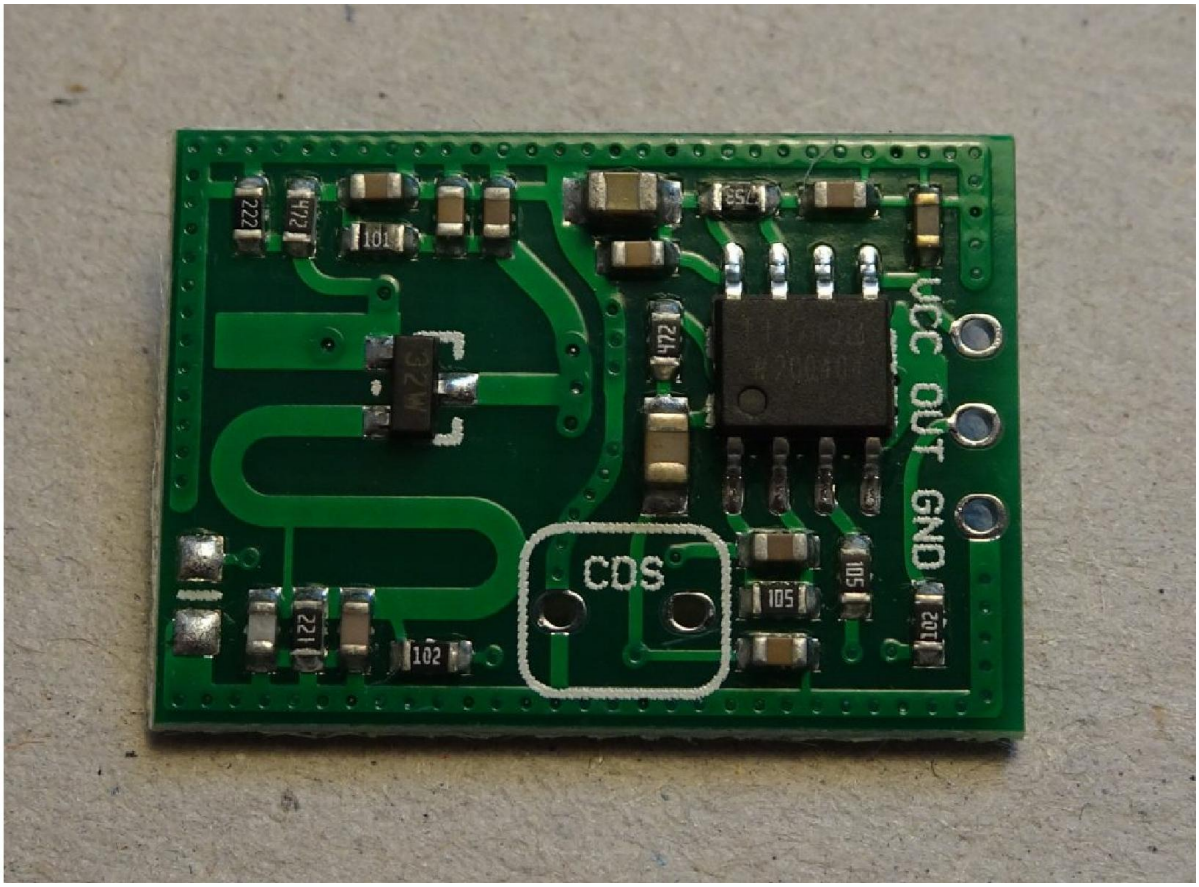
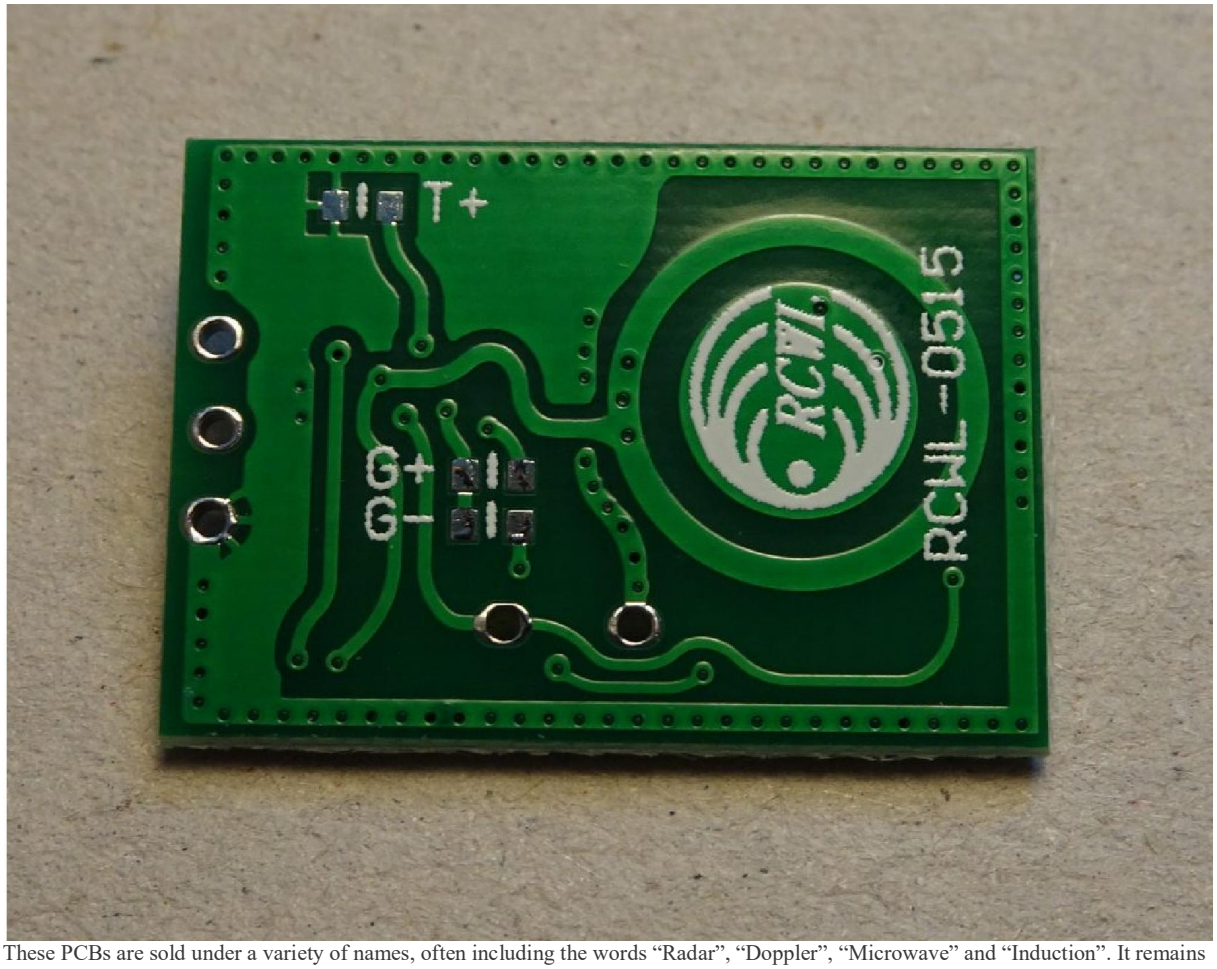
Tiny Transistors

RCWL-0515 Radar Motion Sensor

The RCWL-0515 is a little PCB that can be used as a motion sensor, similar in usage to passive infrared (PIR) sensors. This way you can make a light come on when you enter a room, or sound an alarm when the cat's waiting at the door.



I bought a couple of these things online for €1.15 each, which makes you wonder quite how they can make something like this so cheaply. It contains one IC labelled "TT1712B", one transistor labelled "32W" and a bunch of resistors and capacitors. The IC is some custom part for this purpose (I could find no information on it whatsoever), while the transistor is a BFR520[1], a 9 GHz NPN transistor originally made by NXP but in this case probably by some unknown copycat manufacturer (given that NXP discontinued it in 2016).

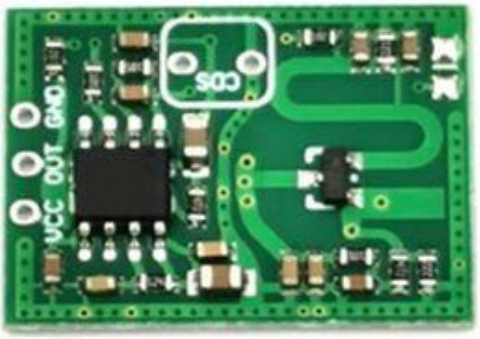


These PCBs are sold under a variety of names, often including the words “Radar”, “Doppler”, “Microwave” and “Induction”. It remains unclear who made it: it is available at a number of online shops, but I haven’t been able to track down who “RCWL” are. There is apparently also a similar PCB named RCWL-0516 which is reviewed on many other websites[2], but I’ve not been able to find much information on the ‘0515.

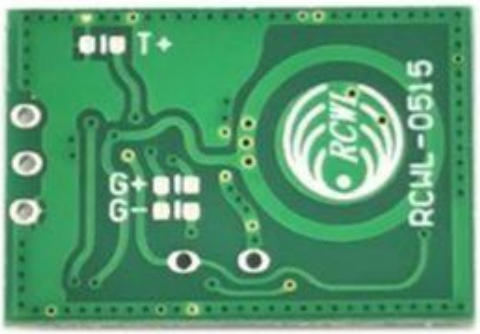
RCWL-0515

小尺寸，远距离（12米）微波感应模块

* 超小尺寸（17X24MM）
* 远距离（12-15米）
* 频率2.7G
* 宽电压（4-15V）
* 高穿透，可放在壳体内
* 增益，延时预留可调



无铅工艺



注意：实际应用，外围高频信号和10CM内的物体遮挡对灵敏度有影响

RCWL-0515 微波感应模块

■ 产品概述

RCWL-0515 是一款采用多普勒雷达技术，专门检测物体移动的微波感应模块。采用 2.7G 微波信号检测，该模块具有灵敏度高，感应距离远，可靠性强，感应角度大，供应电压范围宽等特点。

微波感应是一种新型无死角，基于多普勒雷达原理的感应模式。其平面型天线发出电磁波并接收反射回波，可有效抑制高次谐波和其他杂波的干扰；可靠性强、安全方便。

与红外产品比较：微波开关感应距离更远，角度广，无死区，能穿透玻璃和薄木板，根据功率不同可以穿透不同厚度的墙壁，不受环境、温度、灰尘等影响，在 37 度情况下，感应距离不会缩短。广泛应用于各种人体感应照明和防盗报警等场合。

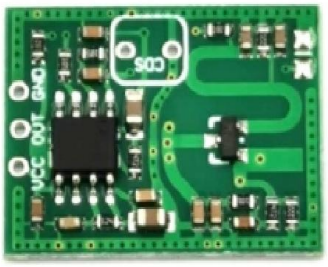
■ 主要特性

- 工作电压：4-18V
- 工作电流：4mA
- 2.7G 工作频率
- 预留贴片与直插 CDS 接口
- 12 米典型感应范围
- 感应距离可调
- 无铅工艺
- 重复触发时间可调

■ 典型应用

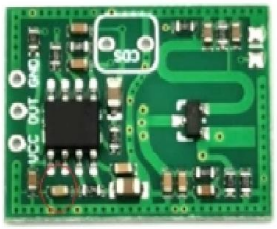
- 楼道灯，感应灯，太阳能灯
- 紫外线杀毒灯
- 人体移动感应

■ 实物图



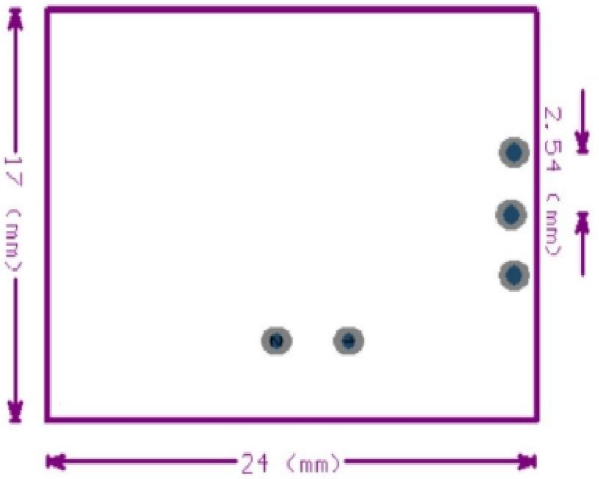
■ 最大额定值（TA=25℃）

T+电容值	延时触发时间
默认 102	5-6S
103	50-60S
104	500-600S

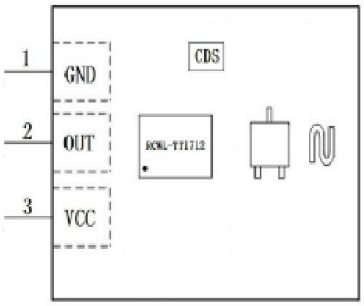


如果客户需要更短的延时时间，改小该电容值。改成470P，延时时间在2S左右。

■ 外型尺寸



■ 功能框图



■ 管脚描述

序号	符号	功能描述
1	GND	电源地
2	OUT	输出：H — 3.3V，L — 0V
3	VCC	4-18V 电源
	CDS	触发控制信号： 小于 0.7V，输出一直是低电平 大于 0.7V，正常工作 CDS 脚外接光敏电阻，白天关闭模块检测功能。内部上拉电阻 1M 到 VCC

■ 最大额定值（TA=25℃）

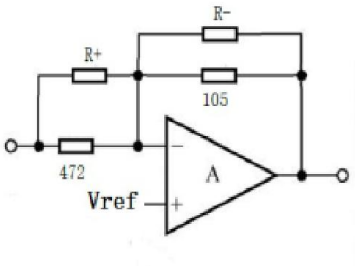
符号	参数	测试条件	数值	单位
V_{DD}	最大工作电压	-	-0.5 to +18	V
V_{OMAX}	输出端最大耐压	-	5.5	V
T_{STG}	存储温度	-	-40 ~ 110	℃
T_{OP}	工作温度	-	-20 ~ 100	℃

■ 直流电气特性（TA=+25℃无特别注明）

符号	参数说明	测试条件	最小	典型	最大	单位
VIN	工作电压范围	VIN 输入	4	-	15	V
I_{IN}	工作电流	输出空载 VIN=4V	-	4	5	mA
		输出空载 VIN=12V	-	4	5	mA
VOUT	输出高电平		3.25	3.3	3.35	V
θ	探测角	天线正面		360	-	°
S	探测距离		7	12*	15	M
d_Front	正面探测距离	θ=0° 无障碍物	-	12*	-	M
d_Back1	反面探测距离	θ=0° 无障碍物	-	10*	-	M
d_Back2	反面探测距离	10CM 混凝土墙体	-	3*	-	M
发射功率				20	30	mW
触发方式				重复触发		

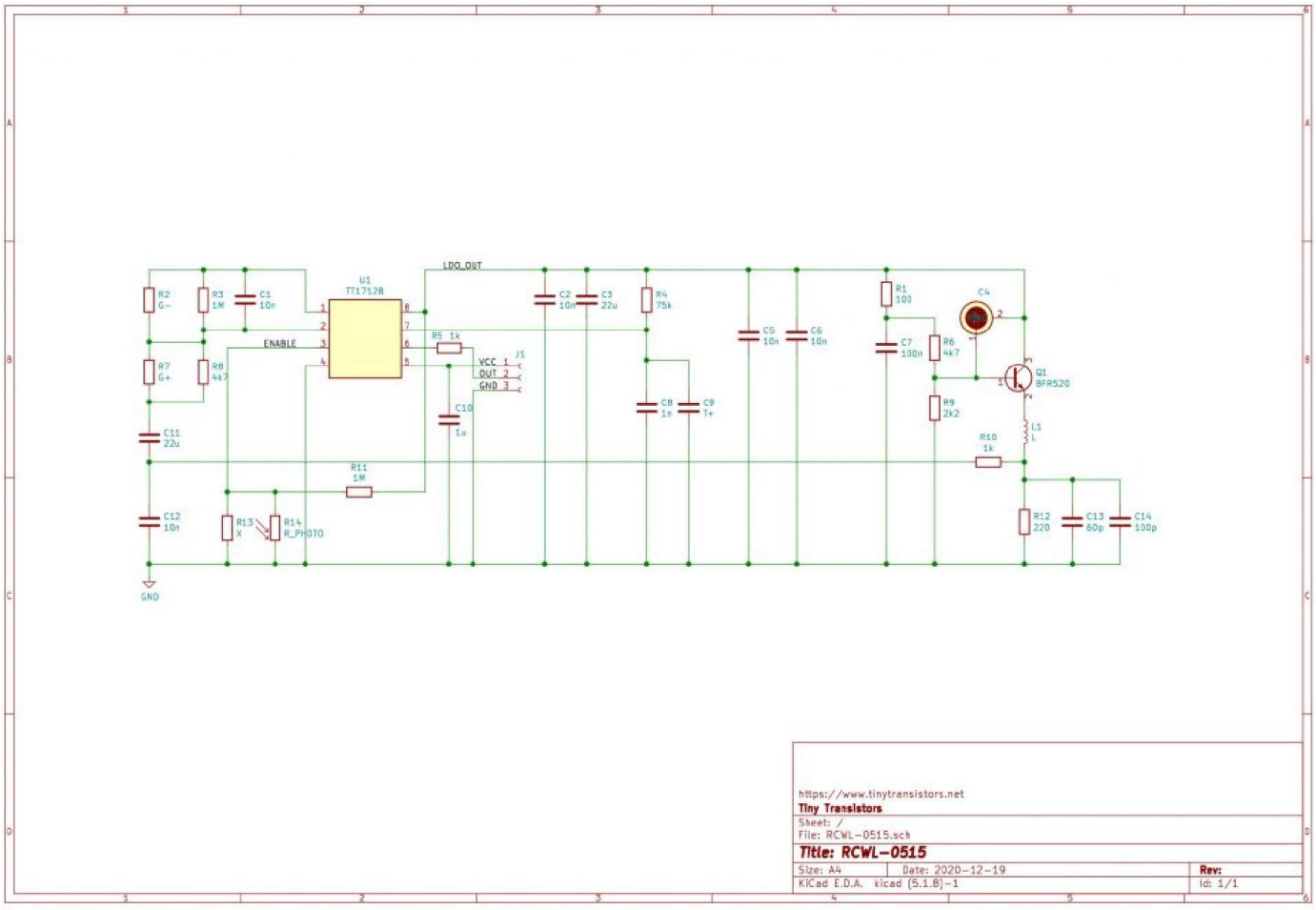
*：会受10CM范围内物体与无线信号影响，实际应用要注意。

■ R+与R-内部设置示意图



并联R+，增益增大，灵敏度变高，感应距离变大；并联R-，增益减小，灵敏度变小。感应距离变小。

This is the closest thing to a datasheet I could find. Note that there is no mention of who manufactured it! Someone, somewhere, put a lot of effort into designing this circuit, testing it under various circumstances, setting up a production line, buying parts, soldering, packaging and selling the PCBs, but did not bother to announce any of this to the world. How is that even possible? There is a company called RC Wulian[3] which seems like a plausible candidate, but their logo is different and they don't mention this product on their website (then again, they don't even mention their own address, so apparently they like operating in the shadows).
Anyway, according to the datasheet the RCWL-0515 can be used at a supply voltage of 4 to 15 V, works at a frequency of 2.7 GHz and can detect objects at a distance of up to 15 metres. When it detects movement, the "OUT" pin is pulled high for five to six seconds. You can increase this by adding an extra capacitor on the "T+" position. It also has an option to add a light sensor so that it only works in darkness (so it won't switch on a light during the day), and you can change the sensitivity of the sensor by adding extra resistors on the backside ("G+" and "G-" to increase and decrease it, respectively).

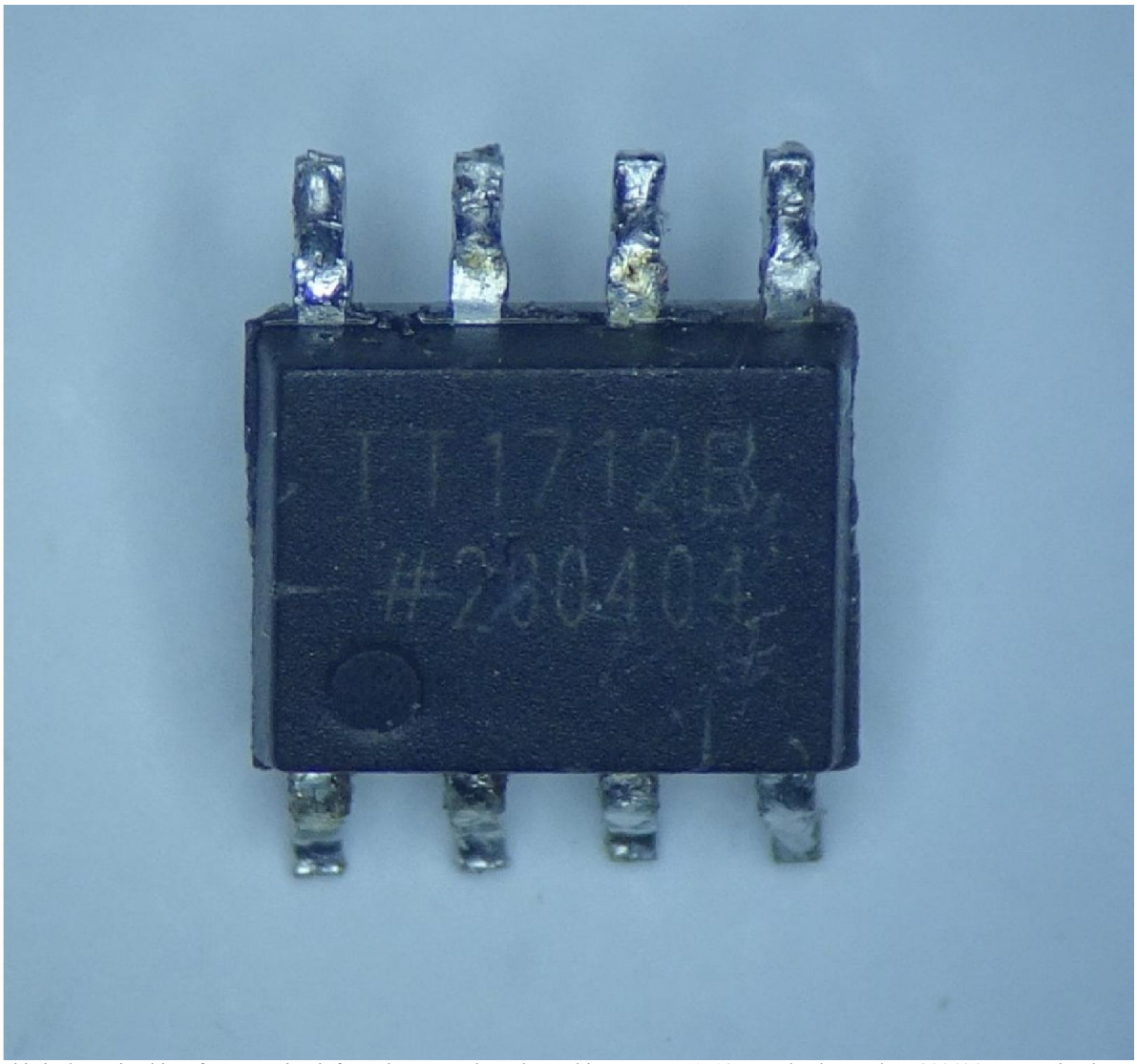


Here is the schematic as I've managed to reverse-engineer it. On the right side there's an oscillator built around the BFR520 transistor. Its oscillation frequency is determined by the inductor L, formed by the S-shaped line on the front of the PCB, and capacitor C4 formed by the circular shapes on the back. R1, R6 and R9 determine the DC operating point, together with R12. The inductor also acts as an antenna, transmitting microwaves perpendicular to the PCB.

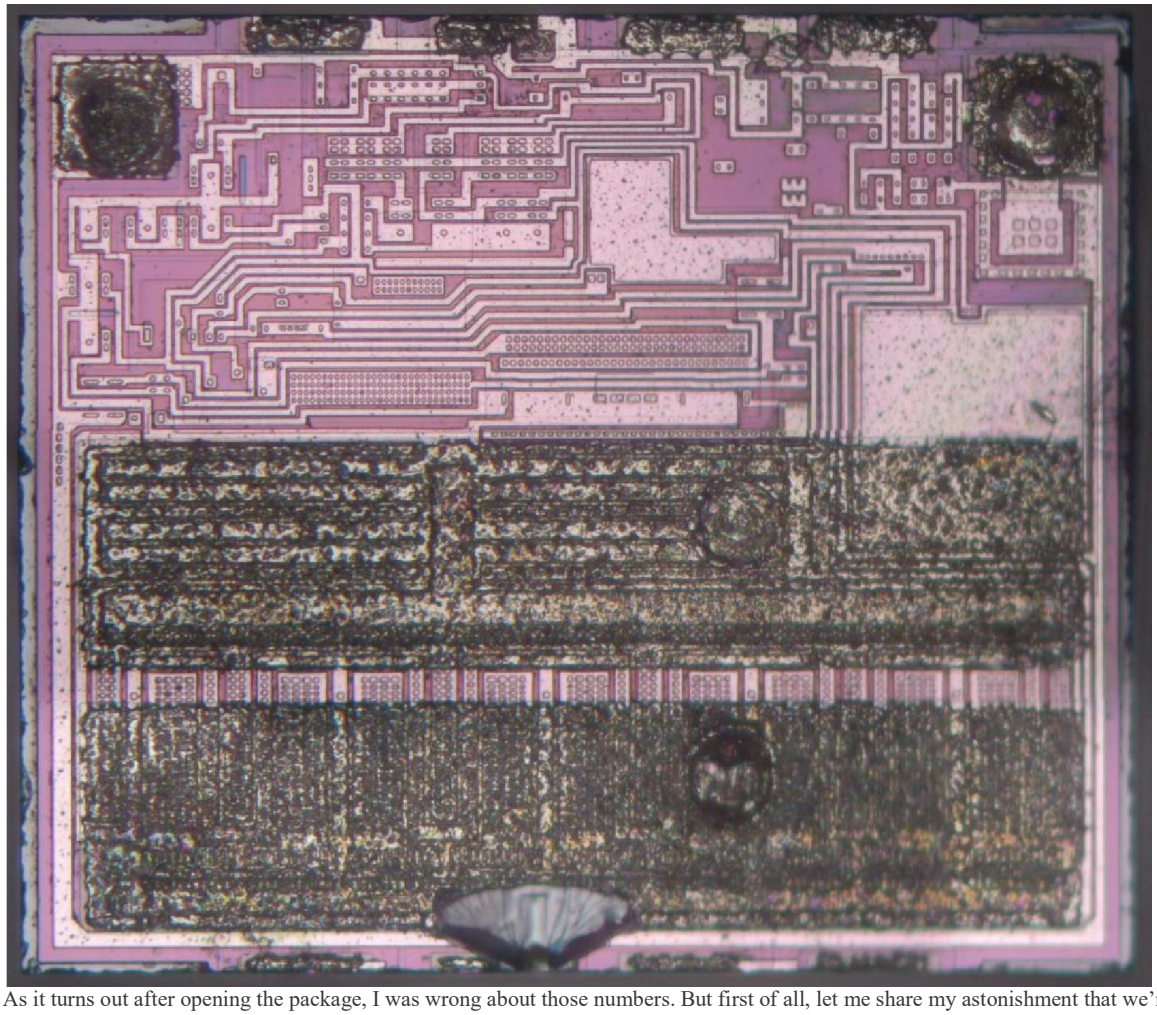
When an object moves nearby it changes the impedance seen by the antenna, and therefore the oscillation frequency, which slightly changes the DC bias of the transistor. You could consider this an extremely crude continuous-wave Doppler radar, with the transistor acting as both the transmitter and the receiving mixer (with a zero IF).

The change in DC emitter voltage is AC coupled to U1, which has a comparator with a gain of about 200 as shown on page 3 of the datasheet. If the change passes a certain threshold, the output pin is driven high and a counter is started, clocked by R4/C8/C9. After a certain number of cycles have passed, the output is switched low again.

A photocell can be added to R13/R14 to pull the enable pin low when there is light. Pin 8 of the IC is regulated to 3.3 V by an internal LDO.

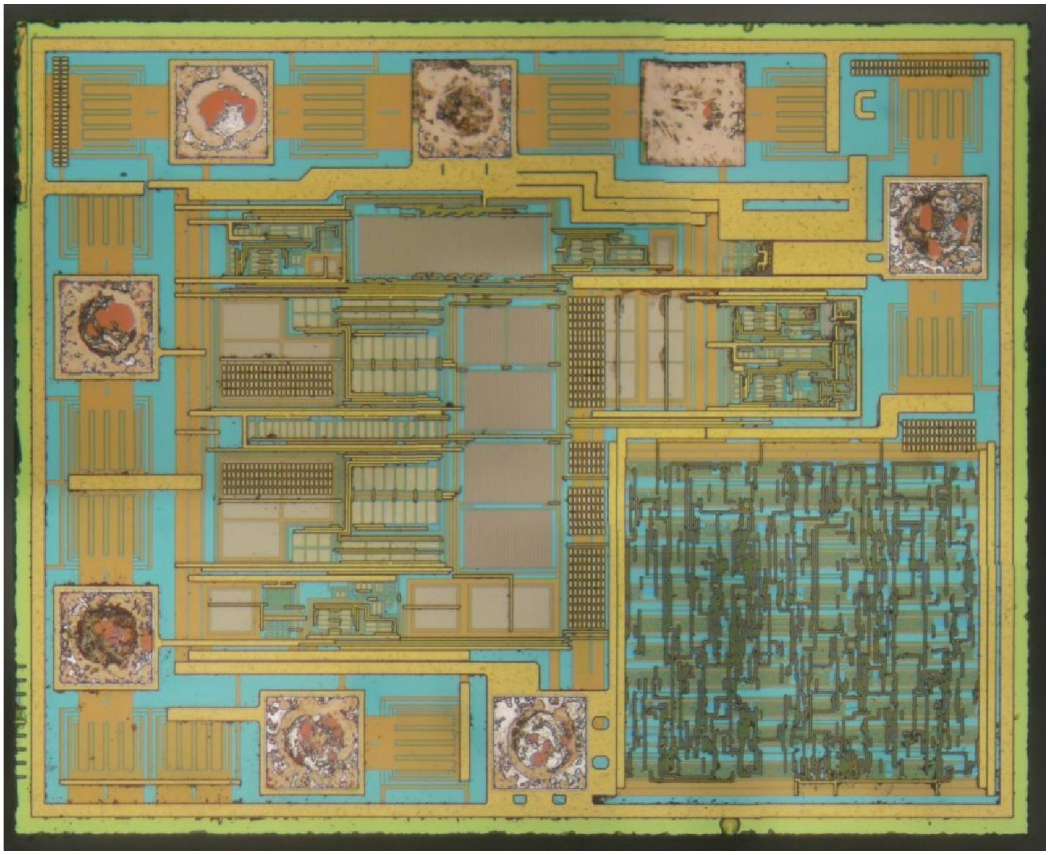


This is the main chip, after removing it from the PCB. The only markings are “TT1712B” and a date code “#200404”. It’s a simple plastic SOIC package with, again, no indication of a manufacturer. On the back it says “1712 1117”, which might indicate the production line or a specific batch.



As it turns out after opening the package, I was wrong about those numbers. But first of all, let me share my astonishment that we're looking at a multi-chip module! There are *two* separate chips inside the TT1712B's package, which is something I definitely wasn't expecting in a device that cannot cost more than a few cents to produce. The "1117" on the back of the package clearly refers to an LM1117 LDO, originally designed by National Semiconductor but nowadays a very popular part in the catalogs of small, unknown IC manufacturers that sell them into cheap consumer goods.

The chip we see above is clearly a voltage regulator: a very large transistor at the bottom with extra thick metal bars to connect it, a simple amplifier circuit above it with two compensation capacitors, and an indication of its output voltage ("33", meaning 3.3 V). It can easily be changed to any desired voltage simply by moving some of the metal jumpers near the "33" to a different position and changing the label.



Then there's the chip that does the rest of the processing; let's call this the TT1712. There is a block of logic on the bottom-right, lots of analog circuits in the middle and a label "C" at the top-right. Again, as might be expected, no indication of a manufacturer or even the chip's functionality.

This chip is made in a much more modern process than the 1117: it has two metal layers, much finer features and apparently requires a certain minimum density on each metal layer, hence several locations with dummies (grids of tiny metal blocks).

Working from the datasheet and the PCB schematic, we can figure out what there needs to be on this chip: it should have an amplifier/comparator, a voltage reference (which might just be a resistive divider from the supply voltage), an enable pin, an oscillator (which uses R4/C8/C9 as a timing reference) and a counter that counts the oscillator's pulses.

It looks like VDD (pin 8, also connected to the LDO's output) is the pad at the middle of the top row, and GND is the right pad at the bottom row (since it's connected to the ring around the die). That would mean the left pad at the bottom row is "enable" (pin 3), the two pads on the left are pins 1 and 2 (sensing the signal from the RF section), and the pad on the top-left is pin 7 (RC). The pad on the right would then be the output, while the one on the top-right end might be a test pad (as it looks unused). The two identical (mirrored) sections in the middle of the chip look like an amplfier or comparator. It is likely that one of them is used for the "sense" pins and the other for the oscillator. The counter, with enable functionality and possibly a power-on reset is in the logic block.

I wouldn't be surprised if this chip is also used in many other products as a generic timer/delay chip. In that case the RCWL-0515 is actually an extremely clever device: sticking together a couple of standard, widely available components and making it into something that performs a useful function that would definitely not be obvious from the components themselves. Whoever designed this thing, good job!