HAMEG
EMI-measurement tools

EMI pre-compliance measurements

Do you intend to market new electrical or electronically controlled apparatus in the EWU (EU plus Island, Liechtenstein, Norway)? If so, did you , in the course of design, continuously check for compliance with the emi norms applicable to your product ? Or were you forced to redesign your circuit extensively after failing the first emi test, practically starting anew? Please read the following article for information about how to prevent such disagreeable "disturbances" of your next project.

The higher clock frequencies and denser integration of modern electronics also lead to steadily increasing demands on the emi measuring equipment in order to achieve the necessary emi performance of apparatus. In order to guarantee the required emi limits a very wide frequency range from 150 kHz to 1 GHz has to be covered. An extension to 3 GHz is to be expected in the course of future norm changes. The measuring efforts and costs are sizeable, but may be controlled by the use of suitable measuring equipment and methods.

Oscilloscope or ...

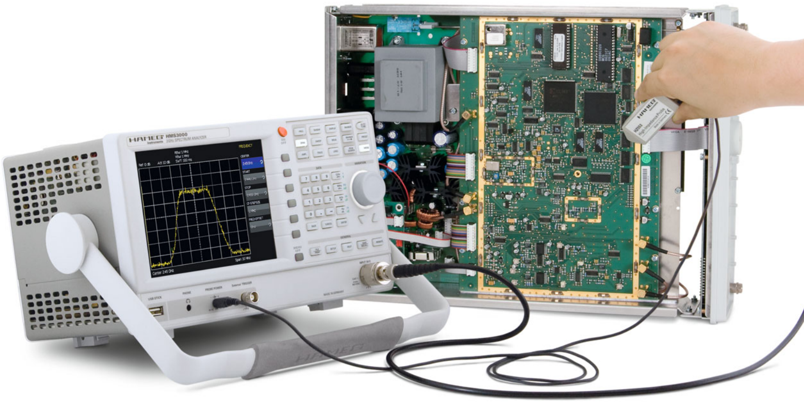
Despite its versatility the oscilloscope is unsuited for active emi measurements because it shows the waveform of a signal vs. time, but not its spectral contents and the level of the individual frequency components of which it is composed.

The norms applying to active emi specify frequency-selective average and quasi-peak measurements in each spectral range; the bandwidth is dependent on the frequency.

The range to be covered for active emi extends from 150 kHz to 1 GHz. The measuring instrument must feature a high sensitivity in the uV range. The display of a large frequency band combined with the logarithmic scale of 80 dB allows to recognize the effects of a design measure at first sight, on the frequencies as well as on the levels of the spectral lines.

Spectrum Analyzer and ...

The rarity of spectrum analyzers in design laboratories is still distressing. Often budget reasons are pretended. Emi checks during the design phase do not require a Rolls Royce spectrum analyzer. Just the fact that spectrum analyzers are not used daily is a reason for preferring instruments which can be operated simply by any design engineer without threshold fear and extensive initial training. It is important to achieve comparative results quickly and with little effort. The following example illustrates how fast a spectrum analyzer will amortize itself: A day in a specialized emi lab may well amount to 1,000 E or more. A simple and cost-effective spectrum analyzer has already amortized itself if its use spared 2 to 3 days in an emi lab. The goal of any professional and effective design management should be to use and pay the external emi lab only once with each newly developed product in order to pass the test according to the norms.



Line impedance standardizer (LISN) and sniffer sensors.

The LISN belongs to the basic equipment apart from the spectrum analyzer in any laboratory and certification application. The LISN is used to isolate, detect, and measure conducted interference. In a certification lab it is used in conjunction with a receiver. For pre-compliance purposes the use of a LISN together with a spectrum analyzer is by far the more practical – and much faster – solution. (Fig. 2)

HAMEG spectrum analyzers series HMS and a LISN HM6050-2 yield results which are comparable to those obtained by professional emi test labs. What are negative results in such a lab worth other than that there is still something wrong? What are we after?

Radiated emi.

Radiated emi differs from conducted emi by the fields emanating from the radiating parts of the circuit. The emi norms determine the range of measurements from

30 MHz to 1 GHz, extensions to higher frequencies are to be expected.

The norms require the use of antennae and receivers inside a socalled absorber hall which prevents reflexions and any influence from third sources.

Such measurements are inefficient during the design phase as they are time-consuming and expensive. What is needed are fast answers about the interference from a circuit especially from all conductors entering or leaving an ec board or instrument. Although we are talking about radiated interference it is the conductors which act as antennae and thus create the disturbing fields.

The emi work in the design lab concentrates predominantly on the interference emanating and spread from such conductors. With suitable means these measurements may be performed directly in the vicinity or on the conductors carrying signals, power, ground, and their shields. He who uses a spectrum analyzer for the first time to test a circuit will be greatly astonished that even conductors of slow or static signals also carry high frequency interference caused by other parts of the circuit. When using an oscilloscope this interference will be buried in other noise and thus hardly detectable. The electromagnetic fields use the metallic conductors as guides for their propagation, quite independently of the desired signals.

In the design lab this interference can be easily and without any appreciable effort visualized by using a spectrum analyzer and sensors appropriate for the specific situation. For this purpose different sensors are necessary.

In order to judge the effects of emi countermeasures socalled sniffer sensors are handy. They are offered as E or H field sensors and, together with high impedance sensors and sensors with extremely low input impedance, they aid in selecting effective interference suppression measures.

Active E field sensor.

The active E field sensor is a wide-band, high sensitivity device. It allows to judge the total emissions of a part or the whole of an instrument. As a rule it is used at a distance of 0.5 to 1 m from the object under test. This not only allows to test the effectiveness of shielding measures but also of emi filters inserted in cables leaving the test object which influence the total emissions.

Due to its high sensitivity an E field sensor may also pick up third party interference from other sources in the lab. These measurements are hence performed in two steps: first the test object is switched off so that only the interference from the environment is measured, then the test object is switched on and the additional signals are analyzed.
The results of an active E field sensor are also dependent on the test set-up as is usual with all far-field measurements. Especially the placement of the cables plays a role not to be underestimated. If reproducible results are intended – not only comparisons of the effects of different measures – it is recommended to define the test set-up and even to fix it to a base plate.

The active E field sensor may also be used to measure interference from the environment. If it is suspected that an instrument’s function is being disturbed by interference from an unknown source, the active E field sensor and a spectrum analyzer can be used to check the electromagnetic environment. Due to the analysis in the frequency domain the source of interference can mostly be identified very quickly. This allows to make the necessary circuit modifications so effectively that no surprises are to be expected in the final emi test.

Active H field sensor.

One of the most effective methods in any emi work is the close scrutiny of interference currents. The usual practice of using oscilloscopes leads to pure “voltage thinking”. Successful emi engineers, however, are trained in “current thinking”. Active H field sensors are the optimum choice to measure interference currents without contacting or cutting conductors (Fig. 1). They are fairly insensitive to third party interference and show a steep rise of signal when closing in on an interference source. Hence they allow to localize and pinpoint interference currents within a circuit. By moving a H field sensor along the outside of a housing or a shield leaks like slots are easily identifiable.

However, the continuing integration on ec boards limits the chance of localizing sources of interference with a H field probe. Here the socalled µH field probe HZ554

Fig. 1: Active H field sensors like this HZ540/550 set are near-field probes which can be used to measure the magnetic field strength. This magnetic field strength in the near-field is directly proportional to the conducted currents.

(contained in the near-field sensor set HZ550) comes in. It allows to pinpoint sources of interference exactly down to the mm range. This probe is hence suited to identify interference on ec boards.

As mentioned, all sorts of metallic conductors are antennae which radiate as well as receive interference. Holding a H field probe close to a cable while using a spectrum analyzer one may be astonished to find unexpected high levels of interference (e.g. harmonics of clock frequencies) even on mains or "slow" data transmission cables like telephone cables. The H field probe in conjunction with the logarithmic amplitude display on the spectrum analyzer allows to check very simply whether all conductors radiate the same amount of interference or whether certain conductors radiate more or less. Thus countermeasures can be precisely applied, and the effectiveness of such measures can be checked quickly and simply in the lab without a shielded room and a large measuring set-up.

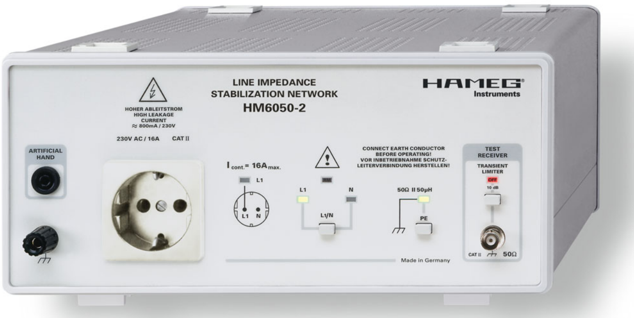


Fig. 2: A line impedance standardization circuit (LISN) like the HAMEG HM6050-2 is used to isolate, identify and measure conducted interference.

High impedance probe.

The high impedance probe is used to measure wide band (< 1 GHz) signals e.g. on ic pins or on a single conductor within a circuit without loading the contact point with the customary 50 Ω input impedance of a spectrum analyzer. The input impedance of the high impedance probes contained in the HAMEG probe sets is mainly capacitive (> 2 pF). The high impedance probe may also be connected to 50 Ω oscilloscope inputs; in this case it will act as a probe with the above specified bandwidth and capacitance.

Still better is the use of a low capacitance probe with reduced capacitance (< 0.2 pF) and higher bandwidth up to 3 GHz (HZ555). The markedly lower load of this probe reduces signal deterioration and assures a more precise measurement even in very high frequency circuits. The vital advantage is the almost nonexistent load on the test point. A lower impedance probe may just damp or suppress the very oscillation to be measured. The higher the frequency to be measured, the more severe the problem. Each pF counts. Due to its extremely low input capacitance this phenomenon may be neglected up to the bandwidth of the HZ555. The low capacitance probe has just a tiny probe tip and is used without a ground return conductor; the return current flows through the body capacitance of the user. Thus it becomes possible to test the interference potential of individual ic pins or a single output conductor. By this capacitive and high impedance method also common mode interference sources may be detected.

Emi problems in practice.

Electronic design engineers know quite a toolbox full of emi prevention means, e.g. on ec boards. However, the contributions of the various means often become only apparent in a radiation test. This is why the contribution of each individual measure is rarely tested because of too much time and effort. But pushing these tests off until several anti-emi measures were taken, it becomes practically impossible to identify the success or failure of the individual measures.

The above described near-field sensors and sniffer probes offer a means for early checks. The E field sensor reacts to electric ac fields. The H field sensor is sensitive to changes of the magnetic flux. It is advisable to consider which fields play the dominant role in modern ec boards before any of these sensors resp. probes is used. With high voltages and low currents it is the electric field which plays the more important role. With low voltages and high currents it is the magnetic field. The first case prevails in electron tube circuits.

Modern ic's operate with low voltages and partly high currents. Here it should be stressed that it is not the absolute value of a current which counts here but its rate of change vs. time. If a radiating wave is generated by the magnetic component again the rate of change vs. time is the determining factor. It is exactly this component which is picked up by the H field sensor. The amplitude of the sensor signal is proportional to the rate of change of the magnetic flux and hence of that of the exciting current. This is why these sensors are exceptionally handy for first and coarse tests of the effectiveness of emi countermeasures. The majority of such sensors, however, suffers from a disadvantage: their resolution in space it very low. Therefore the signal from any such sensor is not clearly traceable to the true source. When buying such sensors it is recommended to also buy a sensor with a high resolution of magnetic fields. This is especially important if the degree of integration of an ec board is so high that the identification of an interference source has to take place within the mm range.

Measurements on 4 layer multilayer boards or...

how to extract interesting details from sensor signals. In principle, the signals can be shown in the time or frequency domains. For the user the representation in the time domain may be more informative than in the frequency domain. The following measurements were taken on a 4 layer multilayer board of the European standard format (100 x 160 mm^2). The power distribution on this board uses wide areas. The distance between the Vcc and the ground planes is 100 µm. A group of capacitors in the center of the board provides for the power supply bypassing.

Fig. 3 shows the current in the area close to the V_{CC} pin of a 74AC163 . The amplitude corresponds to the rate of change of the magnetic field and is hence proportional to the rate of change of the current at this point. The speed is very high, the signal slope is in the subnanosecond range. The high frequency components of the current flow in the immediate vicinity of the Vcc pin as they can only draw from the charges in the capacitance of the area surrounding the pin. The high frequency components can not draw current over longer distances because the impedance is too high. There is no bypassing capacitor at the V_{CC} pin because it would not be able to deliver high frequency current. Of course, the V_{CC} – ground system is additionally supported by a group of capacitors in the board center. However, this group of capacitors can only deliver the lower frequency components of the currents.

Fig. 4 shows the rate of change of the current flowing in the vicinity of this group. It is obvious that this signal is much slower than that of Fig. 3. Here, the rise time is 3 ns. The group of capacitors can only slowly inject current into the capacitance between the two layers. Of course, such details are only visible with the aid of a high resolution µH probe.

The next example demonstrates the effectiveness of absorption measures. The Fig. 5 signal was taken at the Vcc pin of a 74AC00 using a µH probe. Here, the ic is powered through an undamped V_{CC}-ground-plane system. The changes of the magnetic field are quite substantial. In contrast to this Fig. 6 shows the same signal, but here the power is drawn from a two-stage damped power supply system. This means that the Vcc pin is connected to the Vcc plane through a wideband choke, also this plane is carbonized. The amplitude of the signal in Fig. 6 is markedly lower than that in Fig. 5. The effectiveness of this measure is hence clearly visible without the need for a more elaborate measuring set-up.

As a last example of the many possibilites of pre-compliance emi measurements discussed the sensor signal is taken from the clock distribution point of a European standard format ec board. The signal is taken directly from the output of the clock generator. Fig. 7 shows the signal of a uH probe in an environment without any emi countermeasures. A rather high amplitude of 60 mV is registered. The measure to be taken here is the insertion of a resistor in series with the clock output, 82 ohms were chosen. Fig. 8 shows the result: the signal amplitude was cut in half. Also in this case the effect of the countermeasure is immediately apparent.

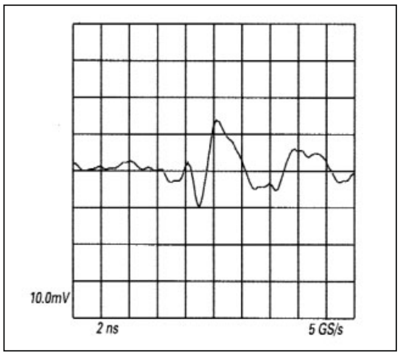


Fig. 3 Current in the area close to the V_{CC} pin of a 74AC163.

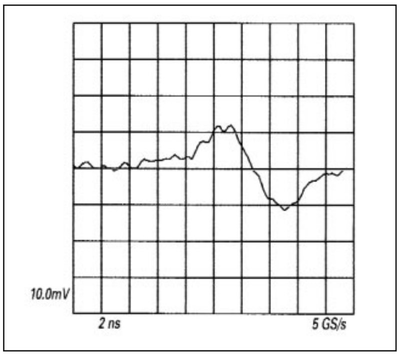


Fig. 4: Change of current in the area close to a group of capacitors.

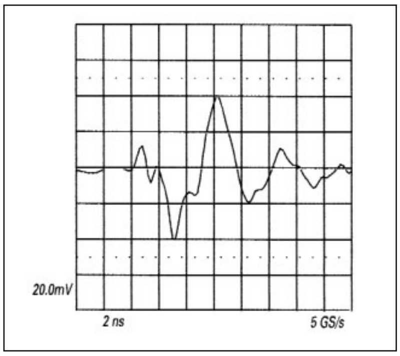


Fig. 5: Signal at the V_{CC} pin of a 74AC00.

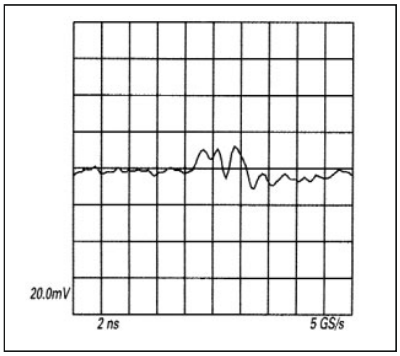


Fig. 6: The respective signal in a system with a two-stage damped power supply system.

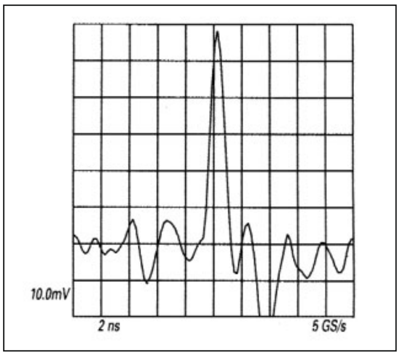


Fig. 7: Mikro – H probe signal taken in a circuit without any emi countermeasures.

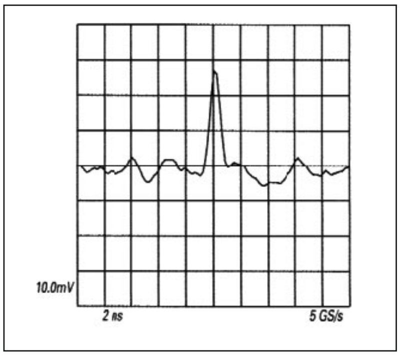


Fig. 8: A series resistor in the output of the clock driver halves the amplitude.