Technical English

Unit 15
Phase Lock Loop

■ 锁相环的构成和工作原理

■ 锁相环的历史和发展

■ 锁相环的应用

detector	检测器，检波器
oscillator	振荡器
entail	引起
corrupt	毁坏
additive	相加的，加性的
instantaneous	瞬时的
suppress	抑制
track	跟踪
eliminate	消除，淘汰
synchronous	同步的
homodyne	零差式的
superheterodyne	超外差的
mixer	混频器

beat-note	差拍信号
tune	调谐
garble	篡改，歪曲
fraction	片断，一小部分，小数
interlace	相间，隔行扫描
frame	（电视的）帧
raster	光栅
strip	剥离
trigger	触发
sweep generator	扫描发生器
relaxation	松弛，弛豫
premature	未成熟的
susceptible	易受影响的
inferior	差的，处于劣势的

superior	优越的
jitter	抖动，颤抖
misfiring	误触发
streak	条纹
fluctuation	起伏
discrepancy	偏差，偏离
flywheel	飞轮
color burst	（电视的）色同步信号
spectacular	惊人的
coherent	相干的
offset	偏移，补偿
transponder	应答器，转发器
discriminator	鉴别器，鉴频器

A phaselock loop contains three components (Figure 15.1):

1. A phase detector (PD) .

2. A loop filter.

3. A voltage-controlled oscillator (VCO) whose frequency is controlled by an external voltage.
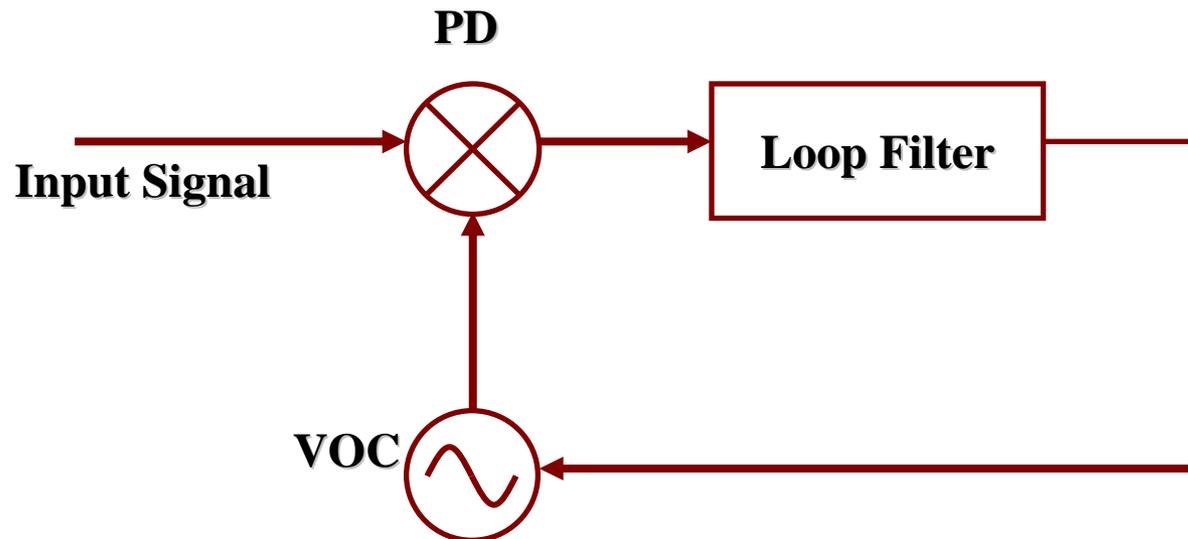
The phase detector compares the phase of a periodic input signal **against** the phase of the VCO. Output of PD is a measure of the phase difference between its two inputs. The difference voltage is then filtered by the loop filter and applied to the VCO. **Control voltage on the VCO changes the frequency in a direction that reduces the phase difference between the input signal and the local oscillator.**[1]

压控振荡器的控制电压使频率朝着减小输入信号与本振之间相位差的方向改变。

当锁相环处于锁定状态时，控制电压使压控振荡器的频率正好等于输入信号频率的平均值。

When the loop is locked, the control voltage is such that the frequency of the VCO is exactly equal to the average frequency of the input signal. For each cycle of input there is one, and only one, cycle of oscillator output. One obvious application of phaselock is in automatic frequency control (AFC). Perfect frequency control can be achieved by this method, whereas conventional AFC techniques necessarily entail some frequency error .

传统的自动频率控制技术不可避免地存在某些频率误差

13

To maintain the control voltage needed for lock it is generally necessary to have a nonzero output from the phase detector. Consequently, the loop operates with some phase error present. As a practical matter, however, this error tends to be small in a well-designed loop .

A slightly different explanation may provide a better understanding of loop operation. Let us suppose that the incoming signal carries information in its phase or frequency; this signal is inevitably corrupted by additive noise. **The task of a phaselock receiver is to reproduce the original signal while removing as much of the noise as possible.**[3]

锁相接收机的作用是重建原信号而尽可能地去除噪声。

与预计信号频率非常接近的本机振荡器

To reproduce the signal the receiver makes use of **a local oscillator whose frequency is very close to that expected in the signal**. Local oscillator and incoming signal waveforms are compared with one another by a phase detector whose error output indicates instantaneous phase difference. To suppress noise **the error is averaged over some length of time**, and the average is used to establish frequency of the oscillator.

误差在一定的时间间隔内被平均

该信息可通过长时间的平均得到，从而消除可能很强的噪声

If the original signal is well behaved (stable in frequency), the local oscillator will need very little information to be able to track, and **that information can be obtained by averaging for a long period of time, thereby eliminating noise that could be very large.**[4] The input to the loop is a noisy signal, whereas the output of the VCO is a cleaned-up version of the input. It is reasonable, therefore, to consider the loop as a kind of filter that passes signals and rejects noise.

Two important characteristics of the filter are that the bandwidth can be very small and that the filter automatically tracks the signal frequency. These features, automatic tracking and narrow bandwidth, <u>account for</u> the major uses of phase lock receivers. Narrow bandwidth is capable of rejecting large amounts of noise; it is not at all unusual for a PLL to recover a signal deeply embedded in noise.

窄带能够抑制大量的噪声，难怪锁相环常用来恢复深深地淹没在噪声中的信号。

但人们一直努力寻求更简单的接收技术

An early description of phaselock was published by de Bellescize in 1932 and treated the synchronous reception of radio signals. Superheterodyne receivers had come into use during the 1920s, but there was a continual search for a simpler technique; one approach investigated was the synchronous, or homodyne, receiver. In essence, this receiver consists of nothing but a local oscillator, a mixer, and an audio amplifier.

它随后被转换成严格为**0Hz**的中频

To operate, the oscillator must be adjusted to exactly the same frequency as the carrier of the incoming signal, which is then converted to an intermediate frequency of exactly 0 Hz. Output of the mixer contains demodulated information that is carried as sidebands by the signal. Interference will not be synchronous with the local oscillator, and therefore mixer output caused by an interfering signal is a beat-note that can be suppressed by audio filtering.[5]

干扰与本地振荡器不同步，因此由干扰信号引起的混频器输出是一个拍音，可用音频滤波器加以抑制。

任何一点频率误差都将严重损坏信号

Correct tuning of the local oscillator is essential to synchronous reception; any frequency error whatsoever will hopelessly garble the information. Furthermore, phase of the local oscillator must agree, within a fairly small fraction of a cycle, with the received carrier phase. In other words, the local oscillator must be phaselocked to the incoming signal.

此外，本振的相位必须与接收的载波相位一致，其间的误差限于周期的很小一部分。

For various reasons the simple synchronous receiver has never been used extensively. Present-day phaselock receivers almost invariably use the superheterodyne principle and tend to be highly complex. One of their most important applications is in the reception of the very weak signals from distant spacecraft.

与视频信号一起传送的脉冲发出电视图像每一行的开始信号和隔行扫描的半帧开始信号。

The first widespread use of phaselock was in the <u>synchronization of horizontal and vertical scan</u> in television receivers. The start of each line and the start of each interlaced half-frame of a television picture are signaled by a pulse transmitted with the video information. As a very crude approach to reconstructing a scan raster on the TV tube, these pulses can be stripped off and individually utilized to trigger a pair of single sweep generators.

作为一种非常粗糙的重建电视显象管扫描光栅的方法，这些脉冲可以剥离出来单独用于触发一对扫描发生器。

设置得略低于水平和垂直（扫描）脉冲频率

A slightly more sophisticated approach uses a pair of free-running relaxation oscillators to drive the sweep generators. In this way sweep is present even if synchronization is absent.

Free-running frequencies of the oscillators are set slightly below the horizontal and vertical pulse rates, and the stripped pulses are used to trigger the oscillators prematurely and thus to synchronize them to the line and half-frame rates (half-frame because United States television interlaces the lines on alternate vertical scans).[7]

剥离出来的脉冲用于提前触发振荡器从而使振荡器与行频和半帧频同步

In the absence of noise this scheme can provide good synchronization and is entirely adequate. Unfortunately, noise is rarely absent, and any triggering circuit is particularly susceptible to it. As an extreme, triggered scan will completely fail at a signal-to-noise ratio that still provides a recognizable, though inferior, picture.

在极端情况下触发扫描将完全失效，尽管在这样的信噪比条件下电视图像虽然较差却还能辩认。

25

在不是极端恶劣的条件下，噪声将造成起始时间抖动和偶尔的误触发。

Under less extreme conditions noise causes starting-time jitter and occasional misfiring far out of phase. **Horizontal jitter reduces horizontal resolution and causes vertical lines to have a ragged appearance.** **Severe horizontal misfiring usually causes a narrow horizontal black streak to appear.**

严重的水平误触发通常会造成画面出现狭窄的水平黑带。

Vertical jitter causes an apparent vertical movement of the picture. Also, the interlaced lines of successive half-frames would so move with respect to one another that further picture degradation would result.

相继半帧之间的隔行扫描行还会相对移动，使图像进一步恶化。

将两个振荡器与剥离出来的同步脉冲锁相可大大减小噪声起伏。

Noise fluctuation can be vastly reduced by phaselocking the two oscillators to the stripped sync pulses. Instead of triggering on each pulse a phase-lock technique examines the relative phase between each oscillator and many of its sync pulses and adjusts oscillator frequency so that the average phase discrepancy is small.[8]

锁相技术靠检查各振荡器和许多同步脉冲之间的相位关系来调节振荡频率，使得平均相位偏差很小，而不是仅用一个脉冲进行触发。

由于锁相同步器检测许多脉冲，因此它不会被偶
发的破坏同步器触发的大幅度脉冲噪声所干扰。

Because it looks at many pulses, a phaselock synchronizer is not confused by occasional large noise pulses that disrupt a triggered synchronizer. The flywheel synchronizers in present day TV receivers are really phase-locked loops. The name "flywheel" is used because the circuit is able to coast through periods of increased noise or weak signal. Substantial improvement in synchronizing performance is obtained by phase-lock.

In a color television receiver, the color burst is synchronized by a phase-lock loop.

跟踪增加的噪声或微弱信号的周期

Spaceflight requirements inspired intensive application of phaselock methods. Space use of phaselock began with the launching of the first American artificial satellites. These vehicles carried low-power (10 mw) CW transmitters; received signals were correspondingly weak.

Because of Doppler shift and drift of the transmitting oscillator, there was considerable uncertainty about the exact frequency of the received signal. At the 108MHz frequency originally used, the Doppler shift could range over a ±3kHz interval.

With an ordinary, fixed-tuned receiver, bandwidth would therefore have to be at least 6kHz, if not more. However, the signal itself occupies a very narrow spectrum and can be contained in something like a 6Hz bandwidth.

如果使用传统的技术，就不得不接受1000倍（30dB）噪声的代价。

Noise power in the receiver is directly proportional to bandwidth. Therefore, if conventional techniques were used, a noise penalty of 1000 times (30 dB) would have to be accepted. The numbers have become even more spectacular as technology has progressed; transmission frequencies have moved up to S-band, making the Doppler range some ±75kHz, whereas receiver bandwidths as small as 3 Hz have been achieved. The penalty for conventional techniques would thus be about 47 dB. Such penalties are intolerable and that is why narrowband, phase-locked, tracking receivers are used.

窄带滤波器能抑制噪声，但是如果滤波器被固定，则信号将几乎总是落在通带之外。

Noise can be rejected by a narrowband filter, but if the filter is fixed the signal almost never will be within the pass-band. For a narrow filter to be usable it must be capable of tracking the signal. A phase-locked loop is capable of providing both the narrow bandwidth and the tracking that are needed. Moreover, extremely narrow bandwidths can be conveniently obtained (3 to 1000 Hz are typical for space applications); if necessary, bandwidth is easily changed.

For a Doppler signal the information needed to determine vehicle velocity is the Doppler shift. A phase-lock receiver is well-adapted to Doppler recovery, for it has no frequency error when locked.

跟踪运动飞船的一种方法涉及到将相干信号发射到飞船上，将信号频率偏移并转发回地面。

The following applications, further discussed elsewhere in the book, represent some of the current uses of phase-lock.

1. One method of tracking moving vehicles involves transmitting a coherent signal to the vehicle, offsetting the signal frequency, and retransmitting back to the ground. The coherent transponder in the vehicle must operate so that the input and output frequencies are exactly related in the ratio *m/n*, where *m* and *n* are integers. Phase-lock techniques are often used to establish coherence.

飞船上的相干应答器必须如此工作以使输入和输出频率严格地成*m/n*的比例关系，此处*m*和*n*都是整数。

36

2. A phase-locked loop can be used as a frequency demodulator, in which it has superior performance to a conventional discriminator.

3. Noisy oscillators can be enclosed in a loop and locked to a clean signal. If the loop has a wide bandwidth, the oscillator tracks out its own noise and its output is greatly cleaned up.

如果环路具有大的带宽，振荡器检测出自己的噪声，其输出被大大净化。

4. Frequency multipliers and dividers can be built by using PLLs.

5. Synchronization of digital transmission is typically obtained by phase-lock methods.

6. Frequency synthesizers are conveniently built by phase-lock loops.

- **Briefly explain how a phase lock loop works.**

- **List some typical applications of PLLs.**

- **Why can a PLL be used as a narrow band filter?**

Exercises

■ **Unfortunately, we will see that it is not as easy to distinguish between <u>psychologically valid and invalid AI programs</u> as it is to distinguish between physically valid and invalid jumper making procedures.**

– **A tell whether or not AI programs are of importance to psychology**

– **B provide psychological differences between a valid AI program and an invalid AI program**

– **C give valid reasons to distinguish psychologically different AI programs**

– **D separate psychologically valid AI programs from psychologically invalid ones**

Exercises

- **We are to develop a code such that fewer bits are assigned to code words representing gray levels having higher probability of occurrence, <u>and vice versa</u>.**

  - A. in other words, gray levels that more frequently occur are given more bits

  - B. and more bits are used for gray levels of lower probability of occurrence

  - C. otherwise, more bits are needed in the similar case

  - D. in other words, more probable gray levels require shorter code words

■ **We shall use this parameter as <u>a measure of degradation</u> during the evaluation of different quantization systems later in this chapter.**

 – **A. an action of processing**

 – **B. a degree of enhancement**

 – **C. a degree of impairment**

 – **D. an effect of interference**

■ **What is fascinating about all this <u>from the perspective of computer architecture</u> is that, on the one hand, the basic building blocks for today's computer miracles are virtually the same as those of the old computers from 50 years ago, while on the other hand, the techniques for squeezing the last iota of performance out of the materials at hand have become increasingly sophisticated.**

  – **A. in view of computer architecture**

  – **B. with proposed computer architecture**

  – **C. taking computer architecture into account**

  – **D. from various aspects of computer architecture**

Exercises

- **At the present, <u>state of the art</u> microwave amplifiers and oscillator tubes can operate in a frequency range up to 40GHz and solid-state microwave devices up to 100GHz.**

  - **A. recent and most advanced**

  - **B. high tech related**

  - **C. sophisticated**

  - **D. artistically manufactured**

■ **If you are unable to separate man from machine then, Turing says, we will have <u>to attribute intelligence to the computer</u>.**

– **A. to make an intelligent computer**

– **B. to consider the computer as being intelligent**

– **C. to contribute to the computer with intelligence**

– **D. to let the computer have intelligence**

- **As <u>DoD urgently wanted military command and control networks that could survive a nuclear war</u>, ARPA was charged with inventing a technology that could get data to its destination reliably even if arbitrary part of the network disappeared as a result of a nuclear attack.**

  - **DoD urgently needed networks of military command and control that would not be crippled in a nuclear war**

  - **DoD urgently needed both the military command and the control networks that could save a nuclear war**

  - **DoD desperately wanted the ability of commanding and controlling the networks in case of a nuclear war**

  - **DoD eagerly wanted to make military command, and to control the network so that they could keep working in a nuclear war**

- **The second major development to occur during 1970 was the development of the low loss optical fiber. The idea of communicating through free space is well and good, but as was previously stated, a major advantage of optical transmitters was their directivity. For broadcasting, it is hard to beat radio waves. For point to point, it is hard to beat optics.**

- **1970年第二项主要发展是低损耗光纤的开发。经自由空间进行通信的想法是很好，但正如前面所述，光发射器的主要优点在于它们的方向性。对广播而言，无线电波很难被超越；而点到点传输却很难胜过光。**

- **But there are problems with using free space as a transmission medium. The first one is very practical. Usually, one is trying to communicate with someone else on the face of the Earth. Two major problems arise from this. One problem is that the Earth is round. Once line-of-sight distances are exceeded, one needs to increase link length by a quantum leap in order to include a satellite repeater.**

- 不过以自由空间作为传输媒介是有问题的。第一个问题很实际。通常人们总是试图与地面另一个人通信。由此产生两个问题：首先地球是圆的，一旦超过了视线距离就需要跨越一大步，采用卫星转发器来增加连接距离。

■ **As was shown by Hertz, although the first trans-Atlantic demonstration was made by Marconi some years later around the turn of the century, low-frequency waves (AM band, ≤1 MHz) will cling to the ground for some distance.**

■ 这个问题对微波和光是共同的。如**Hertz**所示（尽管首次决定性的跨越大西洋传播演示是数年以后在世纪之交由**Marconi**进行的），低频波（小于**1MHz**的调幅波段）会紧贴地面传播。

- **Already by the shortwave band (~10 MHz), the waves begin to skip off the Earth, although up to roughly 100 MHz they still reflect off the ionosphere. At higher frequencies, one needs an orbiting reflector and/or repeater.**

- 在短波段（**10MHz**左右），波已经开始脱离地球，尽管在**100MHz**以下它们仍会从电离层折回。在更高频率上就需要使用轨道上运行的反射器或转发器了。

Assignment

- **The System-on-Chip (SoC) technology is the next step in the evolution of computer science. Unlike a big chip stuffed mainly with random logic, SoC is designed as a programmable platform that integrates most of the functions of the end product in a single chip.**

- 片上系统（**SoC**）技术是计算机科学的下一步进展。不同于一个充塞随机逻辑的大芯片，**SoC**被设计成一个可编程平台，在一块芯片上集成了最终产品的大部分功能。

Assignment

■ **It incorporates at least one processing element (microprocessor, DSP, etc.) that runs the system's embedded software. SoC includes peripherals, random logic and interfaces to the outside world and employs a bus-based architecture. It may contain both memory and analog functions.**

■ 它至少包含一个处理单元（微处理器、DSP等），运行系统的嵌入软件。SoC包括外围设备、随机逻辑、与外界的接口，并使用基于总线的结构。它可能包含存储器和模拟功能。

- **The ability to produce SoCs is a result of new manufacturing techniques that are capable of producing ever-smaller transistors and putting more of them on a single chip — Moore's Law in action — and the development of new tools that make it possible to automate the design and verification of such complex devices.**

- 生产**SoC**的能力是新型制造技术的结果，这种制造技术能生产出愈来愈小的晶体管并将更多的晶体管放进单个芯片（**Moore**定律的实现）；生产**SoC**的能力也是新工具开发的结果，这些新工具使得自动设计和验证如此复杂的器件成为可能。

Assignment

- **It has now become possible to create complex electronic systems that are very small and portable, use very little power and are very reliable. Miniature cell phones and digital cameras are good examples.**

- 现在已经可以造出尺寸很小而且可移动（移植）、功率极低、非常可靠的复杂电子系统。小型蜂窝式电话和数字照相机就是很好的例子。

Assignment

- **Thus far, SoCs have been used almost exclusively in high volume consumer applications, since they are the ones that have the armies of engineers and can afford the burden of time, cost and risk involved in the traditional development of SoC based systems.**

- 迄今为止**SoC**几乎无一例外地用于大批量消费产品中，因为正是这些应用领域才拥有大量的工程师，并能承受基于**SoC**系统传统开发中的时间、成本和风险负担。