still sub Hz at 0.16Hz. It is possible that it could be raised 10 to 100 times without affecting performance. Raising this value would bring the value of C near a level where a high performance film capacitor would be able to replace the Tantalum used for C1.

I will put more info on the web site after I get one built.

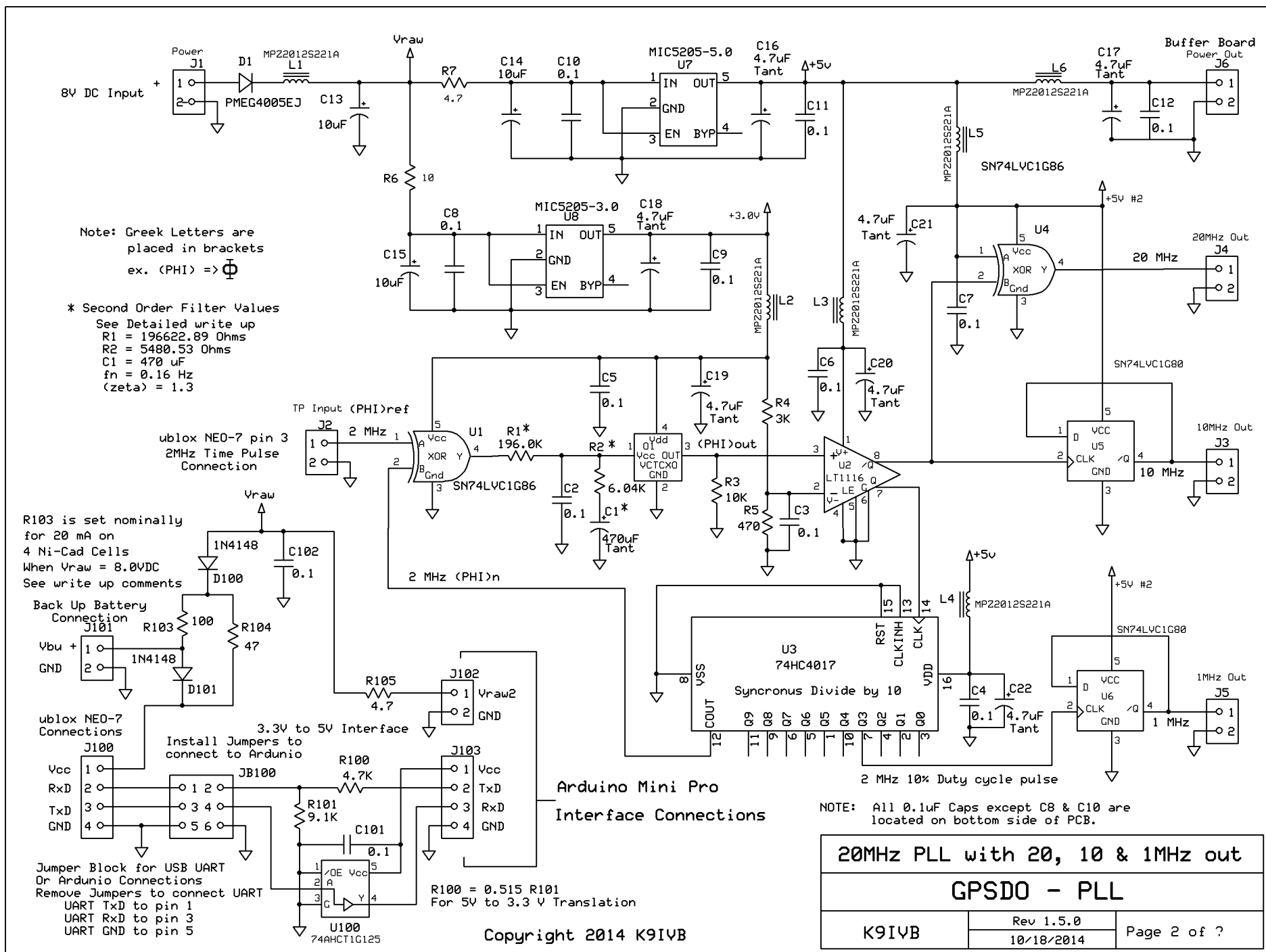
## References:

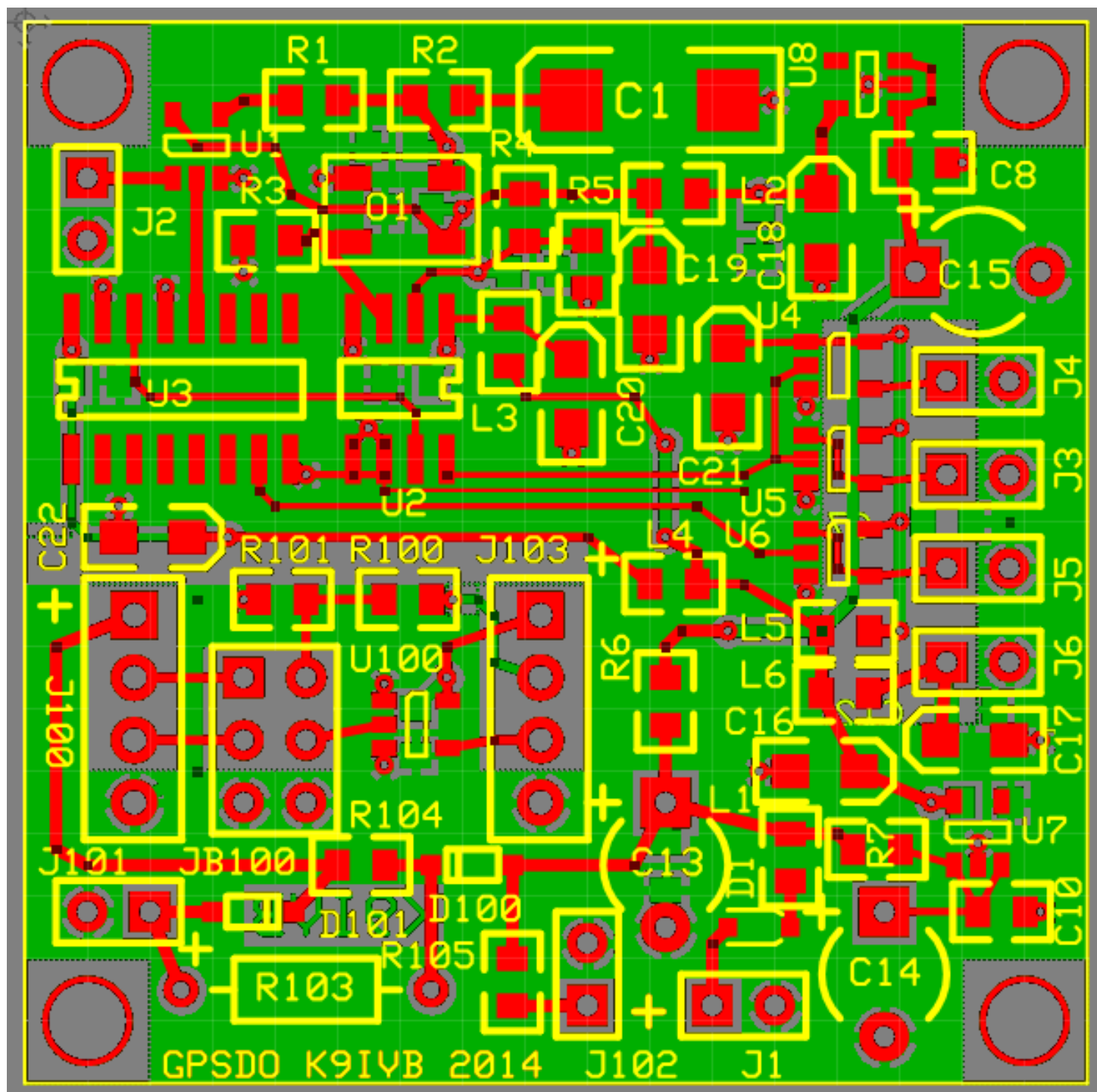
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Gardner, F.M., *Phaselock Techniques*, Second Edition, New York, NY, John Wiley and Sons, 1979.

Long. Prof Steve, *PLL\_intro\_594a\_s05.pdf*, UCSB/ECE Department, April 27, 2005

Stevens, Donald R., *PHASE-LOCKED LOOPS FOR WIRELESS COMMUNICATIONS Digital, Analog and Optical Implementations*, Second Edition, NEW YORK, KLUWER ACADEMIC PUBLISHERS, 2002





# GPSDO-PLL BOM

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Ref Des	Value	Description	Part Number	Mfg	PAD	Mouser	Qty
C1	470uF	Tantalum Capacitors - Solid SMD 6.3V 470uF 10% "Y" Case	TAJY477K006RNJ	AVX	[7343]	581-TAJY477K006RNJ	1
C2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 101, 102	0.1	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25volts 0.1uF X7R 10%	C0805C104K3R	KEMET	[0805]	80-C0805C104K3R	13
C13, 14, 15	10uF	Aluminum Electrolytic Capacitors - Leaded 16volts 10uF 4X7mm L/S=5.0mm Ammo Crmp	EEA-GA1C100B	Panasonic	0.2" LS	667-EEAGA1C100B	3
C16, 17, 18, 19, 20, 21, 22	4.7uF Tant	Tantalum Capacitors - Solid SMD 10V 4.7uF 10% "A"	T491A475K010AT	KEMET	1206	80-T491A475K010	7
D1	PMEG4005EJ	Schottky Diodes & Rectifiers 40V 0.5A	PMEG4005EJ,115	NXP	SOD-323	771-PMEG4005EJ-T/R	1
D100, 101	1N4148	1N4148, SOD-323F		Fairchild	SOD-123	512-1N4148WS	2
J1, 2, 3, 4, 5, 6, 101, 102		1x2 .100" Header					8
J100, 103		1x4 .100" Header					2
JB100		2x3 .100" Header					1
L1, 2, 3, 4, 5, 6	MPZ2012S221A	FERRITE CHIP 220 OHM 3A	MPZ2012S221A		[0805]	810-MPZ2012S221A	6
O1	VCTCXO		ASVTX-09-20.000MHz-T			815-ASVTX-09-20.0MT	1
R1	196K	Thin Film Resistors - SMD 0805 196Kohm 0.1% 25ppm	ERA-6AEB1963V	Panasonic		667-ERA-6AEB1963V	1
R2	6.040K	Thin Film Resistors - SMD 0805 6.04Kohm 0.1% 25ppm	ERA-6AEB6041V	Panasonic		667-ERA-6AEB6041V	1
R3	10K	Thick Film Resistors - SMD 1/10watts 10Kohms 5%	RK73B1JTTDD103J	KOA Speer	[0805]	660-RK73B1JTTDD103J	1

R4	3K	Thin Film Resistors - SMD 0805 1/8W 3Kohms 0.1% 0805	ERA-6AEB302V	Panasonic	[0805]	667-ERA-6AEB302V	1
R5	470	Thick Film Resistors - SMD 1/8W 470ohm 1%	AC0805FR-07470RL	Yageo	[0805]	603-AC0805FR-07470RL	1
R6	10	Thick Film Resistors - SMD 1/8W 10ohm 1%	AC0805FR-0710RL	Yageo	[0805]	603-AC0805FR-0710RL	1
R7, 105	4.7	Thick Film Resistors - SMD 1/8W 4.7ohm 1%	AC0805FR-074R7L	Yageo	[0805]	603-AC0805FR-074R7L	2
R100	4.7K	Thick Film Resistors - SMD 1/8W 4.7K ohm 1%	AC0805FR-074K7L	Yageo	[0805]	603-AC0805FR-074K7L	1
R101	9.1K	Thick Film Resistors - SMD 0805 9.1Kohms 1% Tolerance	ERJ-6ENF9101V	Panasonic	[0805]	667-ERJ-6ENF9101V	1
R103	100	Metal Film Resistors - Through Hole 100ohm 1/4W 1%	MFR-25FRF52100R	Yageo	axial	603-MFR-25FRF52100R	1
R104	47	Thick Film Resistors - SMD 1/8W 47ohm 1%	AC0805FR-0747RL		[0805]	603-AC0805FR-0747RL	1
U1, 4	SN74LVC1G86	Logic Gates 2 Input XOR		TI	SOT-23-5	586-SN74LVC1G86DBVR	2
U2	LT1116		LT1116CS8	Linear Technology	SOIC-8		1
	alt	Analog Comparators High Speed Comp	TL3116CD	TI	SOIC-8	595-TL3116CD	
U3	74HC4017	Counter ICs 5-STAGE JOHNSON DECADE COUNTER [synchronus]	74HC4017D,653	NXP	SO-16	771-74HC4017D-T	1
U5, 6	SN74LVC1G80	Flip Flops Positive Edge Trig	SN74LVC1G80DBVR	TI	SOT-23-5	595-SN74LVC1G80DBVR	2
U7	MIC5205-5.0	LDO Voltage Regulators 5V 150mA 1% Low Noise LD	MIC5205-5.0YM5 TR	Micrel	SOT-23-5	998-MIC5205-5.0YM5TR	1
U8	MIC5205-3.0	LDO Voltage Regulators 3.0V 150mA 1% Low Noise LD	MIC5205-3.0YM5 TR	Micrel	SOT-23-5	998-MIC5205-3.0YM5TR	1
U100	74AHCT1G125	Buffers & Line Drivers Tri-State Single Bus	SN74AHCT1G125DBVR	TI	SOT-23-5	595-SNAHCT1G125DBVR	1