Electronic Blood Pressure Meter HY16F188+HY2163 Instruction Manual

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1. Introduction

With advancement in social, economic and cultural aspects, modern people's daily diets, living styles, and working habit have changed for the worse. Cardiovascular diseases have become one of the nation's leading causes of death. As an incomplete statistics indicated, death toll due to cardiovascular diseases has increased 3% per year regarding to the entire Chinese population, with the figure being more severe among young population. However, our nation has an insufficient preventive measure against cardiovascular diseases, especially high blood pressure. However, blood pressure and pulses is the most important health indicators.

If we can measure our blood pressure constantly, we will get a clearer picture of our health conditions. Early diagnosis always contributes to better treatment results. Regarding to disease diagnosis, pulse signals contain numerous valuable pathological messages for human body. For example, it reflects vascular resistance, blood flow, vascular extensibility, aortic stenosis, and aortic valve insufficiency,etc. Pulse is always taken as a physiological indicating message, since it plays an essential part in blood pressure measurement and blood flow testing. Therefore, we must pay our concern and investigate deeper into the issue in blood pressure and pulse measurement to conduct preventive measures in cardiovascular diseases,.

Base on HYCON HY16F188 internal high accurate ∑△ADC and LCD drive IC HY2613, we conduct measurement in blood pressure and pulses through oscillography and upper arm detection. Resulting statistics have revealed that electronic blood pressure meter realized by this way has characteristics of accurate measurement, strong anti-interference, easy to use, and low cost,etc. Thus, it is suitable for mass production as a health care instrument.

2. Theory Explanation

2.1 Blood Pressure Testing

Development in blood pressure testing can be separated into two categories: Korotkoff method(also called auscultatory method)and oscillometric method(also called vibration method). Today, most electronic blood pressure meters apply oscillometric method in measuring human blood pressure. Main reason is that there are Some intrinsic deficiencies in auscultatory method. First, it is more difficult to measure diastolic blood pressure through auscultatory method. Second, this method involves subjective factors, such as heavy reliance on the observer's visual and audio aid. Unless being medical expert, it is hard for ordinary people to make accurate conjecture. In the 1970s, numerous auscultatory meters have appeared as an attempt to realize automatic blood pressure testing. Before long, it is found that these meters cannot overcome the intrinsic deficiencies existed in auscultatory meters, including great error and low repeatability. As of today, most blood pressure meters aboard have adopted oscillometric methods.

Measurement process in oscillometric blood pressure meters covers pressurization, constant-speed deflation and inflation, and blood pressure measuring technics. An inflatable cuff is applied to impede blood flow in upper arm artery. Due to hemodynamic reaction in the heartbeat, simultaneous oscillation will be repeated at the inflatable cuff corresponding to the heartbeat, and this is what we called the pulse wave. During pressurization process, if pressure in the inflatable cuff were to be lower than systolic pressure, the artery pulse will grow prominent as oscillation wave amplitude increases. If pressure in the inflatable cuff were to equal average pulse pressure, artery wall will become no-load as wave amplitude maximizes. If pressure in the inflatable cuff were to be lower than average pulse pressure, inflatable cuff tightens as wave amplitude begins to decline. Corresponding wave shapes are specified in illustration 1.

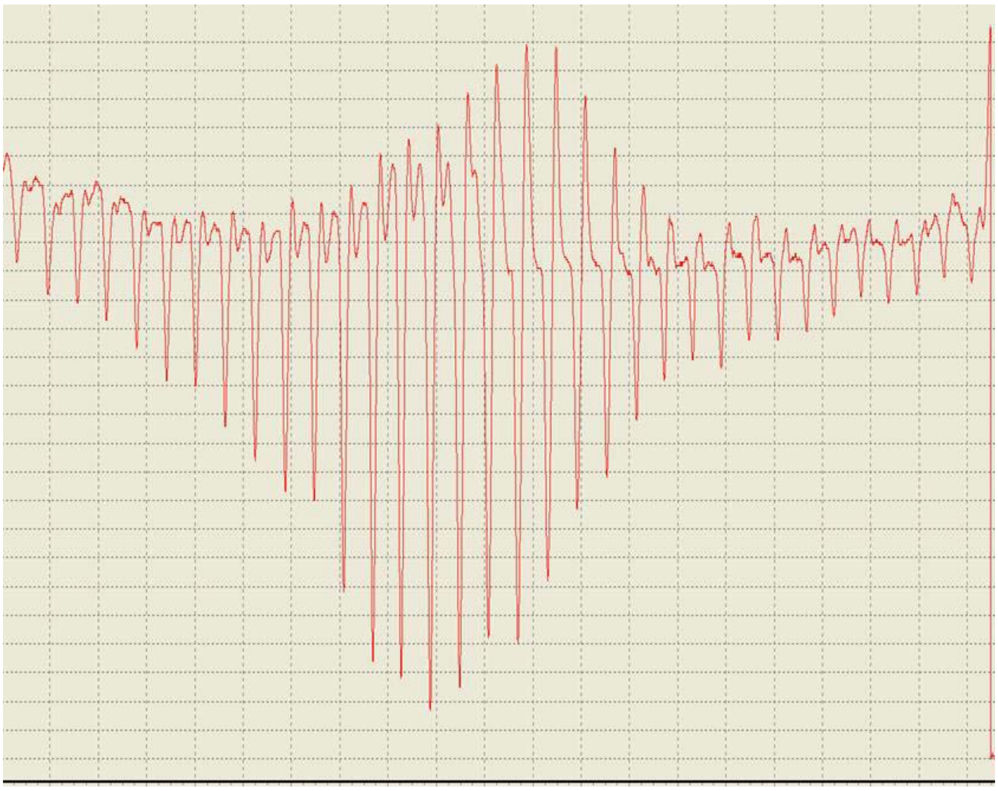


Illustration 1 Oscillometric ADC Pulse Curve Signal

Based regular statistical analysis, we can determine the criteria for average pulse pressure. Minimum inflatable cuff pressure corresponding to maximum inflatable cuff oscillation signal is what we call an average pulse pressure. If inflatable cuff pressure were to equal blood pressure, blood will begin to flow and generate a so called cuff sound. This is a situation which we call systolic blood pressure. At this point, we must start conducting our record. Once cuff sound fades into silence, the point indicates the diastolic blood pressure.

2.2 Sensory Component

Exclusive semiconductor sensor US09111-006S is applied in detecting human blood pressure signals. Since it is a resistance full bridge pressure sensor, it is equipped with an excellent linearity degree, a positive correlation between output voltage and excerted pressure, and a wide working temperature range of -40℃—85℃. Through HY16F188 internal LDO, it provides both terminals on the pressure sensor with 2.4V, so as to directly convert pressure the artery blood exerts onto the wall into 0-100mV electrical signal, with the corresponding blood pressure being 0-40KPa. Since it perfectly matches the designs in blood pressure meter, it is especially suitable for oscillometric pressure measurement.

2.3 Blood Pressure Signal and Control Chip

Through pressure sensory components, human blood pressure is converted into electrical signals. Through HY16F188 internal amplifier with a maximum magnifying capability of 128 times, highly accurate ADC and referential voltage provided by internal LDO module, the electrical signal is quantified. Due to HY16F188 specifications described below, measurement circuit in blood pressure signals becomes extremely simle, with a high price-performance ratio.

HY16F188 Specifications

- System Working Voltage 2.4-3.6V
- 10MIPS 32bit Controller
- Low Current Consumption
  A. 450uA/MIPS Current Consumption under Working Mode
  B. 2.5uA Power Consumption under Sleep Mode
- Inbuilt VDDA voltage stabilizer, with the following electrical voltages to choose from: off, 2.4V, 2.7V, 3.0V, and 3.3V.
- Inbuilt charge pump regulator independently used in system power supply and chip electrical source.
- External oscillation circuit input or internal highly accurate RC oscillator, with 4 working clock selections to choose from.
- Differential Input Methods
- With X1, X2, X4, X8, X16, X32, X64, X128 gain selections available for inbuilt preamplifier (PGA).
- With 0, ±1/8, ±1/4 , ±3/8, ±1/2, ±5/8, ±3/4, ±7/8 biasing voltage selections available for inbuilt DC biasing setting.
- 4 signal input modes are built within the product (positive-going input, S-short circuit, S+ short circuit, and intercross).
- With 10, 20, 40, 80, 160, 320, 640. 1280, 2560, 5120, or 10240 sps data output speed to choose from.
- SPI and UART Data Delivery Interface
- 64K Flash Memory and 8K Bytes SRAM
- 16bit PWM Controller
- Working temperature ranges from □ –40°C to +85°C.

2.4 Power Supply Control

Major controlling part in the blood pressure meter has adopted 16F188 32bit as its kernel single-chip microcomputer, with a charge pump circuit independently used in chip power supply, built within the product. Once the DC electrical machine starts up, a great electrical current will be generated immediately. By applying this power supply control and module, system restoration due to sudden power drop can be avoided. To control 16F188 internal charge pump, working power supply in the chip must be switched through software. Comparing to other blood pressure meters, 16F188 power supply have an easy design, without additional requirement to be connected to pressure rising circuit in the charge pump. It can also supply power with two batteries.

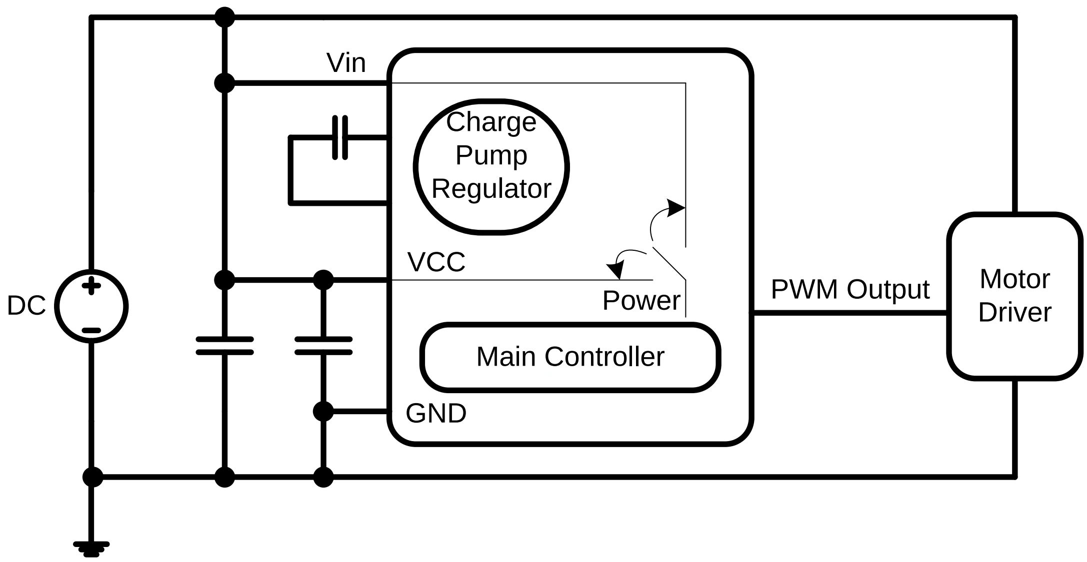


Illustration 2 HY16F188 Internal Power Supply Structure

2.5 Display Control

Display control in blood pressure meter adopts HYCON LCD driver chip HY2613 to drive the LCD panel into displaying, with the following characteristics presented:

- 4*36 Points or 4*32 Points under Backlight Output Mode
- Internal Self Blinking Function
- 1/2 or 1/3 Bias and 1/4 Duty can be set for LCD driving method.
- High side or low side driving can be selected.
- Build-in charge pump is equipped with 8 power source output, with slight adjustment and contrast adjustment CONTRAST function.
- LED Backlight Function & 20mA/4.2V Driving Capacity Stable Current
- 4*36=144bit display data RAM is built within the product.
- 2-way I2C Communication Port
- 32K LPO oscillator is built within the product.

- Support for external crystal resonator.
- Equipped with low power consumption Idle mode.

3. Design Planning

3.1 Hardware Explanation

Overall circuit in the blood pressure meter includes:

- ADC Measurement Circuit
- Inflation and Deflation Control
- Control Display
- Peripheral Electrical Circuit

3.1.1 ADC Measurement Circuit and Internal ADC Setting

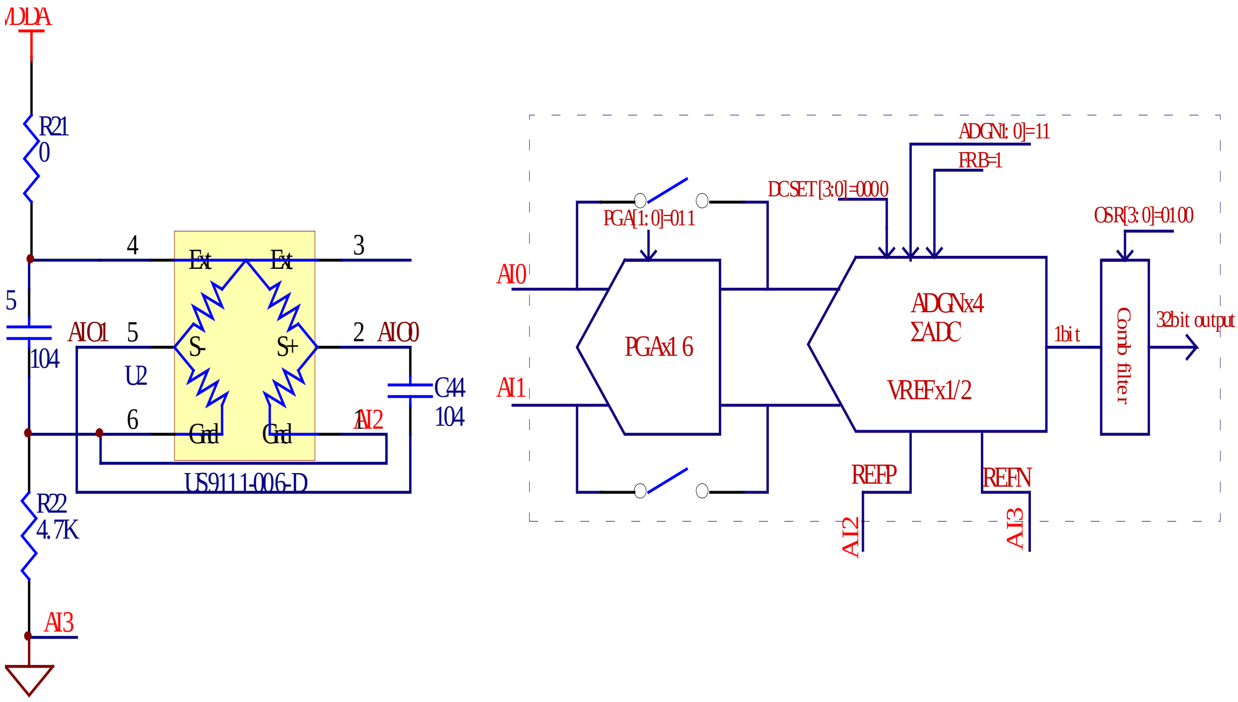


Illustration 2: Blood Pressure Signal Measuring Circuit

Pressure sensor adopts stable voltage driving method, with its input voltage provided by 3.3V VDDA terminals set by HY16F188 internal LDO. US9111-006-D is a full bridge pressure sensor with a 5K internal resistance. Pressure sensor outputs the signal, which is directly converted into numbers through HY16F188 internal highly accurate ∑△ADC.

Regarding to signal processing, referential voltage in HY16F188 internal ADC is provided by VDDA terminal through AI2, which is a referential voltage at the positive terminal (REFP). Through AI3, VSS terminal is short circuited to a referential voltage at the negative terminal (REFN).Since maximum output signal in the pressure sensor is only 42mV, whereas referential voltage is 1.65V, the signal has to be amplified 24 times at HY16F188 internal PGA, so as to suffice ADC measurement demand. VDDA Temperature drift in this measurement circuit has no effect on the measurement system, with temperature drift in HY16F188 internal PGA being ±10ppM/℃. Therefore, temperature drift in HY16F188 only exerts a small influence on the measurement part. In addition, two capacity in referential voltage and signal input terminal must be added, so that ADC will have enough maintaining time during temperature variation.

3.1.2 Inflation and Deflation Control Circuit

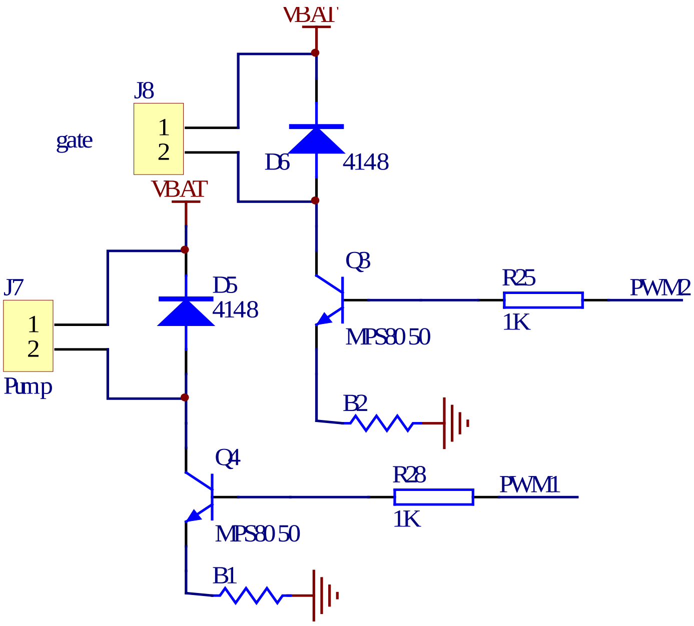


Illustration 3: Inflation and Deflation Control Circuit

Through control circuit in 16F188 internal 16 bit PWM output and triode, inflation control circuit can control DC motor in order to pump up the inflatable cuff. By adjusting duty cycle in PWM output, pumping speed in the inflatable cuff can be controlled. High and low status in PWM can control on and off in electromagnetic valve through switching circuit in the triode, so as to facilitate deflation in the inflatable cuff.

Regarding to inflation control, output frequency in PWM setting is 120HZ. Once inflation motor is started up, speedy inflation can be realized through adjustment in PWM duty cycle. Once gas pressure in inflatable cuff reaches 35mmHg, inflation speed can be changed by adjusting duty cycle in PWM output. Under current gas pressure, ADC can start identifying blood pressure signal in human body.

3.1.3 Display Control Part

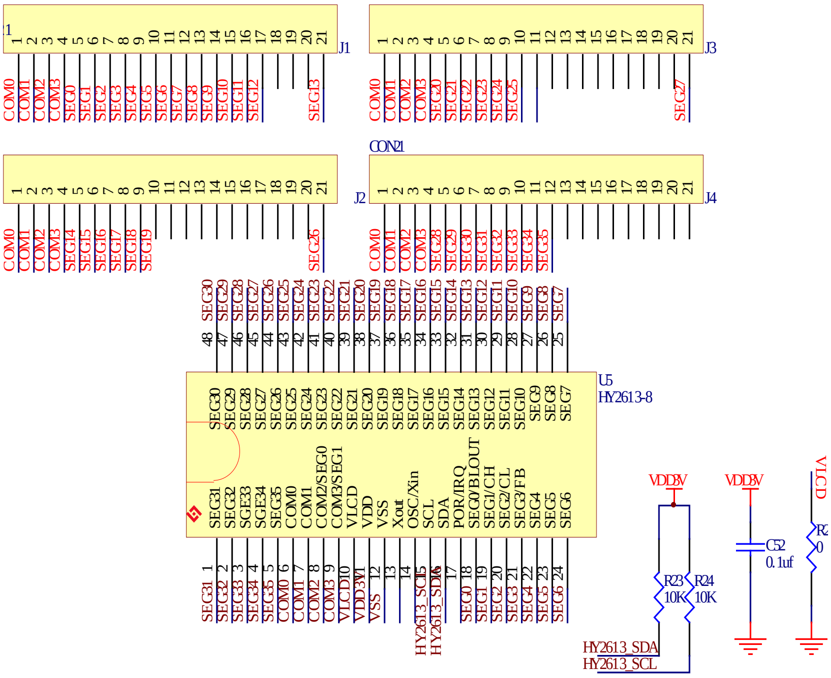


Illustration 4: Control Display Circuit

Regarding to display control, HYCON LCD driver chip HY2613 can drive four LCD panels to facilitate the display. Through I2C port, HY2613 and HY16F188 can arrange HY2613, and control the LCD panel display. Four different panels in illustration 4 respectively display systolic blood pressure, diastolic blood pressure, heart rate and time.

3.1.4 Peripheral Circuit

From integrated electrical circuit presented below, peripheral circuit in blood pressure meter looks very simple, with a RS232 serial communication circuit. Through RS232 communication interface and ADCENOB analytical instrument, AC detach curve in blood pressure meter can realize graphic collection. As to power supply, since HY16F188 carries charge pump regulator, which directly provides chip operation with the required power supply, it can be directly supported by two batteries instead of power supply circuit provided by GS2612 LDO.

3.1.5 Integral Circuit in Blood Pressure Meter

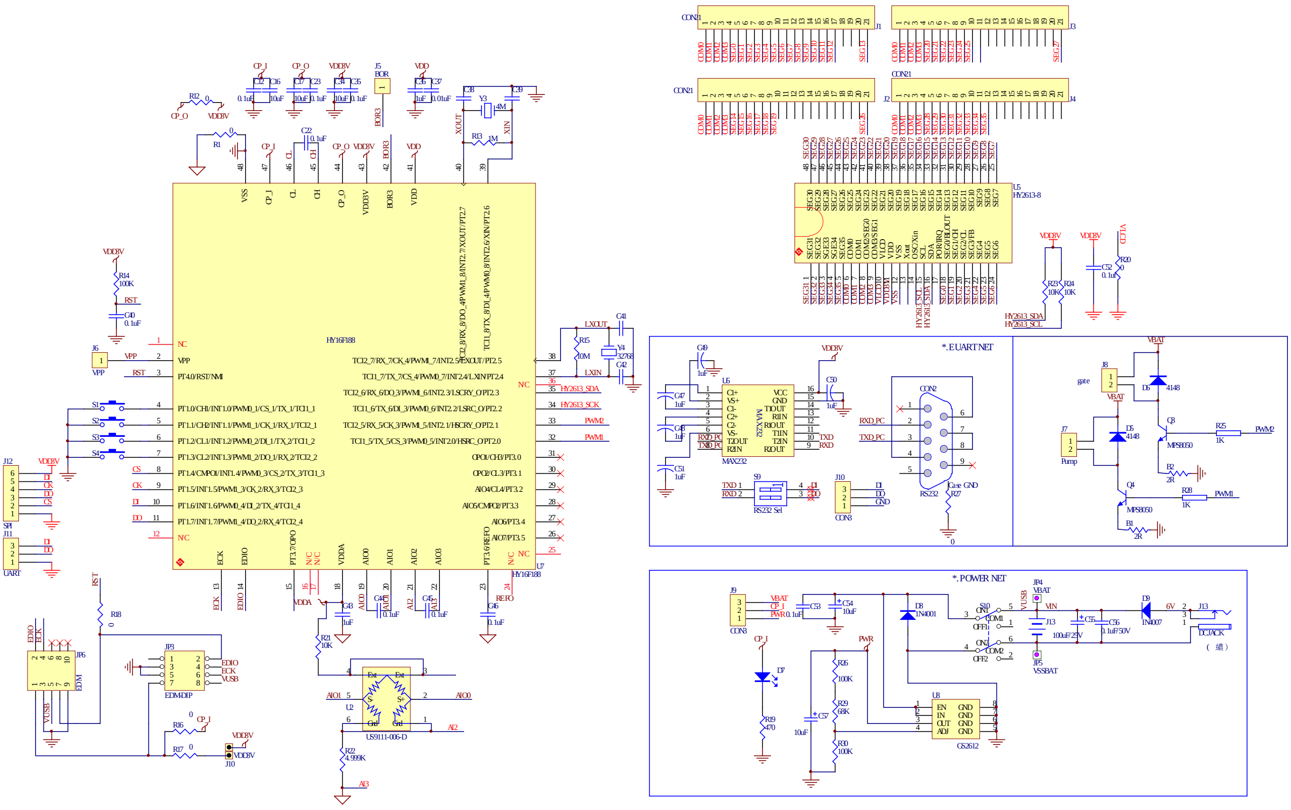


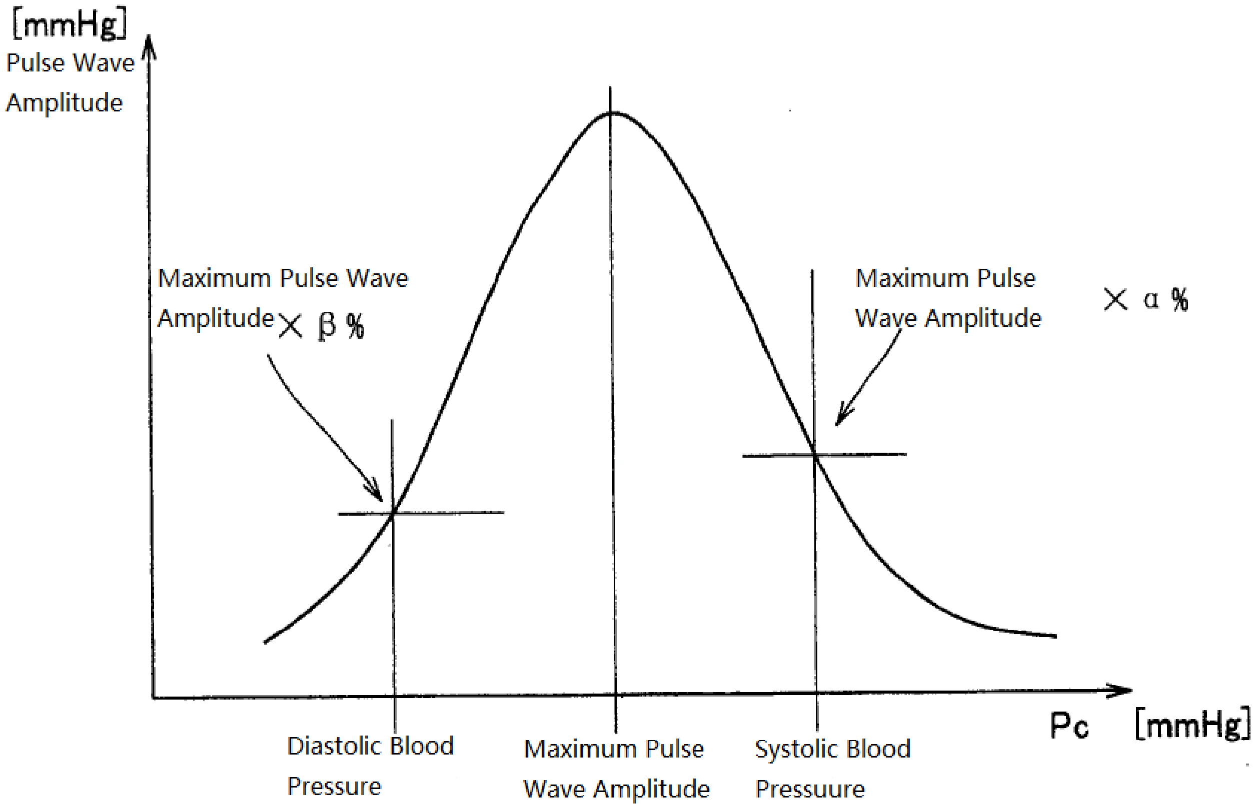
Illustration 5: Integral Circuit in Blood Pressure Meter

3.2 Software Procedure in Determining Blood Pressure

Measurement in blood pressure meter mainly concentrates on measuring systolic blood pressure, diastolic blood pressure, and heart rate. Oscillometric approach is currently adopted as an accurate method in measuring blood pressure. Therefore, it is used most of the time. Since this article applies oscillometric approach to blood pressure measurement, blood pressure analysis through oscillometric approaches is specified below.

3.2.1 Blood Pressure Determining Method

This article applies oscillometric S determining method in blood pressure measurement. The first thing to do is to check the maximum value in pulse wave amplitude Am. At the same time, please integrate oscillation wave corresponding to the maximum value before dividing it by the wave cycle, so as to obtain wave amplitude corresponding to systolic blood pressure A (sp). Wave amplitude corresponding to diastolic blood pressure A (dp) is obtained through difference between maximum wave amplitude and A (sp). Considering the pulse wave curve, if the pulse waves were to be A (sp) and A (dp), the corresponding inflatable cuff pressure are systolic blood pressure and diastolic blood pressure respectively.



3.2.2 Pulse Signal Withdrawal

Regarding to pulse signal collection, HYCON HY16F188 has inbuilt 21 bit highly accurate ∑△ADC. Combining with internal 64-time amplifier, blood pressure signal in human body can be effectively identified. In addition, since pressure value collected by ADC includes DC pressure signal and AC blood pressure signal corresponding to heartbeat cycle,effective AC withdrawal in software processing has become a critical step in blood pressure measurement. Withdrawing procedure in AC blood pressure signal is specified in illustration 7.

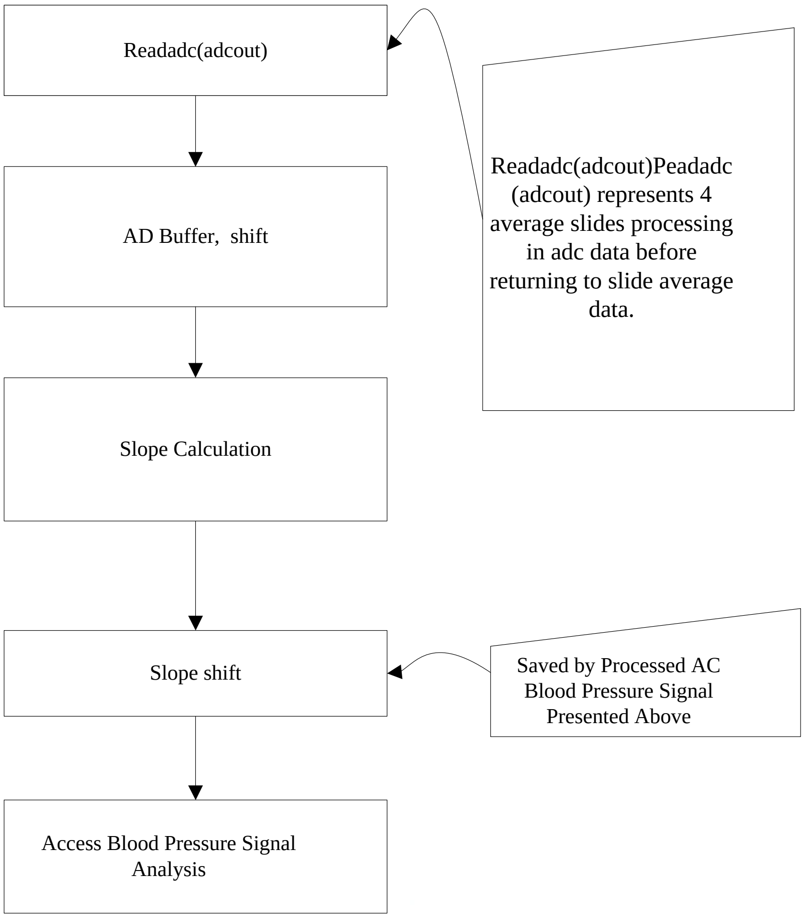


Illustration 7: Blood Pressure Signal Withdrawal

3.2.3 Blood Pressure Processing Procedure

In order to process blood pressure signal, software must be applied to determine amplitude corresponding to difference between wave crest and wave trough of AC signal with each heartbeat. By comparing different amplitudes in blood pressure signals collected, we can determine whether the maximum oscillation wave has been acquired. While processing blood pressure signals, we must save static pressure and pulse amplitude corresponding to each maximum value in blood pressure signal. In addition, we should also integrate signal curve corresponding to each blood pressure pulse.

After determine the current wave shape is the maximum amplitude wave,Only when the following three consecutive wave shapes gradually decline can we ensure that the maximum amplitude wave is found. According to the average amplitude value and the location corresponding to the maximum amplitude wave, we can find the two waves on either sides of the average amplitude value. Average value in static pressure corresponding to these two wave shapes is called diastolic blood pressure. As to amplitude corresponding to systolic blood pressure, we must find the difference value between the maximum amplitude and its corresponding average amplitude. Next, we can continue to find amplitudes on the either sides corresponding to diastolic blood pressure. Base on static pressures corresponding to maximum amplitude between the two diastolic pressures, we can accurately calculate the diastolic blood pressure.

4 Operation Explanation

4.1 Calibration Procedure

Upon entering calibration procedure, we can short circuit PT1.0 during power on status. In another word, we enter calibration status through S1 key.

- First Step in Calibration: "0" is displayed at the diastolic blood pressure. Gas pressure at signaling sensor must be 0 mmHg. Once being stabilized, please click S1 to confirm before moving on to the next step.
- Second Step in Calibration: "300" is displayed at the systolic blood pressure. Gas pressure at signaling sensor must be 300mmHg. Once being stabilized, please click S1 to confirm before moving on to the next step.
- Third Step in Calibration: Calibrated real-time pressure value is displayed at systolic blood pressure. It is applied to inspect accuracy in the calibrated data. Please click S1 to confirm before saving.

4.2 Key Operation

- S1 Key
  - ◆ ON/OFF Key
- S2 Key
  - ◆ Callout memory data to display. Through this key, successive memory values can be inquired, for a maximum of 15 memory data.
  - ◆ Under time setting mode, set number increase key.
- S3 Key
  - ◆ Once shut down, users can access time setting by pressing 3S, with LCD panel displaying data to be set. Through this key, user can set year, month, date, hour and minute.
  - ◆ Under memory mode, user can find memory data by clicking this key.
- Simulated Testing compare Accuracy Setting
  - ◆ Accuracy set by low pressure blinking display ranges from 0 to 40.

4.3 Display Data Explanation

Under blood pressure measurement mode, current static pressure can be displayed. Once blood pressure amplitude wave is collected, heartbeat sign will be displayed glisteningly. After blood pressure is measured, diastolic pressure, systolic pressure and heart rate will be displayed on the LCD panel. Clock will also be displayed during the blood pressure measuring process.

Once shut down, memory value display can be accessed by clicking memory key. Under memory mode, data order in memorized blood pressure can be displayed. By clicking key, group number in memory data can also be displayed, with the maximum group number being 15. Year, month, or data in clock time will be displayed for 1 second every 5 seconds, with clock being displayed at ordinary times.

By pressing “time setting key” for three seconds, user can access “time setting mode”. Clock will be presented first and hour setting begins to blink,users can adjust time through momory key. Upon completing hour setting, press time setting key momentarily to facilitate minute setting. Upon completing minute setting through memory key, press clock set key momentarily , then LCD panel display year glisteningly. Upon completing year setting through memory key, click time setting key to enter month and data setting,and display month glisteningly. Upon completing month setting through memory key, click time setting key to display date setting. Adjust date through memory key before clicking time setting key to access shutdown status.

4.4 Illustration and Data Collection

Through its serial module, combining with HYCON HY11PXX ENOB Communication Instrument and software, data collection of HYCON 16F188 blood pressure meter can realize blood pressure meter wave shape display, which greatly support engineers in their initial developmental process. Illustration 1 presents an integral blood pressure pulse curve through this collection method.

5. Conclusion

By applying HY16F188 build-in highly accurate ADC as simulating signal processing front end,combining with build-in ADC LCD output,this blood pressure meter can completely satisfy design requirement in upper-arm blood signal processing. In addition, with build-in charge pump regulator which provide chip with power supply, external voltage increasing circuit becomes unnecessary. This design system has sufficiently applied HY16F188 internal resource to measure blood pressure signal, with simple peripheral circuit, excellent influence tolerance, and price-performance ratio. Compare to other blood pressure meter design, this blood pressure measurement system possesses great market potential.

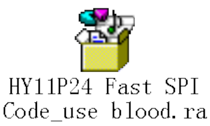
6. Referential Data

Datasheet file：HY2613datasheet

Datasheet file: HY16F188datasheet

Bachelor Thesis of Chongqing University of Posts and Telecommunications: Introduction in Respective Blood Pressure Meters

7. Appendix

Demo code: 

8. Amendment Record

Greater differences in the document are presented below, with variation in punctuation and font excluded.

Version	Page Number	Amendment Summary
V01	All	Initial Publication
V02	8	Electrical Circuit Amendment
V03	ALL	Amendment in EDM Circuit and Correction Procedure Based on HY16F188 C LIBv0.7 Version
V04	ALL	Application Linker and Start up Code Version and Library Partial Amendment.